Competition among Alternative Option Market Structures: Evidence from EuRex vs. EuWax

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Abstract

We study option market design by providing a theoretical motivation and comprehensive empirical analysis of two fundamentally different option market structures, the EuRex derivatives exchange and EuWax, the world's largest market for bank-issued options. These markets exist side-by-side, offering many options with identical or similar characteristics. We motivate the two market structures based on option investor clienteles which differ with respect to the probability of selling the option back to the dealer/issuer before maturity, which in turn affects the investors expected transaction costs. As suggested by the clientele argument, our main empirical finding is that EuWax ask prices and bid prices are consistently higher than comparable EuRex ask prices and bid prices. The difference of the bid prices is larger, resulting in smaller EuWax bid-ask spreads, which makes EuWax preferable for investors with a high probability of early liquidation. We find that competition from one market reduces bid-ask spreads in the other market.

Keywords: Options, Market Design, Microstructure, Bid-Ask Spreads

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1. Introduction

In this paper we compare two option markets, the EuRex and EuWax exchanges in Germany, which exhibit significant structural and institutional differences, yet exist side-by-side offering many options with identical or similar characteristics. While many options in the two markets have similar or identical payoff functions, they are not exchangeable in the sense that an option position entered in one market cannot be liquidated in the other market. Furthermore, arbitrage between the two markets is restricted by the fact that one market, EuWax, does not allow investors to write options, thereby effectively imposing a short-sale constraint. We motivate the existence and structural differences of the two markets using a clientele argument in which option buyers differ with respect to their probability of selling the option back to the market maker before maturity. Using a comprehensive data set of year 2000 market activity, we find evidence consistent with the predictions based on our theoretical argument.

An important difference between many primary markets, such as stock markets, and derivative securities markets lies in the fact that, by exercising an option, investors can convert derivative securities into cash without requiring the liquidity services of a dealer. In particular, buyers with a high probability of holding the derivative security until maturity may be less concerned with bid-ask spreads than investors in primary assets such as stocks. The former essentially face only one-way transaction costs rather than the round-trip transaction costs faced by the latter. Given a choice between two option markets, investors with a high probability of holding the option until maturity are best served buying options in the market exhibiting the lowest ask prices irrespective of the magnitude of the bid-ask spread. On the other hand, investors with a high probability of liquidating the option position before maturity may be willing to buy a more expensive option, if they expect to recover the initial ask price difference via an even higher bid price difference later on.[1] Thus, our clientele argument predicts that one of the two option markets should exhibit consistently higher ask and bid prices and smaller bid-ask spreads at the same time. Figure 1 provides a graphical presentation of our argument. One can interpret the two clienteles as hedgers and speculators, with speculators likely to have higher probabilities of early liquidation than hedgers. While there are other papers such as Franke, Stapleton, and Subrahmanyam (1998), Leisen and Judd (2000), and Franke and Weber (2002), who study how investor heterogeneity can give rise to option supply and demand, they do not connect option clienteles, such as hedgers and speculators, to market design

[1] Similar clientele effects may exist in bond markets as bonds held until maturity incur only one-way transaction costs while bonds sold before maturity incur round-trip transaction costs.

and microstructure issues, as it is done in this paper.

The structural differences between EuRex and EuWax are suited to generate the quoting behavior predicted by the clientele argument. EuRex is a traditional derivatives exchange, whose option market shares many (albeit not all) important features with other option exchanges such as the CBOE. EuRex provides standardized option contracts with a clearinghouse serving as a central counterparty. EuRex options are traded in an order-driven electronic trading system with multiple competing market makers. EuWax, the second market in our study, is an exchange which trades securitized options issued by banks and other financial institutions. EuWax options are non-standardized, and individual issuers are free to choose any option characteristics for which they expect investor demand. At the same time each issuer is the sole counterparty to its own option contracts. However, issuers compete by issuing similar or identical options and obligate themselves to serve as market makers for their own products on an organized exchange. It is precisely the absence of a central EuWax counterparty which enables the market to serve the speculator clientele. Since EuWax options from different issuers are not exchangeable, and the issuer is the primary market maker, EuWax issuers can compete based on bid-ask spreads (expected round-trip transaction costs). As argued above, investors with a high probability of early liquidation may be willing to pay a higher ask price today at the benefit of a higher bid price in the future. EuRex investors on the other hand are indifferent as to which market maker initially sells them an option, since it can be sold back to any other market maker in the future due to the fact that EuRex options have a central counterparty. Thus, EuRex market makers compete on contemporaneous prices alone, since a EuRex market maker offering consistently high bid prices is not rewarded by being able to charge consistently high ask prices.

Furthermore, the standardization of EuRex products and the fact that all EuRex market makers are subject to the same trading regulations (e.g. maximum bid-ask spreads or minimum quote depths), prevents competition along these dimensions.[2] EuWax issuers, on the other hand, compete directly with each other in choosing option characteristics which maximize demand from investors. EuWax issuers can potentially trade off quote competitiveness with other features of market-making quality such as the aforementioned maximum spreads and minimum depths.

We do not argue that the two markets are necessarily completely segmented. Thus, competition from one market may also improve liquidity and market-making quality in the other market. In related work Battalio, Hatch, and Jennings (2003), De Fountnouvelle, Fishe, and Harris (2003), Mayhew (2002), and Wang (2000) examine the effect of competition among option exchanges of the

[2] It is, of course, in the best interest of EuRex exchange management to optimize these design features for the entire exchange to attract trading volume.

EuRex type on liquidity and market-making quality. While Mayhew (2002) finds that U.S. exchange-issued options listed on multiple exchanges have lower effective and quoted bid-ask spreads than single-listed options, Battalio, Hatch, and Jennings (2003) show that U.S. option exchanges listing the same options are not fully integrated, in the sense that trades for multiple-listed options frequently get executed on one exchange at prices that are inferior to those available on other exchanges. Our paper adds to this literature by providing the first comprehensive analysis of bank-issued options along with a comparison to exchange-issued options.

Our empirical results show that there is significant overlap in the contract offerings of EuRex and EuWax. Options in both markets with identical or very similar features for just six heavily traded underlying assets account for roughly one quarter of all year 2000 equity and equity index option trading volume in either market. Consistent with the clientele argument, EuWax is shown to have significantly smaller quoted percentage bid-ask spreads (by an average of 4.3%). The bid-ask spread difference between EuWax and EuRex manifests itself in a regular fashion in that EuWax ask prices are consistently higher than comparable EuRex ask prices (by an average of 4.7%). At the same time EuWax bid prices are consistently higher than comparable EuRex bid prices (by an average of 9.9%). The difference of the bid prices is larger than the difference of the ask prices resulting in smaller EuWax bid-ask spreads. Our empirical results also support the suggested trade-off for EuWax options between quote competitiveness and other market-making features. Furthermore, we also find evidence that bid-ask spreads in either market are lowered by competition from the other market.

The remainder of the paper is organized as follows. The next section describes the theoretical argument regarding option market clienteles and applies it to the EuRex and EuWax option markets. Data and methodology are discussed in Section 3. Section 4 contains the empirical results, and Section 5 concludes.

2. Option Market Clienteles

2.1. Heterogeneous Investors, Early Liquidation, and Transaction Costs

The observation that different market structures for options can exist side-by-side while offering products that appear in many regards as substitutes raises the question of the raison d'être of the different markets. In this section we develop a general theoretical argument based on option market clienteles and then apply the theoretical insights to generate predictions for the comparison of EuRex and EuWax in the following section. We wish to capture two potentially important features. First, we analyze the likelihood of liquidating an option position early before the option's maturity as a

potential difference among option investor clienteles. Such a difference may arise for example from investor heterogeneity with respect to the use of the option (e.g. hedging versus speculation). This difference can be expected to have an impact on an investor's choice of liquidity provider, since it affects whether one-way or round-trip transaction costs have to be paid. The second feature is that we do not allow investors to write (short) options in one market as is the case on EuWax.

Consider the problem of an investor who wants to buy a European option and chooses between two markets R and W in a two-period discrete-time setup, where market W does not allow investors to write options.[3] Let A_t^R and B_t^R stand for market R's ask and bid prices at time t, and let A_t^W and B_t^W stand for market W's ask and bid prices at time t. Assume that the value of the option V_t conforms to the following conditions:

$$A_t^R \geq V_t \geq B_t^R \text{ for } t = 0, 1 \tag{1}$$

$$A_t^W \geq Max\left[V_t, B_t^W\right] \text{ for } t = 0, 1 \tag{2}$$

$$A_t^R = A_t^W = V_t = I_t = B_t^R = B_t^W \text{ for } t = T = 2, \tag{3}$$

where T is the option's expiration date, and I_t is the option's intrinsic value. Equation (1) states that in market R, which does not have a short-sale restriction, investors cannot sell the option for more than its true value nor buy the option for less than its true value. Only the latter condition holds in market W as stated in equation (2). On the other hand, in market W we allow cases in which bid prices may be higher than the option's value as investors cannot exploit this apparent mispricing due to the short-sale constraint. The third condition reflects that at expiration the option is worth its intrinsic value. The subsequent analysis is also valid for American options if we impose the additional assumption that all bid prices will be higher than the intrinsic value before maturity.

The first two conditions together imply a no-arbitrage condition between the two markets:

$$A_t^W \geq Max\left[V_t, B_t^W\right] \geq V_t \geq B_t^R \text{ for } t = 0, 1. \tag{4}$$

Ask prices in market W cannot be less than bid prices in market R, as this would give rise to an arbitrage opportunity where investors could write an option in market R resulting in proceeds of B^R and hedge the resulting exposure by buying an option in market W at a cost of A^W. On the other hand, a comparable no-arbitrage condition does not exist in the other direction in the sense that ask prices in market R can be less than bid prices in market W. Investors cannot exploit such a situation as it would require writing options in market W, which is not allowed.

Now consider the problem of an investor who has probability P of liquidating the option position

[3] Since EuWax options cannot be shorted, the appropriate comparison is for an investor who wants to buy EuWax options. While precise data are difficult to obtain, discussions with market participants indicate that EuRex market makers are on average short in options implying that the average EuRex option investor is also a buyer.

at time $t = 1$. Since the focus is on modelling the investor's transaction costs we assume that this probability is exogenous. The expected transaction costs (arising from bid-ask spreads) $E_0[C]$ of options from the two markets can be written as follows, respectively:

$$\begin{aligned} E_0\left[C^R\right] &= A_0^R - V_0 + P \times \frac{E_0\left[V_1 - B_1^R\right]}{1+r} \\ E_0\left[C^W\right] &= A_0^W - V_0 + P \times \frac{E_0\left[V_1 - B_1^W\right]}{1+r}, \end{aligned} \tag{5}$$

where r is a discount rate used to obtain the present value of future transaction costs. The investor is indifferent between the two options for $E_0\left[C^R\right] = E_0\left[C^W\right]$. This condition can be rewritten as follows:

$$A_0^W - A_0^R = P \times \frac{E_0\left[B_1^W - B_1^R\right]}{1+r}. \tag{6}$$

At time $t = 0$, an option investor who knows with certainty that the option will be held until maturity should always purchase the option with the cheaper ask price. If $P = 0$ for all investors, and if one ask price is consistently lower than the other, the non-preferred market will eventually vanish or should not exist at all. The problem is also trivial (choose the option with the lower ask price today) for the case in which the option with the lower ask price today is also expected to have higher bid prices in the future. Again, if this condition holds consistently, the non-preferred market should not exist.

A more interesting case occurs, if one market consistently exhibits higher ask prices and higher bid prices. In this case an investor with a positive probability of early liquidation may choose an option with a higher ask price today, if he expects that the option will also have a higher bid price in the future when the option position is liquidated. All else equal, the likelihood of choosing the more expensive option today increases with the expected value of the future bid price difference, and with the probability of early liquidation. Rearranging (6) gives a minimum probability P^* of early liquidation required for the investor to choose the higher-priced option today:

$$P^* = \frac{\left(A_0^W - A_0^R\right)(1+r)}{E_0\left[B_1^W - B_1^R\right]}. \tag{7}$$

P^* divides option buyers into two clienteles. Option buyers with $P < P^*$ buy options in the market exhibiting lower ask prices, while option buyers with $P > P^*$ buy options in the market exhibiting higher ask prices. Equation (7) also shows that the expected future bid price difference should be higher than today's ask price difference. This implication is due to two effects. First, the future bid price difference is reduced by the time value of money. Secondly, the expected bid price difference is earned only with probability P while the ask price difference is incurred with certainty, if the more expensive option is purchased today.

