The Limits of Arbitrage: Evidence from Dual-Listed Companies

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Abstract

This study provides empirical evidence of limited arbitrage in international equity markets. Shleifer and Vishny (1997) show that noise trader risk impedes arbitrage when arbitrageurs are specialized professionals managing the capital of outside investors. We empirically examine the Shleifer and Vishny thesis for a sample of dual-listed companies (DLCs). In efficient financial markets, the stock prices of the parent companies of DLCs should move together perfectly. As arbitrage in DLCs does not involve fundamental risk, our sample provides an excellent vehicle for examining the risk and return characteristics of arbitrage. We show that for every individual DLC deviations from the theoretical price ratio are large. We design investment strategies for exploiting this mispricing. Combined arbitrage strategies in all DLCs produce excess returns of up to 10% per annum on a risk-adjusted basis, after transaction costs and margin requirements. However, the strategies involve a considerable amount of idiosyncratic risk. Consistent with Shleifer and Vishny (1997), we conclude that mispricing persists because arbitrage in DLCs is deterred by the great amount of noise trader risk involved. We provide further evidence by examining the subsample of DLCs that unified their share structure. After the announcement of the unification, uncertainty about the arbitrage horizon is negligible, suggesting that the impediments to arbitrage should be greatly reduced. We show that there is a strong immediate movement toward theoretical price parity at the unification announcement and arbitrage opportunities virtually disappear, consistent with the reduction in noise-trader risk. Our findings have important implications for the effectiveness of arbitrage in international financial markets.

Keywords

Market efficiency, arbitrage, noise trader risk, anomalies, international finance

JEL subject codes

F30, G14, G15

1. Introduction

The concept of arbitrage plays an important role in analyses of financial markets. According to finance textbooks, arbitrage brings prices to fundamental values. In textbook arbitrage no capital is required, no transaction costs are incurred, and there is no risk. Recent research contends that there are important impediments to arbitrage in actual financial markets. Shleifer and Vishny (1997) model the behavior of arbitrageurs who invest the capital of outside investors. In their model, there is no fundamental risk, i.e. perfect substitutes exist. However, the incentive structures of specialized arbitrageurs in combination with noise trader risk imply that arbitrage is limited. The model shows that two realistic assumptions – specialized professional arbitrage and noise trader risk – are sufficient to frustrate arbitrage in securities that are perfect substitutes.[1]

We empirically study the Shleifer and Vishny thesis on the limits of arbitrage in situations that closely resemble their theoretical set-up. We examine a sample of dual-listed companies, which provides a setting in real-world equity markets with two traded assets that are perfect substitutes and in which arbitrageurs are specialized professionals managing other people's money. A dual-listed company (DLC) structure (also referred to as a Siamese twin) involves two companies contractually agreeing to operate their businesses as if they were a single enterprise, while distributing cash flows to their shareholders in a prescribed fashion and retaining their separate legal identity and existing stock exchange listings. In fully integrated and efficient financial markets, stock prices of the twin pair should move together perfectly. Well-known examples of DLCs are the Anglo-Dutch combinations Royal Dutch/Shell and Unilever NV/PLC. Rosenthal and Young (1990) show that significant mispricing in these DLCs has existed over a long period of time without a satisfactory explanation for the price disparity. Many studies refer to DLCs as a textbook example of arbitrage opportunities. Recent references include Baker and Savaşoglu (2002), Barberis and Thaler (2004), Ritter (2003), Shleifer (2000, chapter 2), and Thaler (1999).

[1] A number of theoretical papers analyze the effects of noise trader risk on arbitrage. De Long, Shleifer, Summers, and Waldmann (1990) and Shleifer and Summers (1990) contend that arbitrageurs are risk averse and are likely to have short horizons. Therefore, rational arbitrageurs are concerned about possible adverse price movements in the short-run, even when they know that prices will converge eventually. In the model of De Long et al., this noise trader risk limits the effectiveness of arbitrage and can lead to a large divergence between market prices and fundamental values. More recently, Dow and Gorton (1994) and Goldman and Slezak (2003) model the impact of agency relations and the time-horizon of arbitrageurs on the pricing of securities. Both studies postulate that the expected tenure of a fund manager is typically shorter than the horizon needed to benefit from an arbitrage opportunity. Due to this horizon mismatch, fund managers do not have the incentives to put on long-term arbitrage positions.

Froot and Dabora (1999) investigate Royal Dutch/Shell and Unilever in addition to the Anglo-American firm Smithkline Beecham. They show that the relative returns of the twin stocks are correlated with the stock indices of the markets on which each of the twins has its main listing. In the context of the analysis of Barberis, Shleifer, and Wurgler (2003), this comovement effect can be interpreted as evidence of country-specific sentiment, i.e. noise traders. Following the argumentation of Shleifer and Vishny (1997), noise trader risk will deter arbitrage in DLCs if arbitrageurs are specialized professional portfolio managers. In the model these managers are risk-averse and concerned about the short-term performance of the fund, because capital is allocated to the funds on the basis of past returns. In line with the model, most arbitrage in practice is conducted by hedge funds managed by a limited number of professional and specialized traders investing other people's money. Agarwal, Daniel, and Naik (2003) show that hedge funds with good performance in a given year experience significantly larger money-inflows in the subsequent year. Ackerman, McEnally, and Ravenscraft (1999) provide evidence that hedge fund managers have performance incentives that induce risk-aversion. Brown, Goetzmann, and Park (2001) demonstrate that a hedge fund's total risk has a strong positive effect on fund failure. These papers indicate that arbitrageurs in practice are specialized investment professionals who are concerned with the total risk of their portfolio. Because DLCs are characterized by the absence of fundamental risk and the presence of noise trader risk in conjunction with specialized professional arbitrageurs, they serve as a unique opportunity to assess Shleifer and Vishny's theory.

A considerable body of empirical research reports evidence on the limits of arbitrage in financial markets. Pontiff (1996) and Gemmill and Thomas (2002) provide evidence that there is a relation between the discounts of closed-end funds and the costs of arbitrage. Mitchell, Pulvino, and Stafford (2002) examine "negative stub value" situations where a firm's market value is less than the value of a publicly traded subsidiary. Mitchell et al. show that uncertainty about the distribution of returns and risk characteristics limits arbitrage, despite the apparent profitability of trading strategies. Lamont and Thaler (2003) identify a number of tech stock carve-outs in which the market value of the subsidiary was larger than the market value of the parent. They argue that shorting costs prevent rational arbitrageurs from exploiting profitable arbitrage opportunities in these situations. Mitchell and Pulvino (2001) and Baker and Savaşoglu (2002) report empirical findings suggesting limited arbitrage in mergers and acquisitions. Ali, Hwang, and Trombley (2003) attribute the book-to-market anomaly to limited arbitrage, because the effect is greater for stocks with higher idiosyncratic return volatility. The previous empirical studies have in common that they study arbitrage

opportunities in situations with fundamental risk. For example, in merger arbitrage the risk that the deal will not be completed plays a dominant role. Our study is unique in analyzing the limits of arbitrage between perfect substitutes.