While the above explanation does not explicitly address the supply of liquidity/market-making

services, one can identify situations in which suppliers would prefer to separate clienteles of option buyers with differing probability of liquidation. This would, for example, be the case, if the market maker's/supplier's hedging costs are lowered by being able to predict the duration of the necessary hedging program more accurately.[4] Based on the above results, the main empirical prediction is that markets R and W can coexist, if one market consistently exhibits higher ask and higher bid prices, such that the average bid price difference is larger than the average ask price difference. It is interesting to note that the expression for P^* is independent of the option's value. Thus, our hypothesis does not predict that the bid-ask spreads in the two markets will necessarily overlap as depicted in Figure 1. As pointed out above, the short-sale constraint in market W allows for the possibility that bid prices in market W are higher than ask prices in market R. This latter case is depicted in Figure 2. An additional empirical prediction is that investors with a high likelihood of early liquidation also pay more attention to other features of market-making quality affecting expected round-trip transaction costs such as guaranteed maximum bid-ask spreads, which the issuer can trade off with current quote competitiveness.

2.2. Market Structures and Clienteles of EuRex and EuWax

In this section we apply the option clientele argument to the EuRex and EuWax markets. We begin with a description of bank-issued option markets in general and EuWax in particular. Several European and Asian countries have sizable markets of options (also referred to as covered warrants) that are issued by banks as stand-alone securities. These bank-issued options are traded on organized exchanges, such as the European Warrant Exchange (EuWax) in Stuttgart, Germany, the NextWarrants segment of Euronext, or the MCW segment of the Borsa Italiana in Milan. Bank-issued option markets are thus quite different from warrant markets in the USA, where the term warrant typically refers to option securities written on an issuing corporation's own stock. Such U.S. warrants are originally issued in a bundle with another security (e.g. a corporate bond), but can subsequently be traded separately.

Almost all bank-issued options are covered options in the sense that the issuer is obligated (as stated in the prospectus) to hedge all options sold. Thus, bank-issued options are generally considered to be free of default risk.[5] In the prospectus issuers often also commit to make a market for their own options by quoting ask and bid prices on at least one exchange or electronic information and trading system (such as Reuter's) until the option's expiration. The quality of the market-making is often detailed further by providing a maximum bid-ask spread, minimum quote depth, and minimum trade

[4] Note that to minimize exposure the market maker should terminate the hedging program, if an option is purchased back before maturity.

[5] In the German market, there are no reported incidents of major defaults on bank-issued options.

size (number of option contracts) as, for example, in Goldman Sachs (2000). Investors can purchase bank-issued options using regular brokerage accounts, with orders being filled either on any number of exchanges listing the desired option or directly with the issuer as an over-the-counter transaction. However, to the best of our knowledge, it is typically not possible for investors to short bank-issued options (equivalent to the investor writing the option).[6]

In addition to competition among issuing banks in the bank-issued option market itself, there are several cases in which bank-issued option markets exist side-by-side with traditional derivatives exchanges, often offering options with identical or very similar payoff functions. Examples of both markets existing side-by-side are found in Italy, where the MCW market, for bank-issued options, and the IDEM market, for exchange-issued options, even exist as segments on the same exchange, and Germany, where bank-issued options are traded, among other venues, on the aforementioned EuWax exchange and exchange-issued options are traded on EuRex in Frankfurt.

While precise data for all bank-issued option markets around the world are difficult to obtain, the German bank-issued option market is generally considered to be the world's largest. Bank-issued options in Germany are subject to relatively little regulation, and as a result, banks can issue options quickly and at low cost.[7] The International Warrant Institute (2002), an industry association, estimates that in the year 2000 roughly half of the global bank-issued option trading volume (as measured by paid premia) occurred in Germany. EuWax in turn dominates the German bank-issued option market with a market share of over 90% of all bank-issued option exchange transactions according to Börse Stuttgart (2001). Although German bank-issued options can trade on other exchanges such as the Frankfurt Stock Exchange, we also refer to them as EuWax options throughout the paper. For equity and equity index options, year 2000 EuWax trading volume (as measured by paid premia) represents roughly 30% of year 2000 EuRex trading volume. Thus, the EuWax market is of considerable size both compared to EuRex and compared to other international option exchanges. Back-of-the-envelope calculations indicate that the trading volume of EuWax options on the largest underlying, the German DAX index, would rank among the top five underlying assets on the CBOE. EuWax is a special market segment of the Stuttgart Stock Exchange, one of Germany's many regional stock exchanges. Issuers listing EuWax options are required to make a continuous market for their options and are subject to quality control and regulation from the exchange. EuWax orders can potentially be placed with any financial institution willing to make

[6] Similarly, Horst and Veld (2002) report that investors cannot short bank-issued options in the Dutch market.

[7] Discussions with Sal. Oppenheim in Germany indicate that the regulatory process for new bank-issued options in Germany typically takes less than a week, and has direct costs of only a few thousand Euro. New issues are typically advertised in the business press and via electronic media which creates additional issuance costs.

a market. However, discussions with market participants indicate that market-making by someone other than the issuer is rare and that orders are filled almost exclusively with the issuer's market maker. All major issuers of bank-issued options in Germany make markets for their own options on EuWax.[8]

EuRex ranks by most measures as the world's largest derivatives exchange and has many typical derivatives exchange characteristics comparable to the CBOE. Option contracts are standardized with respect to underlying, exercise style, expiration date, and strike prices, and new contracts are created according to specific rules governing, for example, the addition of strike prices and new expiration dates. There are pairs of calls and puts for all option contracts. EuRex Clearing AG, a wholly owned subsidiary of EuRex, serves as the central counterparty and clearinghouse for all contracts. EuRex has market makers who are obligated to supply bid and ask quotes and to enter into transactions upon demand generated by an order. There are exchange-mandated maximum bid-ask spreads, minimum quote depths, and a minimum period for maintaining quotes. Most option contracts have several competing market makers whose parent institutions in some cases are banks which also issue EuWax options as shown in EuRex Communications (1999) and EuRex Communications (2002a). A summary of institutional differences between EuRex and EuWax is provided in Table 1. As argued in the introduction, it is the absence of a central counterparty with competing market makers on EuWax which allows EuWax issuers to compete based on expected round-trip transaction costs, since EuWax options are almost exclusively sold back to the issuer. Therefore it is the EuWax market rather than the EuRex market which should exhibit higher ask and bid prices.

While the predictions from the clientele argument rely only on option investor heterogeneity with respect to the likelihood of early liquidation, one can interpret the two clienteles further as hedgers and speculators. It can be argued that hedgers, and in particular institutional investors with on-going hedging programs, may be more likely to hold option positions until maturity, while speculators are more likely to liquidate option positions early once the event corresponding to the investor's information is realized.[9]

Several stylized facts of the EuWax market are consistent with the idea that it may serve predominantly speculators with a high likelihood of early liquidation. First, EuWax issuers provide many more calls than puts at a rate of roughly five to one, which does not appear to cater to

[8] According to Börse Stuttgart (2002), major issuers are BNP Paribas, Citibank, Commerzbank, Credit Lyonnais, Deutsche Bank, Dresdner Bank, Goldman Sachs, HSBC Trinkaus Burkhardt, HypoVereinsbank, Lehman Brothers, Merrill Lynch, Rabobank, Salomon Brothers (now part of Citibank), Sal. Oppenheim, Societe Generale, UBS Warburg, Unicredito Italiano, and WestLB.

[9] It appears unreasonable to assume that events will cluster on or shortly before option expiration dates.

investors with hedging demands, who are typically long in the underlying asset, and thus need to buy put options rather than call options.[10] Secondly, minimum trade sizes of EuWax options are considerably smaller than the minimum trades sizes of otherwise comparable EuRex options. This observation is consistent with the idea that the average speculator may be a smaller investor than the average hedger, who may be more likely to be an institutional investor.[11] Institutional investors with on-going hedging programs may also prefer the EuRex market due to its superior predictability with respect to the issuance of future contracts, which is governed by detailed rules for EuRex options, while EuWax issuers are under no obligation to issue particular types of contracts in the future.

3. Data and Methodology

In the following we describe our data sources, provide a brief overview of market activity on EuRex and EuWax, and explain the construction of our sample of matching option quotes.

3.1. Data Sources

We obtain data on the characteristics of all equity options and equity index options (hereafter referred to as index options) which existed during the period 5/1/99 through 10/31/1. These characteristics are: underlying asset, type (call or put), exercise style (American or European), strike price, expiration date, and contract size (in units of the underlying) for both EuWax and EuRex options, as well as the issuing bank for EuWax options. The EuWax data are obtained from the EuWax exchange and OnVista AG, a commercial provider of financial data with a particular focus on EuWax options, who in turn obtain the data directly from the issuers.[12] OnVista also provides monthly trading volume statistics for each EuWax option, measured by the number of contracts traded and the paid premia. In addition, we obtain a complete history of year 2000 bid and ask quotes for all EuWax options from the EuWax exchange. The quotes are directly recorded from the issuing bank's market maker via EuWax's electronic limit-control-system. All quotes are time-stamped to the nearest second.

The EuRex option data contain a complete record of all EuRex transactions during the period 5/1/99 through 10/31/1, which is obtained directly from EuRex. In addition to the option charac-

[10] Offering predominantly call options is also consistent with the behavioral finance idea that individual investors are more likely to have bullish rather than bearish sentiment. Brown and Cliff (2002) provide empirical evidence on the connection between investor sentiment and asset valuation.

[11] Conversations with Sal. Oppenheim and Citibank support the notion that Euwax is predominantly a retail market.

[12] Since all EuWax options are assigned the German equivalent of a CUSIP number, we can easily merge and compare the two data sources. In a very small number of cases (less than 1%) where the two sources disagree, we verify the correct information directly from the issuer web site (virtually all EuWax issuers maintain web sites containing detailed information regarding their own options).

teristics, these data also contain the number of contracts traded and the transaction price. Thus, volume data comparable to the OnVista EuWax volume data can be calculated from the EuRex transactions data.[13] For EuRex options, year 2000 quotes are obtained from the capital markets database (KKMDB) at the University of Karlsruhe. The KKMDB data is recorded directly from the electronic trading system at the EuRex exchange. KKMDB quotes are time-stamped to one hundredth of a second. Each record contains the best bid quote and the best ask quote, which are not necessarily from the same market maker out of the set of competing EuRex market makers.[14]

3.2. Overview of Market Activity on EuRex and EuWax

Total volume as measured by paid premia of all EuWax equity and index options during the year 2000 is 22.4 billion Euro. The comparable number for EuRex options is 78.3 billion Euro. Thus, the size of the EuWax market as measured by paid premia is approximately 30% of the size of the EuRex market.[15] By definition, the notional volume of underlying assets represented by transactions in each market is significantly larger than the paid premia. For EuRex equity options the ratio of notional volume to paid premia is roughly ten to one. Hereafter volume always refers to paid premia and total volume always refers to the sum of equity and equity index option volume unless indicated otherwise.

As shown in Table 2, there are 37,248 different EuWax equity and index options, where options with identical characteristics but from different issuers are counted individually, and 67,577 different EuRex equity and index options during the period 5/1/99 through 10/31/1. As the data show, EuRex and EuWax option offerings differ in several ways. EuWax options are typically long-dated with average maturities of about 450 and 400 days for calls and puts, respectively, while the average maturity for EuRex options is about 150 days. EuWax options are predominantly American style, while index options on EuRex are European style and equity options are American style. There are also about five times as many call options (31,116) on EuWax as put options (6,132), while these are always issued in pairs on EuRex. EuWax offers a much larger scope of underlying assets (828 for calls and 431 for puts) compared to EuRex (128 for calls and puts). The number of different

[13] To check for accuracy, we aggregate the EuRex volume data for each underlying and compare them to the volume statistics published in the EuRex annual and monthly reports in EuRex Communications (2002b). In all cases the numbers aggregated from the transactions record are within less than .1% of the published number.

[14] We also contacted both EuRex and EuWax to inquire about data identifying the type of counterparty and/or holding period of specific option positions. This type of data would allow additional tests of different clienteles between the two markets. Unfortunately, such data is unavailable at present.

[15] While the ratio of trading volume in the two markets exhibits some variation over the months in the sample, there is no discernible trend.

underlying assets on EuRex is smaller, since it offers many more contracts per underlying (264) than EuWax (38 for calls and 14 for puts). EuRex offers both more expiration dates per underlying asset and a larger number of strike prices per expiration date and underlying asset.

3.3. Matching of EuRex and EuWax Options

For the subsequent empirical analysis we restrict the sample period to the year 2000 and select all EuWax and EuRex options on six underlying assets: two indices, the German DAX index and the European Dow Jones Euro Stoxx 50 index, and four stocks, Deutsche Bank, Daimler Chrysler, Deutsche Telekom, and Siemens. As a result the sample consists of 5,411 EuRex options and 4,389 EuWax options. DAX and Euro Stoxx 50 options are the most heavily traded EuRex options during the year 2000, accounting for approximately 46% of EuRex total volume. Options on the four stocks are among the most heavily traded EuRex equity options during the year 2000 accounting for approximately 29% of EuRex total volume. Collectively, options on the selected six underlying assets account for approximately 75% of EuRex total volume. Similarly, EuWax options on the six underlying assets represent a large share of EuWax trading volume. However, not surprisingly given the much larger number of underlying assets on EuWax, the share of EuWax total volume represented by the selected underlying assets is lower at approximately 41%. Comparing between the two markets, the volume of the selected EuWax options is approximately 15% of the volume of the selected EuRex options. Comparing the volume of the selected EuWax options to the volume of the selected EuRex options by underlying, we observe considerable variation. At the low end, Euro Stoxx 50 and Deutsche Telekom EuWax options account for 1% and 6%, respectively, of their corresponding EuRex options. The percentages are 13%, 14%, and 17% for Daimler Chrysler, Deutsche Bank, and Siemens options. Finally, EuWax DAX option volume represents 28% of its EuRex counterpart. The EuWax DAX option market is larger than the three smaller EuRex option markets for Deutsche Bank, Daimler Chrysler and Siemens.

3.3.1 Option Characteristics

The next step is to match EuRex options with competing EuWax options which provide investors with identical or similar payoff functions. Given that matched options have identical or similar payoff functions, any differences observed should be due to other factors such as transaction costs. We create three (mutually exclusive) categories of matches that differ with respect to the required matching characteristics. All matches have the same underlying asset and option type. Category 1 matches also have the same strike price, expiration date, and exercise style resulting in identical payoff functions for both options. Category 2 matches have the same strike price, and exercise style, but the EuWax expiration date differs by $\pm$ 1 to 7 days from the EuRex expiration date, as small deviations in

maturity may be perceived similar by investors given the long average maturity of EuWax options discussed above. Category 3 matches have the same strike price, and the EuWax expiration date may differ by $\pm$ 1 to 7 days from the EuRex expiration date. Furthermore, the exercise style can be different, but the matches are limited to index call options. Category 3 has the following rationale. Index options on EuRex are exclusively European style options, while index options on EuWax are predominantly (although not exclusively) American style options. Since both DAX and Euro Stoxx 50 are total performance indices with reinvestment of dividends, option pricing theory suggests that it is never optimal to exercise American call options early. Thus, American and European index call options should have the same value.

In the matching procedure a EuRex option can potentially be matched with several EuWax options both because slight variations in option characteristics are allowed in categories 2 and 3, and because there are EuWax options with identical characteristics from different issuers (which count as individual matched pairs with their EuRex counterpart). However, we enforce a rule such that each EuWax option is matched with only one EuRex option to achieve the best match quality (smallest difference in expiration dates). Table 3 contains summary statistics of the matching procedure. We obtain 2,361 matched pairs for 903 unique EuRex options. Thus, only approximately 17% of all EuRex options in the sample are matched. However, the matched EuRex options account for 32% of all trading volume among the EuRex options for the six underlying assets, and thus represent 24% of EuRex total volume. Similarly, the matched EuWax options account for 59% of all trading volume among the EuWax options for the six underlying assets and thus represent 24% of EuWax total volume. The fact that EuWax trading volume is concentrated in EuWax options with a EuRex match also implies that the trading volume of the matched EuWax options represents a larger share of the trading volume of their matching EuRex options than the above mentioned overall (including matching and non-matching options) average of 15%. This percentage almost doubles to 29%. There are 199 category 1 matches, 898 category 2 matches, and 1,264 category 3 matches. Not surprisingly given the general distribution of EuWax options, there are many more call option matches (2,173) than put option matches (188). The number of matches per underlying asset ranges from 221 for Deutsche Bank options to 1,010 for DAX options. For almost all underlying assets and option types, the sample of matches exhibits considerable variation across strike prices and expiration dates.

3.3.2 Option Quotes

For the year 2000, the KKMDB database contains 25,485,590 unique quotes for EuRex options on the six selected underlying assets. The 903 EuRex options with matching EuWax options account for 5,041,031 unique quotes or roughly one fifth of the total number of quotes. Each of the EuRex quotes is matched with EuWax quotes. Since some EuRex options have multiple EuWax matches,

they may have multiple EuWax quote matches as well. For each EuRex quote and corresponding EuWax option, we find the most recent EuWax quote posted on the same day. Initially, this results in 9,699,923 EuRex-EuWax quote pairs. However, it is frequently the case that the same EuWax quote is matched with several EuRex quotes, because EuRex quotes tend to cluster more in time than EuWax quotes. In the next step, we therefore retain only one EuRex-EuWax quote pair such that the time difference between quotes is minimized. This yields 3,294,694 quote pairs.

Next, we introduce several filters to eliminate bad quotes and reduce asynchroneity. We eliminate all quote pairs with a time difference greater than five minutes (resulting in 3,163,369 quote pairs), all quote pairs where either ask quote is zero or smaller than the corresponding bid quote (resulting in 3,156,848 quote pairs), and all quote pairs with a difference between the two ask quotes or the two bid quotes greater than 50% (of the EuRex quote). This results in 3,062,245 quote pairs. Since match categories 2 and 3 allow for a difference in expiration date between the EuRex option and the matching EuWax option, we exclude all observations for which the EuRex option has less than two weeks remaining until maturity. This ensures that all options included have at least one week remaining until maturity, since EuWax options in match categories 2 and 3 can have up to one week shorter maturity than the corresponding EuRex option. The final sample contains 2,914,515 quote pairs.

For each quote pair we then compute the following measures: the ratio of EuWax ask to EuRex ask, the ratio of EuWax bid to EuRex bid, the EuWax and EuRex percentage bid-ask spreads computed as the ratio of ask and bid difference to ask, and the time difference between the EuWax and the EuRex quote. As argued in Section 2, we expect EuWax to have higher ask and higher bid prices resulting in both ratios being larger than one. In addition, the bid ratio is expected to exceed the ask ratio due mainly to the fact that the probability of early liquidation can be less than one. The number of observed quote pairs per day varies markedly over the EuRex-EuWax option matches. Therefore, we compute daily averages of the above measures for each EuRex-EuWax option match. This results in a panel of 95,566 daily observations of EuRex-EuWax option matches.

4. Empirical Evidence

We first provide a detailed univariate comparison of matched EuRex and EuWax options. We then provide multivariate results and explore alternative explanations to our findings. Finally, we also give evidence on whether competition from one market improves liquidity (as measured by bid-ask spreads) in the other market.

4.1. Univariate Results for EuRex-EuWax Matches

The daily observations are averaged over underlying assets, option type (call or put), and match category, forming 22 group averages. The resulting univariate statistics are shown in Table 4. The average time difference over all groups is 59 seconds. Irrespective of underlying, option type, or match category a systematic pattern emerges. EuWax ask quotes are higher than EuRex ask quotes by an average of 4.7% over all daily observations. Of the 22 per group averages, 20 are significant at the 1% level or better and one more is significant at the 5% level. Among the 21 significant averages, 19 show EuWax ask prices to be higher than EuRex ask prices. The two cases of EuWax ask prices, which are significantly smaller than EuRex ask prices, both have a comparatively small number of daily observations. EuWax bid quotes are on average 9.9% higher than EuRex bid quotes. Of the 22 per group means, 21 are significant at the 1% level or better, and all but one show EuWax bid prices to be higher than EuRex bid prices. For all 19 of the 22 cases, where both EuWax ask and bid are higher than EuRex ask and bid, the bid price difference is significantly larger than the ask price difference at the 1% level or better. The average difference of the bid and ask ratios is 5.2%, which implies that EuWax bid-ask spreads are smaller than EuRex bid-ask spreads. The EuWax bid-ask spreads over all daily observations are 2.8%, which compares fairly closely to the 3.2% reported by Petrella (2001) in a sample of 1,085 Italian bank-issued option quotes, while the spread is 7.1% for EuRex options. EuWax bid-ask spreads are smaller than EuRex bid-ask spreads in each of the 22 groups with 21 of the bid-ask spread differences significant at the 1% level or better. Since EuWax options tend to have lower trading volume than EuRex options, the results on bid-ask spreads are also consistent with results by Cho and Engle (1999) indicating that the negative empirical relation between volume and bid-ask spreads, which is well supported for primary assets, does not necessarily apply to option markets.

The univariate results are consistent with the theoretical arguments in Section 2. An investor who expects to liquidate his option position before the option's expiration may be willing to pay a higher ask price on EuWax expecting to benefit from a higher bid price (and thereby smaller round-trip transaction costs) when the option position is liquidated in the future. Based on the univariate statistics we estimate the probability of early liquidation at which EuWax options become preferable (ignoring time value of money and assuming that the current bid price difference is equal to the expected future bid price difference). The implied probability averages 47% with a maximum of 62%.[16] Given the long maturity of many EuWax options, it appears plausible that a speculator may have a probability of early liquidation in the range of the reported implied values.

[16] For each group, the probability is calculated as average ask ratio minus one divided by average bid ratio minus one.

Next we investigate whether the relation indicated by the averages above holds consistently for many quotes. To do this, we categorize each of the 2,914,515 matching quote pairs based on the relation among the ask and bid quotes. To reduce the number of cases, we ignore quote pairs in which the comparable bid and/or ask are equal. This eliminates fewer than 1% of all quote pairs and leaves us with four cases:

$$\begin{aligned} \text{Case 1} &: \quad A^R < A^W, B^R < B^W \\ \text{Case 2} &: \quad A^R > A^W, B^R < B^W \\ \text{Case 3} &: \quad A^R > A^W, B^R > B^W \\ \text{Case 4} &: \quad A^R < A^W, B^R > B^W, \end{aligned} \tag{8}$$

For each case, we then compute the average ask and bid ratios for different underlyings, option type (call or put), and match category.

Table 5 shows that the previous results hold consistently as case 1 is the most frequent. Averaged over all underlyings, types, and match categories, the share of quote pairs exhibiting both higher EuWax ask prices as well as higher EuWax bid prices is 61%. Over the 22 groups, the share of such quote pairs ranges from 22% to 88%. The average ask price difference in this relation is 7%, while the average bid price difference is 12%. Case 1 allows for situations in which EuWax bid prices exceed EuRex ask prices. However, as pointed out previously, investors are unable to arbitrage such cases due to the inability to short EuWax options.

The next largest average share of quote pairs is 31% for case 2 in which the EuWax ask price is lower than the EuRex ask price and the EuWax bid price is higher than the EuRex bid price. This relation (if maintained over the life of the option) would render EuWax options preferable for all investors regardless of their likelihood of early liquidation. Over the 22 groups, the share of such cases ranges from 11% to 60%. In this situation, EuWax ask prices are on average 3% cheaper than EuRex ask prices and EuWax bid prices are on average 6% higher than EuRex bid prices. Combining the above two cases, in which EuWax options appear preferable to option investors with a positive probability of early liquidation, accounts on average for approximately 92% of all observed quote pairs.

Case 3 in which both the EuWax bid and ask quote are smaller than their EuRex counterpart accounts on average for 7% of quote pairs. Over the 22 groups, the share of case 3 ranges from 0% to 26%. In this case, the EuWax ask price is on average lower by 7%, while the EuWax bid price is only lower by on average 5%. In case 3, an investor expecting early liquidation will prefer EuWax options, if the savings from the lower ask price are larger than the expected loss from the lower bid price. Again assuming the relations are maintained over the life of the option, this is the case for 19

of the 22 groups for which the ask price difference is larger than the bid price difference. Even for the remaining three groups an investor might still prefer EuWax options as long as the probability of early liquidation is not equal to one. Case 3 potentially includes situations in which EuRex bid prices exceed EuWax ask prices for options with identical payoff functions. Ignoring other transaction costs, such situations could constitute potential arbitrage opportunities, as investors are able to write (i.e. short) EuRex options. We find that the potential arbitrage case of $A^W < B^R$ occurs in less than 1% of the 2,914,515 quote pairs in the sample and that the median difference of the two prices is less than 2.5%. Many of the potential arbitrage quote pairs may be due to asynchroneity, which is confirmed by the fact that the mean time difference is around 3 minutes (as compared to 59 seconds for the entire sample). Finally, the relation of a higher EuWax ask price and a lower EuWax bid price (case 4), which, if maintained, would make EuRex options preferable for all investors, on average accounts for only 1% of the observed quote pairs. Over the 22 groups, this share is never larger than 3%.