We examine the limits of arbitrage in a comprehensive sample of 13 DLCs that currently exist or have existed. For each DLC, we find large deviations from theoretical price parity. Average absolute price discrepancies for individual twins range from roughly 2.5 percent to almost 12 percent. The deviations from parity reach values of over 15 percent for every single DLC in the sample and occasionally exhibit levels of up to 50 percent. Mispricing is highly time-varying for all DLCs. Consistent with Froot and Dabora (1999), we find that mispricing can to a large extent be explained by comovement of the prices of twin stocks with domestic stock market indices. For all DLCs, the relative price of a twin rises (falls) when their domestic market rises (falls). This finding is consistent with the view that noise traders affect the relative pricing of DLCs.

We specify a number of investment strategies and examine the characteristics of risk and return in DLC arbitrage. We control for market frictions by taking into account realistic estimates of brokerage commissions, bid-ask spreads, short rebates, and capital requirements. We design arbitrage strategies based on the premise that convergence to theoretical parity occurs after large price discrepancies. The arbitrage strategies produce considerable returns for all 13 twins. Incorporating transaction costs and margin requirements, arbitrage in all DLCs combined generates excess returns of up to 10 percent per annum relative to the Fama-French three-factor model.

As there is no identifiable date at which the twin prices will converge, arbitrageurs are subject to noise trader risk. There is substantial variation in the number of days for which an arbitrageur has to maintain a position before twin prices converge. In some cases, arbitrageurs have to wait for more than 8 years until convergence takes place. This creates uncertainty for arbitrageurs with limited horizons who are unable to close the price gap on their own. Noise traders may cause adverse price movements in the short run. In some cases, the arbitrageur establishes a position when the price discrepancy is equal to 10 percent and observes a deepening of the mispricing to almost 40 percent before prices eventually converge. In these situations, arbitrageurs receive margin calls, after which they are forced to liquidate part of the position at a highly unfavorable moment and suffer a loss. The large variability of the price discrepancies results in high volatility in the returns of arbitrage strategies. The standard deviation of arbitrage returns is generally almost 50 percent higher than the standard deviation of the S&P 500. As the hedge funds that arbitrage in DLCs tend to be specialized, they are

unlikely to be able to diversify these large idiosyncratic risks. Therefore, we conclude that risk associated with the volatility of arbitrage returns deters arbitrage activity in DLCs, consistent with Shleifer and Vishny (1997). Noise trader risk thus constitutes an important explanation for the persistence of the mispricing.

This finding is corroborated in an analysis of the 6 twins that have unified the DLC into a single share structure. The transition from DLC to a single structure allows us to investigate the influence of noise trader risk and uncertainty over the arbitrage horizon on the persistence of the mispricing. As prices are almost certain to converge within a limited time period after the announcement of the unification, the model of Shleifer and Vishny (1997) predicts that noise trader risk will be a far less important impediment to arbitrage. Consequently, the mispricing should dissolve immediately and arbitrage opportunities should disappear. We indeed observe a distinct decline in the mispricing around the unification date for all 6 twins. Moreover, arbitrage opportunities are rare and trading volumes are considerably higher after the unification announcement. This supports the view that noise trader risk impedes arbitrage in DLCs until unification is announced.

The remainder of the paper is structured as follows. In section 2 we describe the structure of dual-listed companies and the data sample. Section 3 examines the magnitude of the mispricing for the twins and the comovements of relative twin prices with local market indices. Section 4 presents the analysis of arbitrage strategies on the DLCs and section 5 discusses the limits of arbitrage in imperfect capital markets. We examine the unification announcement of six of the twins as well as the results of subsequent arbitrage strategies in section 6. Section 7 concludes.

2. Sample description

2.1 The structure of dual-listed companies

We investigate the limits of arbitrage in a sample of 13 dual-listed companies that currently exist or have existed.[2] DLCs are the result of a merger between two firms in which the firms agree to combine their activities and cash flows. At the same time, the corporations keep

[2] We are aware of three other DLCs that have been created. Hoesch AG/Hoogovens NV was established in 1972 and ended in 1982. Because the existence of this DLC only partly overlaps our sample period, we have not included the twin. Investec Ltd/Investec PLC came into existence on July 26, 2002, and a DLC of Carnival Corp., and Princess P&O PLC was created on April 17, 2003. Given the short time span of the existence of the latter two twins, we decided not to analyze these DLCs in this study. In merger negotiations of Abbey National (U.K.) with National Australian Bank and Bank of Ireland with Alliance & Leicester (U.K.), the DLC structure was proposed but both merger plans were abandoned (*Financial Times*, May 25, 1999 and July 12, 2002).

separate shareholder registries and identities and distribute the cash flows to their shareholders using a ratio laid out in an equalization agreement. Note that while DLC shares are perfect substitutes, the twin shares are not convertible into each other. In this section we briefly discuss the characteristics of DLCs as well as the motives for choosing a twin structure and introduce the 13 DLCs in our data set. Since the two previous papers were written, a substantial number of additional DLCs have been established, without any research on their structure, pricing, and other issues related to it.[3]

DLCs can be structured in three alternative ways.[4] The dominant structure is the "combined entities structure." The key characteristic is that the assets of the two companies are held by one or more jointly-owned holding companies. The latter pay dividends to the two companies using a predetermined ratio as outlined in an equalization agreement. The dividends are subsequently distributed to the shareholders of the two companies. The two companies each have their own shareholder base, domiciles, and listings. Alternatively, in the "separate entities structure," the operating activities remain fully owned by each of the two merged companies. The companies also retain their domiciles, listings and shareholders. The equalization agreement is set up to insure that there is equal treatment of both companies' shareholders in voting and economic terms. There are cross-holdings of special dividend access shares or contractual payments between the twins to provide for equalized payments to shareholders. Finally, in the "stapled stock structure," shares in each firm are "stapled" to each other. As an example, Eurotunnel shares are listed in the forms of units (comprising of one share in Eurotunnel PLC stapled to one share of Eurotunnel SA) on the London Stock Exchange and on Euronext Paris. Another example of is Smithkline Beecham, which issued "equity units" (consisting of 5 class B ordinary shares stapled to one preferred share) to the former shareholders of the U.S. based Smithkline Beckham Group, while former shareholders of Beecham Group PLC (a U.K. company) received class A ordinary shares in the new company. The dividends to one class A share are equalized to the dividends of one stapled equity unit.

Table 1 describes the types of structure used by each of the 13 DLCs in our sample as well as their date of merger. The two eldest twins are the Anglo-Dutch combinations Royal

[3] Bedi, Richards, and Tennant (2003) also describe the characteristics of a sample of DLCs. Their study focuses on the transition of firms from a DLC to a unified structure. The authors measure comovement with market indices for four twins before and after unification. The results indicate that comovement increases for the market at which the unified firm is quoted and decreases for the market at which the stock is delisted. The paper also contains an event study for six unified DLCs, which shows that there is little change in total firm value.