4.2. Multivariate Results for EuRex-EuWax Matches

4.2.1 Ask Ratios

In this section we investigate how the competitiveness of EuWax options relative to EuRex options varies in our sample. A natural measure of relative competitiveness is the ratio of ask prices, since it affects all option buyers irrespective of the likelihood of early liquidation. For this analysis we use the 2,914,515 matched quote pairs described in Section 3.3. For each EuWax option in the matched data set, we calculate monthly averages of all variables which results in an unbalanced panel of 8,185 monthly observations for the 2,361 EuWax options with EuRex matches. We use monthly rather than the previously employed daily averages for two main reasons. First, most of the variables used in the subsequent analysis exhibit relatively little time-series variation. Secondly, employing a lower frequency reduces the problem of potential serial correlation in the ask and bid ratio measures.

Summary statistics for the panel are shown in Table 6. Each monthly observation of ask and bid ratios is based on an average of 355 quotes with a standard deviation of 628 quotes. The average ask ratio is around 1.05, and the average bid ratio is around 1.09. The average number of EuWax options competing with each other and the matching EuRex option is 2.7; the maximum is 8 competing EuWax options. The ratio of EuWax minimum trade size (in units of the underlying asset) to EuRex minimum trade size averages 2.6% with a standard deviation of 5.7% and a maximum of 50%. The guaranteed maximum bid-ask spread (in Euro) averages 17 cents for EuWax options with a standard deviation of 50 cents. We create a dummy equal to one, if the issuing institution of a EuWax option is also a market maker for the matching EuRex option. This is the case for 59% of all EuRex-EuWax pairs.

We compute the annualized standard deviation of the underlying asset's daily returns during the observation month. Daily return and price information for the underlying assets is obtained from Datastream. The standard deviation averages 32% and ranges from 11% to 77%. For each option pair we compute daily time to expiration (in days) using the expiration date of the EuRex option, and moneyness (ratio of underlying asset price to strike price for calls; ratio of strike price to underlying asset price for puts) using the underlying asset's closing price. The daily values are averaged for each observation month. Time to expiration averages 221 days with a standard deviation of 155 days and ranges from 14 days to 730 days. Moneyness averages 102% with a standard deviation of 26% and ranges from 37% to 347%.

We employ three regression specifications using the EuWax to EuRex ask ratio as the dependent variable. The following independent variables are present in all specifications: EuWax to EuRex bid ratio, and number of competing EuWax options. Based on the clientele argument, the bid ratio should have a positive coefficient, which should, however, be smaller than one, given that the average investor's probability of early liquidation is also expected to be smaller than one. The number of competing EuWax options is expected to have a negative effect on the ask ratio based on the idea that increased competition should drive down option investors' transaction costs. Underlying asset standard deviation, option type (dummy equal to one for puts), moneyness, and time to expiration are used as control variables in all specifications. In addition to the above variables, specification 1 also contains a EuRex market maker dummy. If the EuRex market is one of the venues used by EuWax issuers to actually hedge their own exposures from selling EuWax options, it could be argued that issuers which are also EuRex market makers in the same underlying asset may enjoy hedging cost advantages. If these hedging cost advantages are passed on to EuWax option buyers, there should be a negative coefficient. In specification 2, we include dummy variables for the underlying assets and EuWax issuers. The dummies are designed such that the regular intercept represents DAX EuWax options (the largest EuWax segment) issued by Citibank (the largest EuWax issuer). The market maker dummy is excluded from specification 2, since it is perfectly correlated with the issuer dummy in several cases. Specification 3 adds the EuWax issuer's guaranteed maximum bid-ask spread and the ratio of EuWax to EuRex minimum trade size to specification 2. One can expect negative coefficients for both variables. Investors wishing to liquidate early should prefer a lower maximum guaranteed bid-ask spread, since it ceteris paribus increases the expected future bid price. If EuWax issuer are compensated for this guarantee they should be able to charge higher ask prices. Secondly, if EuWax investors are on average smaller investors than EuRex investors, they prefer smaller minimum trade sizes, which again allows the EuWax issuer to raise its ask price all else equal. These last two variables are only available for a subset of EuWax options which reduces the

sample to 3,801 monthly observations.

The results of the regressions are shown in Table 7. All standard errors are robust to heteroskedasticity and first-order serial correlation. Since most coefficient estimates appear to be consistent across the three specifications, we combine the discussion. As expected the coefficient for the bid ratio is positive, less than one at approximately .7, and significant, indicating that EuWax option buyers paying higher relative ask prices can expect to be compensated via even higher relative bid prices.[17] The coefficient for the number of competing EuWax options is negative and significant, which is consistent with the idea that competition among EuWax issuers drives down the transaction costs to EuWax option buyers. The coefficient for the underlying asset standard deviation is negative and significant. Given that this result also holds in the specifications that include underlying asset dummies, we interpret this result as an indication that, relative to EuRex options, EuWax liquidity is less affected in periods of higher uncertainty. Time to expiration is negative and significant in the first two specifications, but switches sign and becomes insignificant in specification 3. The put dummy coefficient is negative and significant at the 10% level or better in all regressions. Moneyness has a positive coefficient, but is only marginally significant in one specification. We also run each specification (results not shown) with moneyness and moneyness squared to investigate potential non-linear effects of moneyness but we do not find any significant coefficients. The market maker dummy coefficient has the predicted negative sign, but is insignificant. On the other hand both the maximum bid-ask spread and the relative minimum trade size coefficients have the predicted negative sign and are significant lending further support to the clientele argument in the sense that EuWax issuers can trade off more competitive quotes (lower ask ratios) for other market-making features that are important to the EuWax clientele.

Relative to DAX options several other underlying assets have significantly lower ask ratios: Deutsche Bank options and Deutsche Telekom options in specifications 2 and 3, Euro Stoxx 50 options in specification 3 only. Interestingly, there also appears to be considerable variation in ask ratios across issuers relative to the market leader Citibank. BNP Paribas, and Sal. Oppenheim are cheaper in both specifications, while Dresdner Bank, UBS Warburg, and Unicredito Italiano are cheaper in specification 2 only. Credit Lyonnais, Commerzbank, DG Bank, Rabobank, and Societe Generale are more expensive in both specifications, while Merrill Lynch and West LB are more expensive in specification 3 only.[18] Adjusted fit lies between 73% and 75% for the three specifications.

[17] There are potential endogeneity problems using the bid ratio as a regressor. Thus we repeat specification 3 excluding the bid ratio With the exception of relative minimum trade size, all significant variables from the orginal specification 3 maintain sign and significance.

[18] A potential explanation of significant issuer dummies could be variation in issuer default risk. However, an analysis (results not shown) of a potential link between issuer dummies and accounting

An additional test of the clientele argument can be based on the time-series properties of ask ratios. The idea is that as a particular option approaches maturity, the probability of holding to expiration increases and the probability of liquidating before expiration decreases. Therefore the incentive to pay a higher ask price in the EuWax market decreases, and we should expect the ask ratio to decrease over time. While the results in the above regressions are inconclusive with respect to time to expiration, they suffer from the problem that the estimated coefficient measures both cross-sectional as well as time-series variation in time to expiration. To produce a cleaner test of the time-series effects alone, we split the sample by EuRex expiration dates thereby eliminating any cross-sectional variation in time to expiration. To ensure that all time series are available over the full year 2000 sample period we focus on options expiring in 2001 and 2002 resulting in seven different expiration date samples. We eliminate two expiration dates as their samples contain fewer than 20 monthly observations. The remaining five expiration dates range from March 2001 to June 2002 with sample sizes ranging from 255 to 1,491 observations. We then estimate the above three regression specifications for each of the five expiration date samples. The coefficient on time to expiration in these regressions measures time-series variation only and is expected to be positive based on our argument. Table 8 shows the estimated coefficients and t-statistics for time to expiration. Estimated coefficients for the remaining variables are not shown but are generally consistent with the previous results. As expected all but one of the 15 coefficients on time to expiration are positive and significant at the 1% level or better. Based on the estimated coefficients, the table also shows the decrease in the ask ratio as the options age by one month. This monthly decrease ranges from 20 to 93 basis points and thus also appears to be economically significant.

4.2.2 Probability of Early Liquidation

As pointed out in the univariate results, we can use the observed ask ratios and bid ratios to construct a measure of the probability of early liquidation at which investors are divided into EuRex and EuWax clients. The interpretation of this measure is such that all investors with a higher probability than this cut-off value select EuWax, while all investors with a lower probability than this cut-off value select EuRex. We construct the probability of early liquidation cut-off (PELC) as follows.

$$PELC = \begin{cases} \frac{AR-1}{BR-1} & \text{for } BR > AR > 1 \\ 1 & \text{for } AR > BR > 1 \\ 1 & \text{for } AR > 1 > BR \\ 0 & \text{for } AR < 1 < BR \\ 0 & \text{for } AR < BR < 1 \\ \text{Not defined} & \text{for } BR < AR < 1 \end{cases} \tag{9}$$

where AR is the ratio of EuWax ask to EuRex ask and BR is the ratio of EuWax bid to EuRex

measures of financial strength/leverage/default risk does not reveal any significant results.

bid. As shown by the univariate results, the first case in the above equation is by far the most frequent, where EuWax ask and bid prices are higher with the bid price difference being larger than the ask price difference. The next four cases are situations where either all investors irrespective of their probability of early liquidation prefer EuRex and we set the cut-off value to one or all investors irrespective of their probability of early liquidation prefer EuWax and we set the cut-off value equal to zero. The last case has both lower bid and ask prices on EuWax. In this situation investors initially save money by buying EuWax options, but may loose even more money later on, if the option is liquidated. However, the initial savings are certain while the losses are only incurred with the probability of early liquidation. Unlike case 1, it would be investors with a probability of early liquidation below rather than above a certain threshold who prefer EuWax in this last case. The last case represents fewer than .05% of our monthly observations, and we thus exclude it from the empirical analysis as it is unclear how to combine its PELC measure with the other cases. We compute the PELC measure for each observation in the monthly data set using the monthly ask ratios and bid ratios. The average PELC value is 36% with a standard deviation of 29%. As before the PELC measure incorporates two simplifications in that it ignores the effect of the time value of money on the probability of early liquidation. Furthermore, it uses the current bid ratio as a measure of the investor's expected bid ratio.

Based on the clientele argument our main hypothesis is that options which attract investors with speculative motives will exhibit higher probabilities of early liquidation as measured by the PELC values. We employ two measures of speculativeness. The first measure is the option's omega commonly used by practitioners.

$$Omega = \Delta \times \frac{S}{A^W} \tag{10}$$

where Δ is the option's delta, S is the value of the underlying, and A^W is the EuWax ask price. It is often argued that options with high omegas are attractive to investors with speculative motives, since omega measures the elasticity of option prices with respect to the value of the underlying. Therefore omega measures the return leverage of an option position rather than the price leverage which is measured by the option's delta. The second measure is based on the option's vega Λ.

$$VegaRatio = \frac{\Lambda}{A^W} \tag{11}$$

Options with high vegas are attractive to investors with speculative motives regarding the underlying asset's volatility. Similar to our choice of omega rather than delta, we use the ratio of vega to the option's price rather than vega itself. The vega ratio can be interpreted as the option's percentage price change given a one percent change in the underlying asset's standard deviation. For European EuWax options delta and vega are computed using the option pricing formulas with continuous dividend yields as derived by Merton (1973). For American EuWax options delta and vega are computed

using the analytic approximation as derived by Barone-Adesi and Whaley (1987).[19] Omegas and vega ratios are computed daily, and then averaged for each month in the sample. We regress the probability of early liquidation measure (PELC) on both measures of speculativeness using EuWax market share, computed as the ratio of EuWax option monthly trading volume to the sum of EuWax and EuRex option monthly trading volume, time to expiration, and option type as control variables.[20] To illustrate why we control for variation in market share between EuRex and EuWax consider the case in which EuWax issuers incorrectly set ask and bid prices such that PELC values are very high for an option which is not attractive to speculators as measured by omega and vega ratio. The result will be that very few investors purchase EuWax options and the market share of EuWax will be small. The results of the regression are shown in Table 9. As predicted by the clientele argument there is a positive relation between the probability of early liquidation as measured by PELC and both measures of speculativeness, omega and vega ratio. We also observe a positive relation between the PELC measure and time to expiration. As argued previously, all else equal the probability of early liquidation should increase with time to expiration consistent with the positive coefficient. The market share coefficient is negative but insignificant. The coefficient for option type is negative indicating a lower PELC measure for put options. Adjusted fit for the regression is 19.2%.

4.3. Alternative Explanations

The clientele argument suggests that investors with a high probability of early liquidation are willing to pay higher EuWax ask prices to benefit from lower round-trip transaction costs (as measured by bid-ask spreads) for EuWax options. In the following, we evaluate potential alternative explanations for our findings.

4.3.1 Effective Spreads vs. Quoted Spreads

Our analysis is based on a comparison of quotes rather than transactions due to the unavailability of large-scale transaction data for EuWax options. While we find significant differences in quoted bid-ask spreads between the two markets, it is possible that the same relation does not hold for effective bid-ask spreads if, for example, transactions inside the quoted spread are more frequent on EuRex than on EuWax. The following analysis investigates this issue. A sample of time-stamped transaction prices

[19] For each month in the sample we use risk-free discount rates published by the European Central Bank. We employ historic dividend yields during the year 2000 obtained from OnVista AG. Standard deviations are year 2000 averages of the monthly standard deviations used in the preceeding regressions.

[20] The market share measure is adjusted for differences between EuWax and EuRex in the number of trading days during the month.

is provided by the EuWax exchange.[21] We select transaction prices of EuWax options with matching EuRex options as defined previously. Each EuWax transaction is matched with a corresponding EuRex transaction provided that the time difference between the two is less than one hour. Next each transaction is matched with the immediately preceding quote from each respective market such that the quote is no more than ten minutes before the corresponding transaction. We then compute quoted bid-ask spreads as defined previously and effective bid-ask spreads EFF defined as:

$$EFF = \frac{2 \times |P - M|}{A}, \tag{12}$$

where P is the transaction price, M is the average of the corresponding bid and ask quotes, and A is the corresponding ask quote. We also record the share of all transactions taking place inside the spread. As before, we form groups by underlying, option type (call or put), and match category, and compute averages which are reported in Table 10. We exclude groups with fewer than ten observations leaving us with 1,261 observations in eleven groups. The results indicate that the incidence of inside-quote transactions is indeed higher on EuRex than on EuWax, with averages over all groups of 72.2% and 21.3%, respectively. This higher incidence of inside-quote transactions translates into a larger difference between quoted spreads and effective spreads on EuRex compared to EuWax. Average quoted and effective spreads on EuRex are 8.3% and 4.4%, respectively, while they are 3.6% and 2.6%, respectively, for EuWax. Thus, the difference between bid-ask spreads on EuRex and EuWax shrinks when measured by effective spreads. However, over all groups the difference in effective spreads of 1.8% is still significant at the 1% level indicating that EuRex-EuWax differences still persist when measured via effective spreads..

4.3.2 Liquidity Premium

Chan and Pinder (2000) use a sample of 252 matched trades of Australian bank-issued equity options and exchange-issued equity options. They find that bank-issued options have on average higher transaction prices than comparable exchange-issued options and argue that the difference may be due to a liquidity premium for bank-issued options. This liquidity premium is motivated by the fact that Australian bank-issued options in the sample are electronically traded as opposed to floor trading for exchange-issued options, which Chan and Pinder (2000) argue leads to faster execution and better transparency for bank-issued options. Furthermore, bank-issued options in their sample tend to have larger trading volume than comparable exchange-issued options. It is difficult to see how similar arguments of a liquidity premium could be applied to the EuRex-EuWax comparison. While we do not have direct evidence on speed of execution, the exchange-issued EuRex market

[21] For each day and option EuWax keeps the last entry in its real-time database in a second database of historic records. Most of the time this last entry is a quote rather than a transaction and thus we cannot use it for the analysis leading to the small sample size.

is an electronic market, while the bank-issued market uses order-book brokers without automated matching. More importantly, the monthly trading volume of EuWax options is larger than the monthly trading volume of matching EuRex options in only 17% of the observations.

4.3.3 Bid-Ask Spreads vs. Other Transaction Costs

Another potential reason why investors may be willing to pay higher EuWax ask prices, is that transaction costs unrelated to bid-ask spreads may be lower for bank-issued options. Horst and Veld (2002) compare transaction costs for Dutch bank-issued options and exchange-issued options, and find economically significant transaction cost advantages only in the case of very low-priced ($\leq$ .2 Euro) bank-issued options.[22] To investigate the issue of transaction cost differences unrelated to bid-ask spreads, we perform the following analysis for the German markets using DAX options.[23] We obtain detailed pricing schedules from three large German on-line brokerages which offer both EuWax and EuRex trading: Comdirect (owned by Commerzbank), Consors (owned by BNP Paribas), and Fimatex (majority owned by Societe Generale). In the case of Consors, the comparison is relatively straightforward as both EuWax and EuRex option trades are charged as a percentage of the transaction value (in addition to a flat charge for each trade). The EuWax charge of .25% is half of the EuRex charge of .50%. Comdirect and Fimatex charge EuWax options primarily through a percentage (in addition to a flat fee), while EuRex options are charged per contract. Thus the transaction cost difference depends on the value of the option.

To generate a range of typical option trade values, we first set the EuWax contract size to .01 Euro per index point which is the most common contract size representing 80% of the EuWax DAX options in the sample of EuRex-EuWax pairs. EuRex DAX options have a contract size of 5 Euro per index point. For each EuWax option with .01 Euro contract size, we compute the average ask price over all EuRex-EuWax quote pairs in the sample. Next, we analyze the cross-sectional variation of the ask prices. Over all EuWax options the mean and median ask price is 7.66 and 4.76 Euro, respectively. In addition, we use the top and bottom decile ask prices of 19.01 and 1.05 Euro, respectively. For each of the four option prices, we compute three trade values corresponding to 1, 10, and 100 EuRex contracts. Finally, we calculate the transaction costs for each of the resulting twelve trade values under each brokerage's pricing schedule. The results are shown in Table 11. While transaction costs for EuWax option trades are generally lower than transaction costs for EuRex options, with the exception of the smallest trade for the lowest-price option, all transaction cost

[22] For bank-issued options with prices of .5 Euro or above, the transaction cost advantage is never larger than .9% of the option value, and there are several cases in which exchange-issued options have lower transaction costs.

[23] A similar analysis (not shown) for the other underlying assets yields comparable results.

differences are less than 1% of the trade value. Thus, it is unlikely that transaction cost differences could be responsible for the observed differences in bid and ask prices across the two markets.

4.4. Options with and without Competition from the other Market

While the univariate and multivariate results lend support to the suggested clientele argument, the EuRex and EuWax option markets may not be fully segmented. If investors are willing to switch between the two markets, we would expect that the competitive pressure from the other market will positively affect liquidity relative to options in each market which are not subject to competition from the other market. We investigate this issue using bid-ask spreads as a measure of liquidity.

4.4.1 Effect of EuWax Competition on EuRex Bid-Ask Spreads

For each of the 903 EuRex options, which have at least one competing EuWax option, we find matching EuRex options which at no point during the sample period have a competing EuWax option. We require that the matching EuRex option has the same underlying and type. From the eligible EuRex options without EuWax competition, each month the one with average daily trading volume closest to the average daily trading volume of the EuRex option (with EuWax competition) is selected.[24] Although the previous results indicate that there may not be a strong relation between trading volume and bid-ask spreads, we nonetheless conform to this matching procedure, since it is, for example, used by Mayhew (2002) in the existing literature.

The 2,914,515 quote pairs used in Section 3.3 correspond to 1,362,192 unique EuRex quotes.[25] For each of the unique EuRex quotes we obtain a quote for the matching EuRex option without EuWax competition such that the time difference between the two EuRex quotes is minimized. Next, we introduce a filter to reduce asynchroneity by eliminating all EuRex-EuRex quote pairs with a time difference greater than five minutes. The filtering procedure results in 769,575 quote pairs. As before we eliminate all quote pairs, if at least one of the two options in the pair has less than two weeks until maturity. This reduces the sample to 642,146 pairs. Finally, all pairs are excluded, if the average daily trading volume during the sample month differs by more than 20%. The final sample contains 561,578 quote pairs. For each quote pair we then compute the following measures: percentage bid-ask spreads, ratio of the ask price of the EuRex option without EuWax competition to the ask price of the EuRex option with EuWax competition, and time difference. As previously,

[24] Since matches can have differing expiration dates in this analysis, average daily rather than monthly volume is used because one of the two options in a match may expire during the observation month. Among EuRex options without EuWax competition, multiple matches with different EuRex options (with EuWax competition) are allowed.

[25] The number of EuRex-EuWax quote pairs is higher, since each EuRex option can be matched with several competing EuWax options.

we then compute daily averages of the above measures for each EuRex-EuRex option match. This results in 19,118 daily observations of EuRex-EuRex option matches. We exclude DAX and Euro Stoxx 50 put options as both have fewer than 50 daily observations. This reduces the number of observations to 19,083.

Finally, we compute averages over underlying assets and option types, forming ten groups. As shown in Table 12, the average time difference between matching quotes is 82 seconds. The ratio of volume for options without EuWax competition to volume for options with EuWax competition is close to one in all groups. The ask price ratio is larger than one in all groups. According to prior literature such as Mayhew (2002) the latter result may bias us against finding lower bid-ask spreads for EuRex options with EuWax competition. Nonetheless, we find that in six out of ten groups bid-ask spreads for EuRex options with EuWax competition are significantly (1% level) lower than the bid-ask spreads of their EuRex matches without EuWax competition. Only in one group is the relation significant and reversed. The average bid-ask spread difference over all groups is 1.7% with a maximum of 6.6% for Siemens put options. In general the results indicate that EuWax competition indeed has a positive effect on the liquidity of EuRex options as measured by bid-ask spreads.

4.4.2 Effect of EuRex Competition on EuWax Bid-Ask Spreads

This section analyzes the effect of competition from EuRex on EuWax bid-ask spreads. For each of the 2,361 EuWax options, which have a competing EuRex option, we find matching EuWax options which at no point during the sample period have a competing EuRex option, following the procedure outlined in the previous section. For each of the 2,914,515 unique EuWax quotes used in Section 3.3 we obtain a quote for the matching EuWax option without EuRex competition such that the time difference between the two EuWax quotes is minimized. We apply the same filtering procedures and compute daily averages as in the previous section resulting in 53,607 daily observations of EuWax-EuWax matches. We exclude DAX, Euro Stoxx 50, and Siemens put options as they have fewer than 50 daily observations. This reduces the number of observations to 53,509.

Next, we compute averages over underlying assets and option types, forming nine groups. As shown in Table 13, the time difference between quotes is somewhat larger than in the other two matching procedures, but is still less than three minutes at 146 seconds. The ratio of volume for EuWax options without EuRex competition to volume for EuWax options with EuRex competition is close to one in all groups. Similarly, the ask ratio is larger than one in all groups except one, which would again bias us against finding lower bid-ask spreads for EuWax options with EuRex competition.

In four out of nine groups bid-ask spreads for EuWax options with EuRex competition are

significantly (1% level) lower than the bid-ask spreads of their EuWax matches without EuRex competition. While we also find four groups for which the relation is significant (5% level or better) and reversed, the magnitude of the spread differences is considerably larger for the cases which have the predicted relation. In the cases where the EuWax spreads of options with EuRex competition are lower, the difference ranges from .8% to 4.9%. On the other hand, the largest difference in the reversed case is only .9%. The average bid-ask spread difference over all groups is lower for EuWax options with EuRex competition at .6%. Since the results are biased against finding lower spreads for EuWax options with EuRex competitions, we recompute our tests (results not shown) using only daily observations for which the difference of the ask prices is less than 50% of the ask price for the option with competition. In this case, out of eight groups (across underlying and type) with more than 50 observations, seven have lower bid-ask spreads for EuWax options with competition and are significant at the 1% level or better. Thus, while the results are slightly weaker for EuWax options than EuRex options, the evidence is generally supportive of the idea that EuRex competition has a positive effect on the liquidity of EuWax options.

5. Conclusion

Option market structure matters. This paper provides evidence that it can be rational for two option markets with fundamentally different structures to exist side-by-side and to compete by offering options with identical or similar characteristics. We motivate the above finding by connecting the idea of option market clienteles to market structure issues. The theoretical and empirical findings highlight the importance of exercising great care when translating insights from the microstructure literature on primary asset markets to derivative securities markets. Among other things we provide further evidence that trading volume and bid-ask spreads may be less closely connected in derivatives markets than in primary asset markets, and that the traditional components of bid-ask spreads may also be less relevant for derivatives. As a new insight we show that unlike most primary asset markets, derivatives markets may benefit from a certain type of fragmentation in that the absence of standardized contracts and of a central counterparty fosters competition among issuers/liquidity providers.

The results may also be of importance for regulators and practitioners. It appears that the creation of bank-issued option markets in the U.S. could help serve the clientele of option investors with a high probability of early liquidation, and if nothing else may also improve the quality of existing markets such as the CBOE due to competition. Similarly, current discussions surrounding a pan-European regulatory "securities passport" may consider bank-issued option regulation along the lines of the German model.