[4] See "Dual-Listed Company Transactions and Frustrating Action," issued by the U.K. Panel on Takeovers and Mergers, April 26, 2002.

Dutch/Shell and Unilever NV/PLC. Extensive descriptions of these twins can be found in Rosenthal and Young (1990) and Froot and Dabora (1999). In 1988, almost fifty years after the previous DLC, ABB, a Swiss-Swedish engineering group was created. This DLC set the stage for subsequent DLCs, from Eurotunnel in 1989 to Brambles Industries in 2001. It is clear that the combined entities structure predominates occurring in 7 of the 13 pairs, with the separate entities structure occurring 5 times and the stapled structure twice. Interestingly, the country most often involved by far is the U.K. with 9 individual companies, followed by the Netherlands with 4, Australia with 3, and Belgium, France, Sweden, and Switzerland with 2 firms each.

What are the motivations for firms to adopt a DLC structure, instead of a regular merger where a single share is created? The first motivation is taxation. A capital gains tax could be owed if an outright merger took place, but no such tax consequence would arise with a DLC deal. Differences in tax regimes may also favor the DLC, because cross-border dividend payments are minimized. In addition, there may be favorable tax consequences for the companies themselves.[5] A second motivation is the preservation of the (national) identity of each of the twins. This is a political reason, because by maintaining separate firms, any problems with an important local company being taken over by a foreign firm would be eliminated. A third motive is the reduction of investor flow-back, which would depress the price of the stock of one of the firms in their own market if the merger route were used instead. The thought behind this is that some institutional investors cannot own the shares of firms domiciled outside the home country or can only own such shares in limited quantity. In addition, in a merger, the non-surviving firm would be removed from all indices. Index tracking funds would then have to sell the shares of the surviving company. With the DLC structure, all of this would be avoided.[6] A fourth motive is that DLCs do not necessarily require regulatory (anti-trust) consent and may not be constrained by the requirement of foreign investment approval.[7] Finally, the access to local capital markets may be reduced when in a regular merger a quotation disappears. This is based on the idea that local investors are already familiar with the company from the pre-DLC period. However, the DLC structure also has disadvantages. The structure may hamper transparency for investors and reduce

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5 See Reserve Bank of Australia Bulletin, October 2002, p. 7-13.

6 See Baker & McKenzie newsletter on DLCs of July 2001.

7 Consequently, in the U.K., the DLC structure was brought within the City Code on Takeovers and Acquisitions in 2002. See "Dual-Listed Company Transactions and Frustrating Action," issued by the U.K. Panel on Takeovers and Mergers, April 26, 2002.

managerial efficiency. In addition, capital market transactions (such as share repurchases and stock splits) are more complex under the DLC structure.

2.2 Data

We collect daily stock prices, total returns in local currency, bid and ask prices, trading volume, and the number of shares outstanding from Datastream. Bid and ask prices and trading volume are generally not available in the first years of the sample. Datastream does not supply bid-ask prices for Nordbanken AB and bid-ask prices and volume data for ABB AB, the Swedish part of the ABB twin. For ABB AB, daily bid-ask prices and volume data are obtained from Bloomberg. As data on the Smithkline Beecham Equity Units (class E shares) are not available on Datastream, we use daily data from Bloomberg for the Smithkline Beecham H and E shares. The sample period for Royal Dutch/Shell and Unilever is January 1, 1980 to October 3, 2002. The sample period for all other twins starts at the date of the merger and ends either 20 trading days before the announcement date of the share unification or at the last date in our full sample period.

We extract information about the theoretical price ratio of the twin prices from corporate annual reports, the merger prospectus, and/or the unification prospectus. For seven out of 13 twins, the theoretical price ratio is equal to 1:1. For the other six twins, we apply the procedure outlined in Rosenthal and Young (1990) for the calculation of the theoretical price ratio. This involves taking account of the number of shares outstanding for both parts of the twin, as the current and future equity flows of these twin pairs are fixed at a specified ratio.

Daily exchange rates are obtained from Datastream. For domestic stock market indices we use the ASX All Ordinaries index for Australia, the Brussels Allshare index for Belgium, the SBF 250 index for France, the Helsinki HEX index for Finland, the CBS Allshare index for the Netherlands, the Stockholmbörsen Allshare index for Sweden, the Swiss Performance index for Switzerland, the FTSE Allshare index for the U.K., and the S&P 500 index for the U.S. All indices are from Datastream, except for the FTSE and the S&P indices employed for the Smithkline Beecham twin, which are taken from Bloomberg. Data on the 3-month Treasury Bill rate are from the website of the Federal Reserve Bank of St. Louis. Daily returns on the Fama-French SMB and HML factors are computed from CRSP data.

3. Price disparities and comovement

3.1 Deviations from theoretical parity

Figure 1 depicts graphs of the log deviations of the relative price from theoretical parity for all 13 twins. It is obvious from the graphs that log deviations from parity are often very large. Moreover, they fluctuate considerably over time. These observations are supported by the summary statistics of the price differentials for each twin as presented in Table 2. The mean absolute price differential ranges from 2.60 percent (Eurotunnel) to 11.94 percent (ABB), which is very large in economic terms.[8] For all of the twins, the deviation from theoretical parity exceeds 15 percent in absolute value at some point in time. For 5 out of 13 twins, absolute price gaps amounting to 20 percent or more occur, while 3 of the twins have an absolute price differential of more than 35 percent at some point during the sample period. An extreme example of price disparity is provided by ABB AG, which traded at a near 50 percent discount relative to the theoretical price ratio with ABB AB on January 13, 1988.

Log deviations from parity exhibit great variation over time for most twins. For all twins but BHP Billiton and Zürich Allied/Allied Zürich, the deviation from theoretical parity assumes both positive and negative values over the sample period. As can be observed from Figure 1, the price discrepancy changes from negative to positive (or vice versa) frequently for many twins. The substantial time-series variation in the price differential is reflected in the estimates of the standard deviation depicted in the third column of Table 2, which range from 2.8 percent for Eurotunnel to 14.2 percent for ABB. There does not seem to be any indication that the price gap is smaller (or larger) for twins that were established later in the sample period. Price differentials are highly correlated for several twins, however. The correlation between the log deviations from parity of Anglo-Dutch twins Royal Dutch/Shell and Unilever amounts to 0.86, while the correlation between the Royal Dutch/Shell and Elsevier/Reed International price differentials is equal to 0.71. Disparities of the Anglo-Australian twins Rio Tinto and BHP Billiton show a correlation of 0.57, but neither moves together with the price gap of Brambles Industries. The substantial correlations suggest that common factors may drive the price differentials of dual-listed companies from specific countries. This supposition is borne out in section 3.2, in which we investigate whether relative movements in the stock market indices in the home countries of the twins have an effect on the price differentials.

[8] Unreported results of a t-test of the null-hypothesis that the mean deviations from parity (in log-form) are equal to zero are strongly rejected for all 13 dual-listed companies. The results are available from the authors on request.

3.2 Comovement with local market indices

Froot and Dabora (1999) present evidence that the pricing of Royal Dutch/Shell, Unilever, and Smithkline Beecham is affected by the location of trade. They find that differences in relative prices of twin stocks are correlated with their domestic market indices. This section reports the results of an analysis of the comovement of twin stock prices with local market indices for all 13 DLCs in the sample. We run the following regression for each twin:[9]

$$r_{A,t} - r_{B,t} = \alpha + \beta\left(r_{A,t-1} - r_{B,t-1}\right) + \sum_{i=0}^{1} \gamma_i^1 Index1_{t+i} + \sum_{j=-1}^{0} \gamma_j^2 Index2_{t+j} + \sum_{k=-1}^{1} \delta_k e.r._{t+k} + \varepsilon_t \,, \qquad (1)$$

where A and B represent the twin pair, $r_{A,t}$ and $r_{B,t}$ are the log returns at time t of the first and the second part of the twin in their local currencies, respectively (Table 1 defines what the first and the second part is), *Index1* and *Index2* denote the log returns of the domestic market indices corresponding to the home country of twin A and twin B, and *e.r.* represents the log changes in the exchange rate between the home currencies of twin A and twin B.[10] As all twins are defined in such a way that the country of twin B is in an earlier time zone than the country of twin A, we include a lead of *Index1* and a lag of *Index2*. Our null-hypothesis is that the return difference of the twin is uncorrelated with the right hand side variables. In absence of non-synchronous measurement of currency returns and stock returns, we expect the coefficient on the exchange rate to equal –1, and the coefficients of the lead and lag of the exchange rate returns to be equal to 0. Under the alternative hypothesis, stock markets are segmented and the return differential of a twin is positively affected by a shock in *Index1* and negatively affected by a shock in *Index2*.

Table 3 reports estimation results of equation (1) for all 13 twins in the sample. We employ Newey-West standard errors in order to correct for heteroskedasticity and auto-correlation. The reported coefficients represent the sum of the coefficients on the lead or lag, and the current independent variable. The null hypothesis of perfect market integration is strongly rejected for all the twins in the sample. The market index of the country of the first

[9] Note that our specification differs from the basic Froot and Dabora (1999) regression framework in three ways. First, we do not include the S&P and the exchange rate of the U.S. dollar for all twins (except for Smithkline Beecham). Second, Froot and Dabora include a lead and a lag for all variables, while our set of leads and lags is based on the actual time differential. Third, we incorporate a lagged dependent variable in the regression, as the Durbin-Watson statistic indicates substantial autocorrelation in the error term. Neither of these methodological differences materially affects our results. The regression results of the basic Froot and Dabora regression are available from the authors on request.

[10] Following Froot and Dabora (1999), we measure the location of trade effect using broad equity indices. Froot and Dabora point out that the inclusion of several of the twins in the respective indices leads to a bias in the estimated coefficients. They show that this bias is too small to affect the regression results. As Royal Dutch forms a considerable part of the Dutch market index, however, we remove Royal Dutch from the CBS Allshare index.

part of the twin, *Index1*, shows up significantly for 11 out of 13 twins, while the cumulative coefficient on *Index2*, the domestic market index of the country of the second part of the twin, is highly statistically significant for every single twin. All signs of the domestic market indices are as predicted by the location of trade effect reported by Froot and Dabora (1999). A positive shock in the market index of country 1 leads to an increase in the relative price of twin A. Whether this implies that the deviation from theoretical parity increases or decreases depends on whether the price differential was positive or negative. A positive shock in the market index of country 2 leads to an increase of the relative stock price of twin B.

The economic importance of the market index effect is considerable, as the coefficients on the domestic market indices are remarkably high. The coefficient on *Index1* varies between 0.086 for Smithkline Beecham and 0.667 for ABB. The coefficient on *Index2* ranges from –0.145 for Eurotunnel to –0.866 for Brambles. This implies, for example, that an one-percent increase in the Swiss Performance index increases the relative return of ABB AG versus ABB AB by 67 basis points and an one-percent increase in the FTSE Allshare index decreases the relative return of Brambles Industries Ltd versus Brambles Industries PLC by 87 basis points. The coefficients on the domestic stock market indices are similar to those reported by Froot and Dabora. The effect of the domestic market index is able to explain considerable part of the daily variation of relative twin returns. The R^2 indicates that 10 to 40 percent of daily return differentials can be explained by the lagged dependent variable, the local stock market indices, and the exchange rate.[11]

Froot and Dabora offer three possible explanations for the location of trade effect. First, tax-induced investor heterogeneity may be a source of market segmentation. Froot and Dabora show that this explanation is incomplete for the three twins they consider. In our extended sample of DLCs, tax-driven stories do not seem to be able to explain more than a minor part of the effect either. The large time-series variation in price discrepancies and the remarkable similarities in the regression results across twins are inconsistent with this explanation. Second, the observed comovements may be related to institutional frictions related to agency problems. Equity fund managers are sometimes restricted to investing in domestic or international stocks and are often benchmarked against market indices which may contain stocks from DLCs. Finally, market-wide noise shocks stemming from irrational

[11] The fact that the coefficient on the lagged dependent variable is negative suggests that return differentials display some kind of mean reversion. This was partly confirmed in unreported tests for a unit root in the log deviations from parity. For 7 out of 13 twins, an augmented Dickey-Fuller tests that includes a trend and four lags rejects the unit root hypothesis at the 5 percent level. Note that this test is known to suffer from low power, however. Detailed results are available from the authors.

traders which have a bigger impact on local than on foreign stock returns can account for the comovement. Recently, a more specific view on the two latter explanations has been put forward by Barberis, Shleifer, and Wurgler (2003) in three sentiment-based theories of comovement. In the "category" view, investors group assets into categories in order to simplify portfolio decisions and subsequently allocate capital over the categories. The "habitat" view originates from the observation that investors trade only a subset of all available securities. As a result, a common factor arises in the returns of securities held by a specific subset of investors. Finally, the "information diffusion" view is that information is incorporated more quickly into prices of some stocks than others. The former two views may well form an explanation of our Froot-Dabora regression results, as stocks from a specific country can be conceived as a category as well as a habitat. Although the information diffusion view may explain short-run comovement, it cannot fully explain the mispricing in DLCs, because deviations from parity last too long to be explained by slower incorporation of information. Other empirical studies have also found comovement effects and attribute these to country-specific investor sentiment. For example, Bodurtha, Kim, and Lee (1995) show that the prices of closed-end country funds in the U.S. are strongly affected by movements in the U.S. market, while the value of the assets are not. Chan, Hameed, and Lau (2003) find that since the move of the listing of the Hong Kong-based Jardine Group from the Hong Kong exchange to Singapore's exchange the stock returns are correlated less with the Hong Kong market and more with the Singapore market.