Several avenues for future research remain. For one, other measures of liquidity/market-making quality, such as quoted depth, could be considered for a comparison of the two markets. With respect to quoted depth, the clientele argument would predict that the EuRex market will be deeper than the EuWax market, since depth is less of a concern for smaller investors using the EuWax market. Bank-issued option markets also allow researchers a look at option demand functions, since issuers are free to choose option characteristics which they expect to have high demand from investors. In particular, issuance can be studied dynamically to investigate how it responds to events in the underlying asset markets (e.g. issuing put options after large underlying price drops) and the markets for already existing derivative securities. Similarly, there may be dynamic interaction among issuers and markets with respect to both issuance and market-making behavior. This seems particularly interesting in light of the fact that many bank option issuers are also exchange-issued option market makers in the case of EuRex and EuWax.

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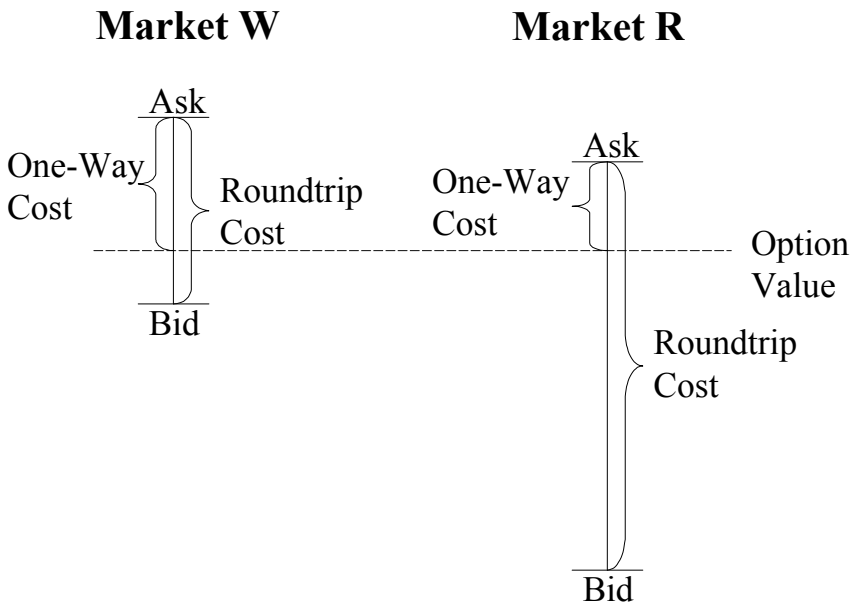

Figure 1. One-Way vs. Round-Trip Transaction Costs

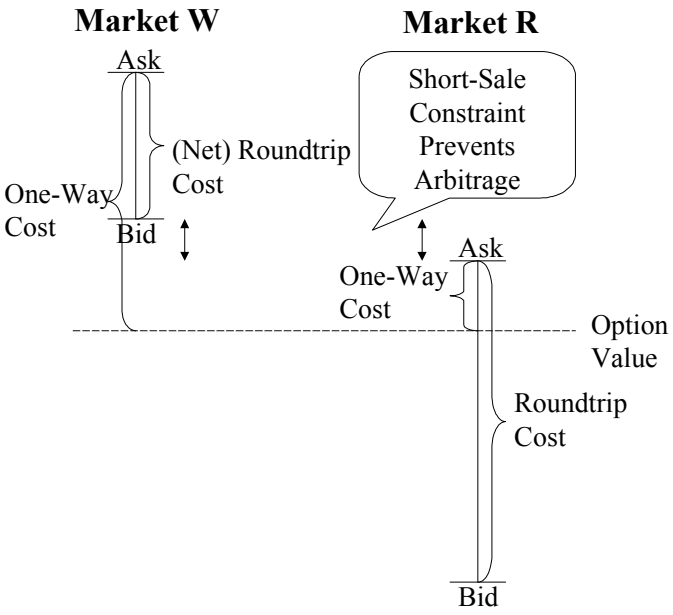

Figure 2. One-Way vs. Round-Trip Transaction Costs with Short-Sale Constraint in Market W

Table 1: Institutional Differences between EuRex and EuWax

The table shows institutional differences between the EuRex and EuWax option markets.

Feature	EuRex	EuWax
Counterparty	Central	Different Issuers
Market-Making	Several Competing Market Makers	Issuer as Predominant Market Maker
Shorting	Possible	Not Possible
Market-Making Guarantees (e.g. trade size, depth)	Same for All Market Makers	Vary by Issuer
Contract Design	Standardized	Chosen by Issuer
Creation of New Contracts	Governed by Rules	At Issuer's Discretion

Table 2: Market Activity in the EuRex and EuWax Option Markets

The table shows the number of EuRex market makers/EuWax issuers, underlying assets, average time to expiration (in days), and the mean, median, and standard deviation of the number of option contracts for EuWax and EuRex options during the period 5/1/99 through 10/31/1. Contract numbers are broken down by option type, issuer, underlying asset, and expiration date. Data on option characteristics are from EuWax, EuRex, and OnVista.

		EuRex		EuWax	
		Call	Put	Call	Put
Market Makers / Issuers		42	42	23	20
Underlying Assets		128	128	828	431
Underlying Assets per Market Maker / Issuer	Mean	28	28	142	67
	Median	16	16	132	44
	St. Dev.	30	30	110	55
Option Contracts	American	28,434	28,431	30,724	6,064
	European	5,356	5,356	392	68
	Total	33,790	33,787	31,116	6,132
Option Contracts per Issuer	Mean			1,353	307
	Median			1,214	299
	St. Dev.			1,173	265
Option Contracts per Underlying Asset	Mean	264	264	38	14
	Median	224	224	8	3
	St. Dev.	222	222	94	51
Expiration Dates per Underlying Asset	Mean	18.5	18.5	10.9	6.2
	Median	20.5	20.5	4.0	3.0
	St. Dev.	7.8	7.8	17.2	9.5
Expiration Dates per Underlying Asset, Issuer	Mean			3.2	2.2
	Median			2.0	2.0
	St. Dev.			2.7	1.5
Time to Expiration (in days)	Mean	152	152	453	409
	Median	88	88	455	416
	St. Dev.	153	153	154	159
Strike Prices per Underlying, Expiration Date, Issuer	Mean	14.3	14.3	3.2	2.1
	Median	10.0	10.0	2.0	1.0
	St. Dev.	12.2	12.2	3.1	2.7

Table 3: Summary Statistics for Matched Eurex and Euwax Options

The table shows the number of observations, absolute value of expiration date difference, annual trading volume (in Euro million paid premia), strike price (mean, standard deviation, minimum, maximum), expiration date (mean, minimum, maximum), contract size, Euwax minimum trade size, and ratio of Euwax and Eurex trade size for a sample of matched pairs of Eurex and Euwax options during the year 2000. Match category 1 has the same underlying asset, type, strike price, expiration date, style. Category 2 is as catetgory 1 except ± 7 days expiration date difference. Category 3 is as category 2 except difference in style is allowed for index call options. All numbers are means unless indicated otherwise. Underlying assets are: Deutsche Bank, Daimler Chrysler, Deutsche Telekom, Dax index, Dow Jones Euro Stoxx 50 index, and Siemens. Simple and observation-weighted averages are also computed. Data on option characteristics and volume are from Euwax, Eurex, and OnVista.

		Deutsche Bank		Daimler Chrysler		Deutsche Telekom		Siemens		DAX		Euro Stoxx 50		All	Weighted
		Call	Put	Call	Put	Call	Put	Call	Put	Call	Put	Call	Put		
Obs.	Total	191	30	189	47	224	44	280	48	1,010	4	279	15	2,361	
	Category 1	28	4	22	8	38	3	45	7	4	4	21	15	199	
	Category 2	163	26	167	39	186	41	235	41					898	
	Category 3									1,006		258		1,264	
	Exp. Date Diff.	3.4	3.2	3.4	3.0	3.6	3.3	3.6	3.2	2.4	0	1.7	0	2.6	2.8
	Eurex Volume	1,419	194	445	441	1,502	487	1,310	153	7,307	14	5,261	581	1,593	4,223
	Euwax Volume	108	4	340	5	264	37	521	17	4,059	64	60	0	456	1,867
Strike	Mean	93	81	73	69	60	53	142	116	7,143	7,100	4,842	4,373	2,012	
	St.Dev.	17	12	18	17	24	15	40	35	1,125	115	900	555	239	
	Min.	50	60	40	40	26	26	60	60	4,000	7,000	3,000	3,200	1,464	
	Max.	140	100	120	100	140	80	250	180	10,000	7,200	7,000	7,000	2,526	
Exp.	Mean	8/7/1	8/21/1	5/17/1	3/24/1	7/10/1	4/11/1	7/26/1	6/22/1	2/27/1	9/21/1	4/28/1	12/12/1	6/26/1	5/2/1
Date	Min.	3/17/0	6/16/0	3/17/0	3/17/0	3/17/0	3/17/0	3/17/0	3/17/0	1/21/0	9/21/1	3/17/0	6/15/1	6/11/0	2/27/0
	Max.	12/20/2	12/20/2	12/20/2	6/21/2	12/20/2	6/21/2	12/20/2	12/20/2	6/21/2	9/21/1	6/21/2	6/21/2	8/28/2	9/2/2
	Eurex Contr. Size	100	100	100	100	100	100	100	100	5	5	10	10	69	48
	Euwax Contr. Size	.21	.19	.18	.16	.25	.34	.24	.13	.01	.01	.01	.01	.14	.10
	Euwax Trade Size	24	33	29	29	33	43	36	31	37	1	53	80	36	37
	Rel. Size	5%	6%	5%	5%	8%	15%	9%	4%	7%	0%	3%	7%	6%	6%

Table 4: Univariate Results for Matched EuRex and EuWax Options

The table shows the type (call or put), underlying asset (Deutsche Bank, Daimler Chrysler, Deutsche Telekom, Dax index, Dow Jones Euro Stoxx 50 index, and Siemens), match category, number of daily observations, number of quote pairs, average time difference, average ratio of ask prices, average ratio of bid prices, implied early liquidation probability, and average bid-ask spread (ratio of (ask minus bid) to ask) for a sample of matched quote pairs of EuRex and EuWax options during the year 2000. Match category 1 has the same underlying asset, type, strike price, expiration date, style. Category 2 is as category 1 except ± 7 days expiration date difference. Category 3 is as category 2 except difference in style is allowed for index call options. Averages are calculated by first computing daily averages of observed quotes for each EuRex-EuWax option pair. The daily observations are then averaged by underlying, type, and match category. T-tests are computed for ask ratio (different from 1), bid ratio (different from 1), and the difference of the bid-ask spreads (different from 0). Insignificant t-tests are indicated with #. T-tests are shown for the difference of bid ratio and ask ratio (different from 0). Simple and daily-observation-weighted averages of all measures are computed across all options in the sample. Data on option characteristics are from EuWax, EuRex, and OnVista. Quote data are from EuWax and KKMDB.

Underlying	Type	Match	Daily	Quote	Time	EuWax / EuRex		Diff.	Impl.	BA Spread	
		Cat.	Obs.	Pairs	Diff.	Ask	Bid	t-Stat.	Prob.	EuWax	EuRex
Deutsche	Call	1	1,075	28,952	1:20	1.06	1.13	14.7	46%	4.8%	10.6%
Bank		2	7,979	196,781	1:13	1.02	1.09	49.1	24%	2.5%	8.2%
	Put	1	27	401	1:33	1.06	1.10	2.2	62%	#9.0%	#12.4%
		2	1,122	12,174	1:32	1.03	1.11	16.0	30%	6.2%	12.6%
Daimler	Call	1	583	7,054	1:29	1.08	1.14	7.5	56%	10.5%	15.3%
Chrysler		2	7,219	76,358	1:35	1.09	1.16	31.8	55%	8.1%	13.8%
	Put	1	162	2,818	1:15	#1.00	1.05	6.2	0%	4.8%	9.4%
		2	2,790	26,874	1:28	1.04	1.10	24.8	42%	2.2%	7.3%
Deutsche	Call	1	1,291	33,894	1:18	1.07	1.15	18.1	45%	7.0%	13.7%
Telekom		2	8,044	164,835	1:16	1.04	1.12	42.2	34%	6.2%	12.5%
	Put	1	46	1,915	1:06	1.01	1.05	4.6	23%	5.5%	9.3%
		2	2,857	111,250	1:04	1.02	1.08	27.5	26%	2.3%	7.3%
DAX	Call	1	63	201	0:50	1.02	1.07	6.4	31%	0.3%	5.0%
		3	43,069	1,903,803	0:39	1.05	1.09	66.8	55%	1.1%	4.6%
	Put	1	47	303	0:38	1.02	1.05	2.7	40%	0.2%	2.9%
Euro	Call	1	79	1,609	1:09	.98	#1.01	2.6	0%	3.2%	6.0%
Stoxx 50		3	7,500	212,871	1:08	1.05	1.09	29.4	56%	3.1%	6.5%
	Put	1	55	1,363	0:58	.96	.98	2.3	0%	2.8%	4.8%
Siemens	Call	1	943	14,815	1:15	1.02	1.07	12.9	27%	3.8%	8.0%
		2	9,399	103,898	1:09	1.04	1.08	34.9	45%	2.1%	6.1%
	Put	1	45	1,099	1:22	1.05	1.13	6.6	37%	2.6%	9.3%
		2	1,171	11,247	1:20	1.05	1.10	12.7	52%	3.2%	7.5%
All			95,566	2,914,515	1:13	1.035	1.089		36%	4.2%	8.8%
All (Weighted)			95,566	2,914,515	0:59	1.047	1.099		47%	2.8%	7.1%

Table 5: Univariate Results for Matched EuRex and EuWax Options by Quote Relation

The table shows the type (call or put), underlying asset (Deutsche Bank, Daimler Chrysler, Deutsche Telekom, Dax index, Dow Jones Euro Stoxx 50 index, and Siemens), match category, share of observations (in %), average ratio of ask prices, average ratio of bid prices, and sum of all shares of observations for a sample of matched quote pairs of EuRex and EuWax options during the year 2000. Match category 1 has the same underlying asset, type, strike price, expiration date, style. Category 2 is as category 1 except ± 7 days expiration date difference. Category 3 is as category 2 except difference in style is allowed for index call options. Quote pairs are categorized into four groups according to the ratio of ask prices and the ratio of bid prices (observations with either ratio equal one are excluded). Averages of all observed quote pairs are computed across underlying, type, match category, and ratio category. Data on option characteristics are from EuWax, EuRex, and OnVista. Quote data are from EuWax and KKMDB.