In order to better understand the underlying causes of the comovement in our sample, we had numerous discussions with members of the investment community on DLCs. We spoke with professionals who advise institutions engaging in DLC arbitrage and with a portfolio manager whose investment vehicle is actively involved in DLC arbitrage.[12] Indexing (or index tracking as it is called in Europe) is viewed as an important reason for why price discrepancies exist. To the degree that indexing is important in any market, and given the size of that market, inclusion in an index will increase the price of one firm in the DLC relative to parity. The impact of this can be seen when Standard & Poor's decided to eliminate non-U.S. companies from the S&P 500 in 2002. Two of the companies covered in this study were eliminated – Royal Dutch NV and Unilever NV. When the decision was announced and in the weeks leading up to the deletion, prices of both of these firms fell relative to the their U.K. counterpart. The impact was perhaps more significant than other such changes, since the U.S

[12] We would like to thank these individuals for spending time with us and are grateful for their insightful comments. All expressed the desire to remain anonymous.

equity market is the largest in the world, and indexing is a significant portfolio strategy in the U.S. One person indicated that many institutional investors have a mandate to invest in Euroland leaving out stocks in the U.K., so this favors the non-U.K. part of any Anglo-other country DLC. The comments of the interviewees regarding indexing and other institutional mandates are consistent with Barberis, Shleifer, and Wurgler's (2003) sentiment-based theories of comovement, and in particular with the category and habitat models.

Shleifer and Vishny (1997, p. 52) suggest that the first step in understanding an anomaly is to investigate the source of noise trading that generates the mispricing in the first place. For DLCs, the location of trade effect captures part of the mispricing. Along the lines of Froot and Dabora and related studies, we contend that this comovement effect cannot be attributed to fundamental factors, but is likely to be related to sentiment-based explanations.

Although the exact source of the location of trade effect is difficult to identify, the phenomenon helps to understand why considerable deviations from theoretical parity arise. Shleifer and Vishny's second step is to evaluate the costs and benefits of arbitraging. This brings us to the principal aim of this paper, which is to investigate why arbitrage in international equity markets does not correct the price differentials. In the next sections we examine the risk and return characteristics of simple arbitrage strategies designed to exploit the price discrepancies between the twins.

4. Arbitrage strategies

We are interested in the performance of arbitrage positions in the 13 DLCs in our sample. Our approach is inspired by the studies of Mitchell, Pulvino, and Stafford (2002) and Lamont and Thaler (2003). The former analyze a sample of 82 negative stub value situations, which constitute all the situations of this kind the authors were able to identify in U.S. markets in the period 1985-2000. The findings suggest that investment strategies that involve buying the parent and shorting the subsidiary produce risk-adjusted excess returns (after transaction costs) of up to 15 percent per year. Mitchell et al. show that uncertainty about the distribution of returns and risk characteristics limits arbitrage. Lamont and Thaler (2003) study 6 negative stub value situations after carve-outs of technology stocks. Simple arbitrage strategies on average yield returns of 10 percent per month. Lamont and Thaler contend that arbitrage does not correct the mispricing due to shorting constraints, in particular for the carved out shares. This is due to the relatively small float of the carved out stock making it expensive to short these shares.

We specify investment strategies involving a long position in the relatively underpriced part of the twin and shorting an equal dollar amount in the relatively overpriced part of the twin. In a frictionless market in which the investor gets access to the short sale proceeds, this strategy is a zero-cost or self-financing strategy. However, in practice arbitrageurs must post collateral for both the long and the short position. We investigate the investment strategy from the perspective of U.S. arbitrageurs. As in Mitchell et al. (2002), we impose Regulation T initial margin requirements equal to 50 percent of the long market value and 50 percent of the short market value.[13] Following Mitchell et al., we assume that the short rebate is equal to 3 percent per year. We further assume that cash balances receive 5 percent per year and margin loans pay 5.5 percent annually. Daily returns are calculated on the basis of daily equity values, which are computed in the way outlined by Mitchell et al. (p. 560). We present results both with and without maintenance margin requirements.

The trading strategy requires the investors to specify three different elements. First, we assume that investors set-up an arbitrage position when the price discrepancy (measured by the log deviations from parity) crosses a certain "buy threshold." Secondly, the investors need to determine the "sell threshold" for the log deviations from parity, at which point the arbitrage position is terminated. Finally, the investors choose a maximum investment horizon, after which any investment is interrupted. We impose the condition that the arbitrageur holds at most one position in each twin at each point in time and discard any open positions at the end of the sample period. In order to prevent investment strategies with modest daily returns, but very short durations from having a have a big influence on the results, we assume that when a strategy terminates within one month, the arbitrageur invests the investment proceeds in the 3-month T-bill for the remainder of the month. Following Lamont and Thaler (2003), we use daily closing prices to assess the profitability of the strategy.[14]

Table 4 reports the results of following an investment strategy with a buy threshold of 10 percent, a sell threshold of 5 percent, and a maximum horizon of one year (260 trading days). The investment horizon used is the same as in Mitchell et al. (2002). For each individual twin in the sample, Table 4 reflects information on the number of arbitrage positions established, the distribution of the number of days for which the positions are

[13] A number of the DLCs have never traded in the U.S. Therefore, arbitrageurs would not be subject to U.S. shorting and margin rules, which are generally stricter than in other countries where DLCs trade. However, we bias our results against finding significant trading profits by having the arbitrageurs subject to the stricter U.S. shorting and margin rules.

[14] Again, we potentially bias our results against finding significant trading profits, because arbitrageurs may be able to pick more favorable buy and sell opportunities during the day.

maintained, and the distribution of investment returns. The last row of the table reports summary statistics of all arbitrage positions in the 13 twins. Over the sample period 1980-2003, a U.S. arbitrageur would have set up 141 positions in the DLCs in the sample. There is a substantial amount of variation in the investment horizon over the arbitrage positions. All 13 twins generate at least one arbitrage strategy that lasts shorter than one month (22 trading days), while in total 8 arbitrage positions (distributed over 6 twins) are interrupted after one year (260 trading days).

The results in Table 4 show that returns on the investment strategy are substantial. Returns are calculated as a percentage per month and the returns of individual positions are weighted by the number of days the position is maintained. Following the arbitrage strategy for all twins in the sample would have yielded a weighted average return of 1.8 percent per month (21.6 percent per annum). Median returns for individual twins vary between almost 1 percent to over 6 percent per month. Returns exhibit considerable dispersion, both across twins and for each individual DLC. Roughly 7 percent of the positions (10 out of 141) produce negative investment returns. These are associated with positions terminated at the end of the maximum horizon at an unfavorable point in time. In some cases, termination after one year yields a loss of up to 14 (= 12×−1.165) percent of the arbitrageur's total invested capital.

Table 5 depicts the distribution of investment horizons and arbitrage returns for the strategies after taking transaction costs and maintenance margin requirements into account. Based on conversations with a number of large investment firms, we assume that arbitrageurs pay a commission of 25 basis points per transaction. In addition, setting up an arbitrage position involves transaction costs of half the bid-ask spread for both of the twin stocks. Arbitrage returns are calculated assuming a bid-ask spread of 40 basis points, which is the median bid-ask spread of all 26 twin stocks in the sample. The median was calculated on the basis of the available data on bid and ask prices, as described in section 2. The estimate is realistic in comparison with estimates provided by Froot and Perold (1997), Hupperets and Menkveld (2002), and the Elkins/McSherry trading costs survey.[15] Table 6 reports a sensitivity analysis of these assumptions.