			Case 1			Case 2			Case 3			Case 4			All
Underlying	Type	Match Cat.	%	Ask >1	Bid >1	%	Ask <1	Bid >1	%	Ask <1	Bid <1	%	Ask >1	Bid <1	%
Deutsche Bank	Call	1	56	1.09	1.16	41	0.96	1.07	2	0.92	0.93	0	1.02	0.96	99
		2	40	1.06	1.12	51	0.97	1.05	7	0.94	0.97	0	1.02	0.97	99
	Put	1	87	1.08	1.12	11	0.98	1.06	0	0.94	0.83				99
		2	55	1.09	1.16	35	0.97	1.07	9	0.87	0.91	0	1.06	0.94	99
Daimler Chrysler	Call	1	67	1.13	1.18	20	0.89	1.14	7	0.91	0.90	3	1.09	0.90	98
		2	73	1.13	1.20	17	0.92	1.12	6	0.90	0.90	1	1.07	0.93	98
	Put	1	41	1.04	1.07	44	0.96	1.06	10	0.93	0.95	1	1.04	0.98	96
		2	67	1.07	1.12	28	0.97	1.06	4	0.94	0.96	0	1.02	0.99	99
Deutsche Telekom	Call	1	74	1.10	1.18	23	0.94	1.11	2	0.92	0.93	0	1.07	0.95	99
		2	58	1.08	1.16	33	0.95	1.08	7	0.91	0.94	0	1.06	0.93	98
	Put	1	43	1.03	1.07	44	0.98	1.04	10	0.97	0.99	1	1.01	0.99	97
		2	33	1.05	1.10	59	0.98	1.05	7	0.97	0.98	0	1.02	0.98	99
DAX	Call	1	77	1.05	1.10	18	0.98	1.04	5	0.95	0.99				100
		3	84	1.06	1.10	14	0.97	1.05	2	0.90	0.91	0	1.07	0.94	99
	Put	1	33	1.04	1.07	38	0.99	1.01	26	0.96	0.99				96
Euro Stoxx 50	Call	1	77	1.02	1.06	17	0.99	1.03	6	0.91	0.92				100
		3	82	1.06	1.10	16	0.99	1.03	2	0.95	0.97	0	1.11	0.93	100
	Put	1	22	1.01	1.03	60	0.99	1.01	18	0.94	0.96				100
Siemens	Call	1	55	1.06	1.10	35	0.95	1.07	9	0.93	0.95	0	1.04	0.95	99
		2	62	1.07	1.11	32	0.97	1.05	5	0.94	0.96	1	1.05	0.94	99
	Put	1	88	1.05	1.13	11	0.96	1.11	0	0.98	1.00				99
		2	67	1.08	1.13	28	0.97	1.07	3	0.94	0.95	0	1.11	0.92	100
Average			61	1.07	1.12	31	0.97	1.06	7	0.93	0.95	1	1.05	0.95	99

Table 6: Multivariate Analysis Summary Statistics for Matched EuRex and EuWax Options

The table shows the mean, standard deviation, minimum, and maximum of quotes per month, match category, absolute value of expiration date difference, ratio of ask prices, ratio of bid prices, number of competing EuWax options, ratio of minimum trade size, EuWax maximum bid-ask spread (in Euro), a dummy equal to one for EuWax issuer being a EuRex Market-Maker for the same underlying asset, annualized standard deviation of underlying asset returns during the observation month, time to expiration (in days) of the EuRex option, and moneyness for a sample of matched quote pairs of EuRex and EuWax options on the following underlying assets: Deutsche Bank, Daimler Chrysler, Deutsche Telekom, Dax index, Dow Jones Euro Stoxx 50 index, and Siemens. Match category 1 has the same underlying asset, type, strike price, expiration date, style. Category 2 is as category 1 except ± 7 days expiration date difference. Category 3 is as category 2 except difference in style is allowed for index call options. Number of observations is shown and broken up by option type and underlying asset. For the ask and bid ratios monthly averages are calculated from all observed quotes during the observation month for each EuRex-EuWax option pair. For time to expiration and moneyness data is calculated daily, and then averaged over all observations during the month. Data on option characteristics are from EuWax, EuRex, and OnVista. Quote data are from EuWax and KKMDB. Daily data on underlying asset returns and prices are from Datastream. All data is monthly. Sample period is the year 2000.

Panel A: Descriptive Statistics of Variables

	Mean	SD	Min	Max
Quotes / Month	355	628	1	6,666
Match Category	2.5	0.6	1	3
Abs (Expiration Date Difference)	3.1	2.3	0	7
EuWax Ask / EuRex Ask	1.05	0.09	0.56	1.48
EuWax Bid / EuRex Bid	1.09	0.11	0.54	1.50
# Competing EuWax Options	2.7	1.6	1	8
Minimum Trade Size: EuWax / EuRex	2.6%	5.7%	0.0%	50.0%
EuWax Maximum Euro Spread	0.17	0.50	0.02	5
EuWax Issuer = EuRex Market Maker (=1)	0.59	0.49	0	1
Underlying Asset Standard Deviation	32%	14%	11%	77%
Time to Expiration	221	155	14	730
Moneyness	102%	26%	37%	347%

Panel B: Sample Size

	Observations
Total	8,185
- Calls	7,511
- Puts	674
- Deutsche Bank	808
- Daimler Chrysler	892
- Deutsche Telekom	931
- DAX	3,444
- Euro Stoxx 50	915
- Siemens	1,195

Table 7: Multivariate Results for Matched EuRex and EuWax Options

The table shows the coefficient estimate, t-statistic, number of observations, and adjusted fit for regressions of ratio of ask prices on ratio of bid prices, number of competing EuWax options, annualized standard deviation of underlying asset returns during the observation month, option type, time to expiration (in days) of the EuRex option, moneyness, a dummy (=1 for EuWax issuer being a EuRex Market-Maker for the matched option), EuWax maximum bid-ask spread (in Euro), ratio of minimum trade size, underlying asset dummies, and issuer dummies using a sample of matched quote pairs of EuRex and EuWax options on the following underlying assets: Deutsche Bank, Daimler Chrysler, Deutsche Telekom, Dax index, Dow Jones Euro Stoxx 50 index, Siemens. Match category 1 has the same underlying asset, type, strike, exp. date, style. Category 2 is as category 1 except ± 7 days exp. date difference. Category 3 is as category 2 except difference in style is allowed for index call options. For the ask and bid ratios monthly averages are calculated from all quotes during the observation month for each EuRex-EuWax pair. For time to expiration and moneyness data is calculated daily, and averaged over all observations during the month. Data on option characteristics are from EuWax, EuRex, OnVista. Quote data are from EuWax, KKMDB. Daily data on underlying asset returns and prices are from Datastream. Standard errors are robust to heteroskedasticity and first-order serial correlation. All data is monthly. Sample period is the year 2000.

	Spec. 1		Spec. 2		Spec. 3	
Variable	Coeff.	t-Stat.	Coeff.	t-Stat.	Coeff.	t-Stat.
Intercept	.32	22.7	.32	21.1	.31	12.4
EuWax Bid / EuRex Bid	.69	37.1	.68	36.3	.69	22.8
# Competing EuWax Options	-.0027	-7.5	-.0027	-7.3	-.0048	-7.7
Underlying Asset Standard Deviation	-.043	-10.8	-.030	-4.3	-.047	-4.9
Type (Put = 1)	-.0085	-3.6	-.0047	-1.7	-.0086	-3.2
Time to Expiration	-2.4E-05	-4.8	-1.9E-05	-3.6	9.0E-06	1.1
Moneyness	.0055	0.6	.014	1.7	.0015	0.1
EuWax Issuer = EuRex Market Maker (=1)	-.00029	-0.2				
EuWax Maximum Euro Spread					-.0059	-3.8
Minimum Trade Size: EuWax / EuRex					-.12	-4.6
Deutsche Bank			-.019	-10.6	-.014	-6.0
Daimler Chrysler			-.0031	-0.9	-.0051	-1.2
Deutsche Telekom			-1.2E-02	-3.5	-.0076	-2.0
Euro Stoxx 50			-5.0E-05	0.0	-.015	-4.9
Siemens			.0028	1.2	.0033	1.2
Banque Nationale de Paris Paribas			-.0098	-2.8	-.011	-3.1
Credit Lyonnais			.028	2.5	.057	4.1
Commerzbank			.0071	3.2	.0074	2.0
Deutsche Bank			.00088	0.5	.0023	1.0
DG Bank			.0040	2.2	.024	5.7
Dresdner Bank			-.0069	-2.0	-.0043	-1.2
Goldman Sachs			-.0013	-0.2	-.00062	-0.1
HypoVereinsBank			-.00058	-0.2	.0063	1.5
Lehman Brothers			-.0076	-1.1	.0062	0.8
Merrill Lynch			.0059	0.6	.019	1.9
RaboBank			.034	3.7	.027	4.9
Societe Generale			.0075	3.7	.029	7.3
Sal. Oppenheim			-.023	-7.2	-.025	-6.1
HSBC Trinkaus Burkhardt			-.0023	-1.3	-.0023	-0.8
UBS Warburg			-.0063	-2.2	.0045	0.9
Unicredito Italiano			-.018	-3.1	.0049	0.8
Westdeutsche Landesbank			-.0070	-1.2	.021	2.8
Observations	8,185		8,185		3,801	
Adj. R^2	73.1%		74.8%		74.8%	

Table 8: Time-Series Variation in Ask Ratios

The table shows the coefficient estimate, t-statistic, estimated effect of a 1-month change in time to expiration on ask ratios, and number of observations for regressions of ratio of ask prices on ratio of bid prices, number of competing EuWax options, annualized standard deviation of underlying asset returns during the observation month, option type, time to expiration (in days) of the EuRex option, moneyness, a dummy (=1 for EuWax issuer being a EuRex Market-Maker for the matched option), EuWax maximum bid-ask spread (in Euro), ratio of minimum trade size, underlying asset dummies, and issuer dummies using a sample of matched quote pairs of EuRex and EuWax options on the following underlying assets: Deutsche Bank, Daimler Chrysler, Deutsche Telekom, Dax index, Dow Jones Euro Stoxx 50 index, Siemens. Match category 1 has the same underlying asset, type, strike, exp. date, style. Category 2 is as category 1 except ± 7 days exp. date difference. Category 3 is as category 2 except difference in style is allowed for index call options. For the ask and bid ratios monthly averages are calculated from all quotes during the observation month for each EuRex-EuWax pair. For time to expiration and moneyness data is calculated daily, and averaged over all observations during the month. The sample is split by EuRex expiration dates. Data on option characteristics are from EuWax, EuRex, OnVista. Quote data are from EuWax, KKMDB. Daily data on underlying asset returns and prices are from Datastream. Standard errors are robust to heteroskedasticity and first-order serial correlation. All data is monthly. Sample period is the year 2000.

EuRex Expiration Date		Specification 1	2	3
16/03/2001	Time to Expiration	1.1E-04	9.8E-05	1.1E-04
	t-Statistic	2.1	3.8	3.7
	1-Month Effect	0.34%	0.30%	0.34%
	Observations	909	909	909
15/06/2001	Time to Expiration	7.1E-05	6.7E-05	6.9E-05
	t-Statistic	5.7	5.5	5.4
	1-Month Effect	0.21%	0.20%	0.21%
	Observations	1,491	1,491	1,482
21/09/2001	Time to Expiration	1.6E-04	1.7E-04	1.7E-04
	t-Statistic	3.5	3.0	3.9
	1-Month Effect	0.48%	0.50%	0.51%
	Observations	418	418	408
21/12/2001	Time to Expiration	9.8E-05	9.0E-05	9.6E-05
	t-Statistic	4.0	4.5	3.9
	1-Month Effect	0.29%	0.27%	0.29%
	Observations	759	759	747
21/06/2002	Time to Expiration	3.1E-04	3.1E-04	3.0E-04
	t-Statistic	3.8	4.1	3.8
	1-Month Effect	0.92%	0.93%	0.90%
	Observations	255	255	255

Table 9: Probability of Early Liquidation

The table shows the coefficient estimate, t-statistic, mean, standard deviation, minimum, maximum, number of observations, and adjusted fit for a regression of probability of early liquidation cut-off (PELC) on option omega, ratio of option vega to EuWax ask, option type, time to expiration (in days) of the EuRex option, and EuWax market share using a sample of matched quote pairs of EuRex and EuWax options on the following underlying assets: Deutsche Bank, Daimler Chrysler, Deutsche Telekom, Dax index, Dow Jones Euro Stoxx 50 index, Siemens. Match category 1 has the same underlying asset, type, strike, exp. date, style. Category 2 is as category 1 except ± 7 days exp. date difference. Category 3 is as category 2 except difference in style is allowed for index call options. PELC is computed from ask ratios and bid ratios. For the ask and bid ratios monthly averages are calculated from all quotes during the observation month for each EuRex-EuWax pair. Omega is computed as delta times the ratio of the value of the underlying to the EuWax ask price. Omega, vega, time to expiration, underlying value, and EuWax ask price are calculated daily, and averaged over all observations during the month. Market share is computed as the ratio of EuWax monthly trading volume to the sum of EuRex and EuWax monthly trading volume. Data on option characteristics and volume are from EuWax, EuRex, OnVista. Quote data are from EuWax, KKMDB. Daily data on underlying asset returns and prices are from Datastream. Standard errors are robust to heteroskedasticity and first-order serial correlation. All data is monthly. Sample period is the year 2000.

Variable	Coefficient	t-Statistic	Mean	SD	Min	Max
Intercept	0.150	16.1				
Omega	0.008	7.5	6.9	6.3	.8	80.1
Vega / EuWax Ask	1.437	11.6	.038	.047	0	.527
Type (Put = 1)	-0.048	-4.0	0.08	0.27	0	1
Time to Expiration	5.0E-04	20.0	224	156	14	730
Market Share	-.015	-1.6	0.21	0.33	0	1
Observations	7,484					
Adj. R^2	19.2%					

Table 10: Effective Spreads for Matched EuRex and EuWax Options

The table shows the type (call or put), underlying asset (Deutsche Bank, Daimler Chrysler, Deutsche Telekom, Dax index, Dow Jones Euro Stoxx 50 index, and Siemens), match category, number of observations, average time difference, average quoted bid-ask spread (ratio of (ask minus bid) to ask), average effective bid-ask spread (ratio of absolute difference between transaction price and mid quote to ask price times two), and share of inside-the-quote transaction prices for a sample of matched quote/transaction pairs of EuRex and EuWax options during the year 2000. Match category 1 has the same underlying asset, type, strike price, expiration date, style. Category 2 is as category 1 except ± 7 days expiration date difference. Category 3 is as category 2 except difference in style is allowed for index call options. Simple and daily-observation-weighted averages of all measures are computed across all options in the sample. Data on option characteristics are from EuWax, EuRex, and OnVista. Quote and transaction data are from EuRex, EuWax and KKMDB.

Under-lying	Type	Match Cat.	Obs.	Time Difference			Spread				Share of Inside Trans.	
				Trans-actions	Trans./Quote		Quoted		Effective			
					EuRex	EuWax	EuRex	EuWax	EuRex	EuWax	EuRex	EuWax
Deutsche Bank	C	2	39	24:28	01:55	03:21	8.8%	4.0%	4.9%	3.3%	71.8%	12.8%
Daimler	C	1	13	20:31	02:51	03:30	21.9%	10.9%	12.9%	8.0%	84.6%	23.1%
Chrysler		2	102	18:08	02:50	03:28	11.7%	8.3%	6.5%	6.3%	74.5%	8.8%
	P	2	17	20:14	02:48	04:15	9.5%	5.0%	5.6%	4.4%	64.7%	5.9%
Deutsche	C	1	19	21:49	03:43	03:17	10.7%	5.8%	5.6%	4.9%	73.7%	10.5%
Telekom		2	87	19:56	02:19	03:56	10.9%	7.2%	5.6%	4.9%	73.6%	26.4%
	P	2	22	24:23	03:07	04:21	11.2%	10.1%	6.8%	5.1%	68.2%	63.6%
DAX	C	3	840	15:20	01:49	02:20	7.1%	2.3%	3.7%	1.6%	70.8%	23.3%
Euro Stoxx 50	C	3	51	21:21	01:47	03:28	7.5%	4.0%	3.2%	3.6%	84.3%	3.9%
Siemens	C	2	61	20:03	01:46	03:22	12.1%	4.0%	7.1%	3.1%	75.4%	16.4%
	P	2	10	08:25	01:32	03:02	5.6%	3.9%	4.0%	3.2%	70.0%	30.0%
All			1,261	19:31	02:24	03:29	10.6%	5.9%	6.0%	4.4%	73.8%	20.4%
All (Weighted)			1,261	16:57	02:00	02:46	8.3%	3.6%	4.4%	2.6%	72.2%	21.3%

Table 11: Transaction Costs for EuRex and EuWax Options

The table shows EuWax option price (in Euro), number of EuRex contracts, trade value (in Euro), EuRex transaction costs (in Euro), EuWax transaction costs (in Euro), and the difference of EuWax and EuRex transaction costs as a percentage of the trade value for three brokerages, Comdirect, Consors, and Fimatex. Contract size for EuWax and EuRex options is .01 Euro and 5 Euro per index point, respectively. Data on option characteristics are from EuWax, EuRex, and OnVista. Quote data are from EuWax and KKMDB. Transaction cost data are from Comdirect, Consors, and Fimatex. Sample period is the year 2000.

			Transaction Costs								
EuWax	# EuRex	Trade	Comdirect			Consors			Fimatex		
Price	Contracts	Value	EuRex	EuWax	Diff.	EuRex	EuWax	Diff.	EuRex	EuWax	Diff.
	1	525	19	1	3.4%	20	10	1.8%	13	9	0.7%
1.05	10	5,250	45	11	0.7%	39	18	0.4%	50	9	0.8%
	100	52,500	450	105	0.7%	275	69	0.4%	500	42	0.9%
	1	2,380	19	5	0.6%	24	11	0.6%	13	9	0.1%
4.76	10	23,800	45	48	0.0%	131	65	0.3%	50	19	0.1%
	100	238,000	450	476	0.0%	1,202	69	0.5%	500	47	0.2%
	1	3,830	19	8	0.3%	31	15	0.4%	13	9	0.1%
7.66	10	38,300	45	77	-0.1%	204	69	0.4%	50	31	0.1%
	100	383,000	450	766	-0.1%	1,927	69	0.5%	500	47	0.1%
	1	9,505	19	19	0.0%	60	29	0.3%	13	9	0.0%
19.01	10	95,050	45	190	-0.2%	488	69	0.4%	50.0	47	0.0%
	100	950,500	450	1,901	-0.2%	4,765	69	0.5%	500	47	0.0%

Table 12: Effect of EuWax Competition on EuRex Bid-Ask Spreads

The table shows the type (call or put), underlying asset (Deutsche Bank, Daimler Chrysler, Deutsche Telekom, Dax index, Dow Jones Euro Stoxx 50 index, and Siemens), number of daily observations, average time difference, average volume ratio, average ratio of ask prices, and average bid-ask spreads (ratio of (ask minus bid) to ask), and t-statistics for the difference of the average bid-ask spreads for a sample of matched quote pairs of EuRex options with competition from EuWax options and EuRex options without competition from EuWax options during the year 2000. EuRex-EuRex quote pairs are generated by starting with a set of EuRex option quotes which have matching quotes from competing EuWax options. The EuRex quotes are matched to EuRex quotes for options without EuWax competition such that the matching EuRex option has the same type and underlying and comparable trading volume (as measured by paid premia) during each observation month. Averages are calculated by first computing daily averages of observed quotes for each EuRex-EuRex option pair. The daily observations are then averaged by underlying and type. Simple and daily-observation-weighted averages of all measures are computed. Data on option characteristics are from EuWax, EuRex, and OnVista. Quote data are from EuWax and KKMDB.

Underlying	Type	Daily Obs.	Time Diff.	No EuWax Comp. / EuWax Comp.		Bid-Ask Spread		
				Volume	Ask	EuWax Comp.	No EuWax Comp.	t-Stat.
Deutsche Bank	Call	1,540	1:16	.98	1.3	9.6%	13.9%	10.3
	Put	528	1:06	.99	4.0	14.6%	14.8%	.4
Daimler Chrysler	Call	1,608	1:19	1.00	2.3	18.3%	16.9%	(2.7)
	Put	1,051	1:24	.98	1.0	9.8%	11.4%	4.3
Deutsche Telekom	Call	2,641	1:18	.99	2.5	14.9%	14.7%	(.5)
	Put	1,420	1:13	.99	1.6	8.3%	10.2%	7.3
DAX	Call	6,452	1:27	.99	2.4	6.9%	9.5%	15.4
Euro Stoxx 50	Call	1,957	1:17	.98	1.8	7.8%	7.9%	0.4
Siemens	Call	1,549	1:33	.98	1.2	9.3%	12.5%	7.4
	Put	337	1:33	.99	1.1	7.6%	14.2%	7.0
All		19,083	1:21	.99	1.9	10.7%	12.6%	
All (Weighted)		19,083	1:22	.99	2.0	10.0%	11.7%	

Table 13: Effect of EuRex Competition on EuWax Bid-Ask Spreads

The table shows the type (call or put), underlying asset (Deutsche Bank, Daimler Chrysler, Deutsche Telekom, Dax index, Dow Jones Euro Stoxx 50 index, and Siemens), number of daily observations, average time difference, average volume ratio, average ratio of ask prices, and average bid-ask spreads (ratio of (ask minus bid) to ask), and t-statistics for the difference of the average bid-ask spreads for a sample of matched quote pairs of EuWax options with competition from EuRex options and EuWax options without competition from EuRex options during the year 2000. EuWax-EuWax quote pairs are generated by starting with a set of EuWax option quotes which have matching quotes from competing EuRex options. The EuWax quotes are matched to EuWax quotes for options without EuRex competition such that the matching EuWax option has the same type and underlying, and comparable trading volume (as measured by paid premia) during each observation month. Averages are calculated by first computing daily averages of observed quotes for each EuWax-EuWax option pair. The daily observations are then averaged by underlying and type. Simple and daily-observation-weighted averages of all measures are computed. Data on option characteristics are from EuWax, EuRex, and OnVista. Quote data are from EuWax and KKMDB.

Underlying	Type	Daily Obs.	Time Diff.	No EuRex Comp. / EuRex Comp.		Bid-Ask Spread		
						EuRex	No EuRex	t-Stat.
				Volume	Ask	Comp.	Comp.	
Deutsche Bank	Call	6,763	2:26	.99	2.9	2.8%	1.9%	(15.6)
	Put	303	2:30	.96	9.3	5.7%	6.1%	.5
Daimler Chrysler	Call	4,751	2:28	.99	2.4	8.1%	7.7%	(1.8)
	Put	943	2:29	.99	2.1	2.5%	2.2%	(3.7)
Deutsche Telekom	Call	6,085	2:29	1.00	2.7	7.0%	6.4%	(2.9)
	Put	1,209	2:27	.99	.7	2.6%	7.5%	16.4
DAX	Call	25,322	2:25	1.00	4.9	1.3%	2.2%	20.9
Euro Stoxx 50	Call	3,381	2:25	1.00	3.0	3.4%	7.2%	15.8
Siemens	Call	4,752	2:28	1.00	2.4	2.8%	3.6%	6.5
All		53,509	2:28	.99	3.4	4.0%	5.0%	
All (Weighted)		53,509	2:26	1.00	3.7	3.1%	3.7%	