In line with Mitchell et al. (2002), the returns in Table 5 are calculated under the assumption that the arbitrageur will receive a margin call if twin prices move such that the investor's position has less than the required maintenance margin of 25 percent for long positions and 30 percent for short positions. After receiving a margin call, the arbitrageur

[15] The Elkins/McSherry information is obtained from various Institutional Investor publications.

responds by partially liquidating the position. This leads to a negative return on that day, as the mispricing has deepened. The account is marked to market each day. Table 5 reveals that transaction costs and margin calls diminish average arbitrage returns by approximately 0.5 percent per month, implying a weighted average return of 15.6 percent per year over all twins. More than 10 percent of the 141 investment strategies result in one or more margin calls. Most of these investments receive a number of subsequent margin calls forcing the arbitrageur to partial liquidation of the position, as the mispricing deepens several days in a row.

In order to determine the sensitivity of our return calculations to the thresholds and the horizon as well as the level of the bid-ask spread, we present returns for buy/sell thresholds of 10/5 and 5/1 and horizons of 1 month, 3 months, and 1 year as well as unlimited horizon results in Table 6. The table present the results of 8 different trading rules aggregated over all twins. All strategies produce a considerable number of arbitrage positions (ranging from 126 to 382 positions) and substantial monthly returns (weighted averages vary between 0.58 and 1.35 percent per month). The number of strategies decrease with the investment horizon, as long horizons prevent other positions from being set-up in the same period. For the unlimited horizon strategies, investment horizons of individual arbitrage positions exhibit substantial variation. Although the majority of investments last only 1 month, the average horizon is about 4.5 months and some positions are open for several years before convergence takes place. Reducing the uncertainty about the length of the investment horizon comes at a cost. The termination of positions before convergence has occurred leads to negative returns. For the strategies with a maximum horizon of 1 month, almost half of the arbitrage positions result in a negative return. The losses may be very large for individual arbitrage positions (up to 23 percent of total capital for some strategies). Moreover, transaction costs have a more negative impact on returns for short horizon strategies. On the other hand, longer horizons may lead to lower average returns, because positions that are open for a long time have positive, but very small monthly returns and a large weight in the weighted-average return. The overall effect is that average arbitrage returns are higher at longer horizons. The last two rows of Table 6 illustrate the impact of the magnitude of the bid-ask spread on the arbitrage returns. Increasing or decreasing the bid-ask spread by 10 basis points has a limited effect on the average return.

Taken as a whole, the results presented in Tables 4, 5, and 6 indicate that investment strategies in the 13 DLCs in our sample produce substantial arbitrage returns. Arbitrage in DLCs is not risk-free, however. Uncertainty over the time to convergence is large and imposing a maximum horizon leads to a large fraction of positions that yield negative returns.

The next section examines the risks associated with the arbitrage strategies and reviews possible impediments to arbitrage.

5. Arbitrage risk and the limits of arbitrage

Our results in section 4 indicate that significant arbitrage returns can be realized by applying a simple trading rule. The fact that these returns persist together with the prolonged mispricing present in DLCs raises the question which impediments prevent rational arbitrageurs from arbitraging the price discrepancies away in practice. First, this section examines whether short selling constraints restrict arbitrageurs from setting up hedged arbitrage positions. Second, we present an analysis of the risks of the strategies.

A number of studies indicate that there may be important constraints on short-sales. D'Avolio (2002) describes the market for borrowing stock in the U.S. and shows that while this market is generally very active and liquid, for some stocks supply is constrained and fees are significant. Lamont and Thaler (2003) present evidence that the shorting market appears to exhibit important imperfections for a sample of U.S. tech stocks. Bris, Goetzmann, and Zhu (2003) document short-sales restrictions in international equity markets. For example, in Belgium there is no organized market for stock lending and borrowing, in Sweden shorting has only been allowed since 1991, and in Finland shorting started in 1998, but transfer taxes make it expensive. While these and other legal or institutional obstacles may have hampered arbitrage strategies in several of the twins in the sample (notably Dexia, Fortis, ABB, and Merita Nordbanken), it is implausible that for most firms in the sample short sales constraints can explain more than a minor part of the mispricing. The DLCs in our sample generally involve very large and liquid stocks for which equity lending is relatively easily available.

A second possible impediment to arbitrage is DLCs is risk. As a starting point of the analysis of the risks associated with DLC arbitrage we measure excess arbitrage returns after correcting for systematic risk. Table 7 displays estimates of the parameters in the Fama-French three-factor model for all 8 investment strategies described in Table 6. These are obtained from time-series regressions of daily portfolio returns in excess of the 3-month T-bill rate on the excess return on the S&P 500 index and the size (SMB) and book-to-market (HML) factors. Daily portfolio returns (expressed in % per month) were constructed by pooling the daily returns on the individual investment positions after incorporating transaction costs and maintenance margin requirements. Out of the 8 strategies analyzed, 6 produce abnormal returns that are statistically significant at the 1 percent level. Average abnormal

returns on these strategies range from 6.5 to 10.3 percent when expressed on an annual basis. These returns appear to be economically large and are comparable to the negative stub value arbitrage returns reported by Mitchell et al. (2002).

Shleifer and Vishny (1997) argue that in practice most arbitrage is conducted by relatively few professional and highly specialized investors. These arbitrageurs are more concerned about the total risk than about the systematic risk of their portfolio, because specialization limits the degree of diversification of their portfolios. This causes the arbitrageurs to bear idiosyncratic risks for which they must be rewarded. Moreover, their incentive contracts make them risk averse. Consequently, even when returns adjusted for systematic risk are high, arbitrage will be deterred if idiosyncratic risk is large. This argument is supported by both empirical research and casual empiricism. Ackermann, McEnally, and Ravenscraft (1999) describe the performance incentives of U.S. hedge funds. The compensation structure includes some elements that may encourage risk-taking behavior. Bonus compensation is on average 14 percent of annual profits and this fee is normally only paid if the returns are positive. If a fund has negative returns, the manager has to make up for the loss(es) before being able to earn performance compensation. This is often referred to as the "high-water mark." However, several other characteristics of hedge funds induce strong risk aversion. First, hedge fund managers receive an annual management fee of on average 1 percent of assets under management. Because fund size determines the fee, a good track record is important as this attracts new funds (Agarwal, Daniel, and Naik, 2003). Second, many hedge fund managers invest substantial amounts of their own money in the fund and are therefore poorly diversified. Third, the arbitrageurs are typically partners and thus liable for losses. Brown, Goetzmann, and Park (2001) model the probability of fund failure and report evidence that a hedge fund's total risk has a strong positive effect on failure. These authors also provide evidence on managerial career concerns and conclude that the threat of termination is a much stronger motivation than single-year gains. As a result of the compensation structure, fund managers are concerned with the total risk of their positions.

Lowenstein (2000) describes arbitrage positions of Long-Term Capital Management (LTCM) in Royal Dutch/Shell. LTCM established an arbitrage position in the twin in the summer of 1997, when Royal Dutch traded at a 8% to 10% premium. In total $2.3 billion was invested, half of which long in Shell and the other half short in Royal Dutch (Lowenstein, p. 99). In the autumn of 1998 large defaults on Russian debt created significant losses for the hedge fund and LTCM had to unwind several positions. Lowenstein reports that the premium of Royal Dutch had increased to about 22% and LTCM had to close the position and incur a

loss. According to Lowenstein (p. 234), LTCM lost $286 million in equity pairs trading and more than half of this loss is accounted for by the Royal Dutch/Shell trade.[16]

Although the LTCM trade may strike as an extraordinary case, situations like these are by no means unique in DLC arbitrage. Price discrepancies in DLCs are very volatile and disparities regularly reach levels amounting to more than 15 percent in absolute value. The high volatility of arbitrage positions in DLCs and the possibility that prices will diverge even further from theoretical parity may hamper arbitrage. As an example, an arbitrageur following an investment strategy with a 10 percent buy threshold and a 5 percent sell threshold would have set-up a long position in Unilever NV and a short position in Unilever PLC on January 7, 1980, as the log deviations from parity changed from –9.8 percent to –10.2 percent on the day before. On May 9, 1983, log deviations from parity crossed the sell threshold by moving from –5.6 to –4.9 percent, after which the arbitrage position was terminated. This investment produced a return of 0.27 percent on a monthly basis. However, while the position was open, the mispricing worsened dramatically, leading to a peak of –39.1 percent on August 18, 1981.

The characteristics of real-life arbitrageurs call for an analysis of whether the idiosyncratic risk of the arbitrage positions is substantial, even though the systematic risk of arbitrage in DLCs is limited.[17] The final two columns in Table 7 present estimates of the standard deviation of returns (on a daily basis) for the DLC investment strategies as well as for the S&P 500 over the same period. The idiosyncratic risk of arbitrage returns is importantly larger than the idiosyncratic risk of the S&P 500. The volatility of arbitrage returns consistently exceeds the S&P 500 volatility by almost 50 percent. This is especially striking in light of the fact that our arbitrage strategies involve hedged long-short positions. The volatility of arbitrage positions in DLCs is also much higher than the volatility of hedge fund returns. Agarwal, Daniel, and Naik (2003) report that the volatility of monthly returns amounted to 4.72% on average for 3431 hedge funds over 1994-2000. The high idiosyncratic volatility of arbitrage strategies in a limited number of companies ("the long and bumpy path to convergence," as Mitchell et al. (2002) put it) is to a large extent unhedgeable to specialized arbitrageurs. Following the arguments of Shleifer and Vishny (1997), arbitrage is

[16] Lowenstein (2000) does not provide the precise loss on the Royal Dutch/Shell trade, but a back-of-the-envelope calculation indicates that it is at least half of the total loss in pairs trading. An interesting detail is that Lowenstein (p. 111) describes Shleifer and Vishny (1997) as a warning that an arbitrage firm could be overwhelmed by noise traders pushing prices further away from fundamental value. He mentions that LTCM insiders read the paper prior to publication, but were not convinced by the arguments.

[17] In addition to uncertainty about the time to convergence and the risk that arbitrageurs face margin calls, Mitchell et al. (2002) mention "buy-in risk" as a third relevant component of the idiosyncratic risk of arbitrage strategies. The risk that equity lenders recall their loan and arbitrageurs are unable to maintain their short position may be significant in practice, but is not incorporated in our analysis.

thus likely to be deterred for twins with high idiosyncratic risk and as a result DLC mispricing persists.

We discussed the apparent arbitrage opportunities in the twins with several members of the investment community. DLC arbitrageurs or those advising them use both fundamental and technical analysis to determine when to put on a position. For some, there is no strict decision rule in terms of premium/discount as to when to put on a position. Some arbitrageurs use mean reversion as a signal, while others look for some fundamental catalyst to drive their decision. For example, a change in top management whose capabilities are well respected in one of the DLC countries can lead to a decision to buy the twin in that country and short the other one where those talents are no known. As mentioned above, deletion from (or, for that matter, inclusion in) an index can be a signal to short one and buy the other DLC. Holding periods for DLC arbitrageurs vary considerably. Brokerage houses that engage in or advise on proprietary trading have short horizons of about three months, while some institutional investors have long-term mandates which permit them to put on long-term positions. In such cases, they are willing to put up additional collateral in the case of margin calls and wait until prices converge. Two major reasons were cited for the continued existence of price disparities in DLCs. One has to do with the small size of the arbitrage community, perhaps $2 to $3 billion. The relatively small amount of money available to try to arbitrage DLCs hinders the closing of the price discrepancies. The second reason has to do with DLC arbitrage being viewed as being much riskier than other risk arbitrage strategies, such as those involving mergers and acquisitions. In this case, the arbitrageur is at risk for a finite period of time until the deal closes or fails. DLCs, on the other hand, are open-ended, so that the arbitrageur has no idea when a price discrepancy will narrow. In fact, as long as investors think that a DLC structure is working and that unification is highly unlikely, price disparities will continue. These views confirm the importance of noise trader risk in DLC arbitrage.

Taken together, we find strong support of Shleifer and Vishny's model of the limits of arbitrage. Our findings indicate that while arbitrage positions in DLCs have negligible fundamental risk and low systematic risk, substantial idiosyncratic risk arises as a result of noise traders. We show that the characteristics of specialized professional arbitrageurs in combination with noise trader risk deter arbitrage activity. These limits of arbitrage impede efficient pricing.

6. Unifications

An interesting feature of our sample is that six pairs have chosen to end the DLC structure, i.e. they unified their shares. This section further studies the importance of noise trader risk by examining these unifications. In the period between the announcement and the actual unification, noise trader risk is negligible because prices will certainly converge within a set and limited amount of time (subject to governmental or shareholder objections). Thus, if noise trader risk is an important impediment to arbitrage, we expect two observations after the announcement of a unification. First, prices should converge to parity instantaneously. Second, price discrepancies and arbitrage opportunities should be absent after the unification announcement. An investigation of the development of the price discrepancy and an analysis of arbitrage opportunities provide further evidence on the influence of noise trader risk on DLC arbitrage. The first part of this section presents a description of the unification process and the motivations for a unification, while the second part examines mispricing and arbitrage strategies.

6.1 Legal structures and motivations

The final two columns of Table 1 display the dates of the announcement of the unification and the actual unification dates. The first unification was announced by Smithkline Beecham in 1996, while the other five announcements took place in 1999 and 2000. The share unification was announced two to sixteen months before the actual transition to the new structure.

A unification can be structured in two ways. The first is a stock swap, in which one of the twins makes an offer for the shares of the other twin and only the former twin continues to exist. Dexia and Merita/Nordbanken chose this approach. For example, each Merita shareholder received 1.02 Nordbanken shares for each Merita share. After 96% of the Merita shareholders had exchanged their shares, the remainder was acquired through a mandatory offer. The surviving Nordbanken company was renamed Nordea. The second method, chosen by the other four pairs, is to create a new entity that exchanges its shares for the shares of both twins. For example, the new firm Zürich Financial Services offered one share for each 42.928 Allied Zürich shares and one share for each Zürich Allied share. In addition to choosing either of these structures, some firms provide incentives to specific shareholders. In the case of ABB, the holders of ABB AG bearer shares received a one-time 30 Swiss franc dividend, while the AG registered holders got a one-time 6 Swiss franc dividend. This dividend equalized the differing asset values of ABB AB and AG. In the case of Dexia, the tendering

holders of the French twin received a 2.5% bonus in the form of additional shares, because more than the required 90% was tendered. SmithKline Beecham paid holders of the equity units US $0.225 per share or $1.125 per unit to redeem the preferred stock that was part of the unit. Finally, Allied Zürich holders received 40 pence a share as compensation for having to hold a company with a primary listing in Switzerland and the fact they would no longer own a company that was part of the FTSE 100 index. Since Allied Zürich was part of the FTSE 100, the directors anticipated that index fund trackers in the UK would sell their shares. As a result, £650 million was authorized for buying back Allied Zürich shares through a tender offer. As the unification date got closer, Deutsche Bank estimated that index funds would sell up to 200 million Allied shares, which the tender offer could not fully absorb.[18] At the same time, Zürich Allied authorized the repurchase of up to 1 billion Swiss francs of its stock "to facilitate the management of the flow back resulting from the proposed unification."[19]

Several reasons for unification were mentioned by the twins. Four of the six DLCs explicitly discussed the fact that the shares of the companies systematically did not trade at parity as per their equalization agreements. They viewed the premiums or discounts as undesirable and indicated that one of the purposes of unification was to eliminate them. Four of the DLCs pointed out that unification should result in greater liquidity. Four of the firms expected that unification would facilitate access to capital markets and make it easier to raise capital. Three DLCs explicitly mentioned that unification would eliminate investor confusion caused by their complicated structure. Two of the DLCs mentioned the greater presence and weighting in certain indices and that would be enhanced by unification. Two DLCs expressed the expectation that unification would lead to a broader shareholder base and the likelihood of listing on the NYSE. Consolidation in industry sector and the European Monetary Union were cited by two of the financial service companies, Merita/Nordbanken and Dexia. These DLCs, and particularly Dexia, had previously indicated that the DLC structure was an intermediate step to a full cross-border merger. Both Merita/Nordbanken and Dexia stated that competing as one firm would be lead to greater success. Zürich Allied/Allied Zürich also faced a consolidating industry and mentioned that a single firm would be better able to make acquisitions. SmithKline Beecham discussed that the administration of the unit shares issued to U.S. shareholders was cumbersome and pointed at difficulties with settlement of trades. In

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[18] "Market Report: Allied Zurich Faces Selling Frenzy As It Exits London Stage," *The Independent*, October 10, 2000.

[19] Press Release dated May 3, 2000, "Zurich Financial Services Group – Transaction Agreement Signed in Respect of Plan to Unify the Holding Structure."

addition, a change in taxes on dividends in the U.K. would make unification more desirable for investors. Merita/Nordbanken also said that a unified company would be faced with a reduction in operational and legal risks that the company felt the DLC structure presented.

6.2 Movements towards parity

As soon as the unification is announced, we expect the prices to converge toward parity, as unification becomes closer to being realized. Figure 2 shows the development of the log deviations from parity starting 120 trading days before the announcement up to the last trading day of the twin shares. The log deviations are reflected by the bold lines and the scale is presented on the right-hand vertical axis.

Dexia traded at a discount of around 10% in the period before the announcement. This discrepancy is eliminated virtually instantaneously: the deviation changes from –9.22% to –0.14% in a single day. We find similar changes in Merita/Nordbanken (from –5.44% to –0.13% in one day), Zürich Allied/Allied Zürich (from 8.29% to 1.91% in one day and to 0.34% in two days), and Fortis (from 0.71% to 0.11% in one day). The price differential remains somewhat larger for ABB (from 12.30% to 5.56% in one day) and Smithkline Beecham (from –3.08% to –2.11% in one day). However, the sign of the deviation from parity is consistent with the dividend for ABB AG shareholders and the cash compensation for US Smithkline Beecham shareholders. These striking results suggest that the financial markets are fully aware of the mispricing of the twin and that corrections to prices occurs within one or two days.[20]

During the period between the announcement and the actual unification, the deviations from parity remain relatively stable for ABB, Smithkline Beecham, Fortis, and Zürich Allied/Allied Zürich. Two twins, Dexia and Merita/Nordbanken, exhibit considerable swings, however.[21] This phenomenon can be explained by the stock swap structure of these unifications. The deviations from parity on the final trading day are in line with the cash

[20] Analyses similar to ours for closed-end funds are Brauer (1984) and Brickley and Schallheim (1985). These studies find that the announcement of an open-ending of a closed-end fund induces significant abnormal returns. The discount to net asset value normally present in a closed-end fund is reduced upon the announcement. A problem in this literature is the absence of a precise benchmark for the abnormal return, because upon announcement the reported net asset value may suffer from measurement error.

[21] In the period after the unification announcement we traced all changes of the deviation from parity larger than 3%. In total we find 32 trading days with large changes for five of the six twins. We investigated each trading day by reading newspaper and news wire articles in Lexis/Nexis. On 18 occasions news about the unification is announced, such as the initial announcement, bonuses, and percentages of shares tendered. For each of these occasions the change of the deviation from parity can be attributed to the news. On 9 other occasions important firm specific news is announced, such as a merger or annual results. On only 5 occasions no news was found.

compensation that accompanies the exchange offers for ABB, Smithkline Beecham, and Zürich Allied/Allied Zürich. Fortis does not show a noteworthy deviation on the last day. Dexia trades at a negative deviation, which contrasts with the bonus for the shareholders of the French twin. Merita/Nordbanken closes at a positive deviation.[22]

6.3 Arbitrage strategies

As noise trader risk is negligible after the unification announcement, we are interested whether the trading rules that are discussed in section 4 yield different results in the post-announcement period. We also investigate trading volumes in the unified DLCs in order to obtain an idea about whether arbitrage actually takes place around and after the unification announcement.

In case arbitrageurs are active after the announcement of the unification in order to exploit mispricing, we would expect to find larger volumes after the announcement and particularly large volumes when deviations are larger. Figure 2 plots the relative trading volumes for each part of the six unified twins. We calculate relative trading volumes over a period starting 120 days before the unification announcement till the last trading day before unification. Trading volumes are measured relative to the average volume over the period from 120 to 21 days before the announcement date, which is denoted day 0. The dotted (solid) line reflects relative trading volume in the first (second) part of the twin and the left-hand scale applies.[23] The figure yields several interesting results. First, on the announcement day, the trading volumes are large. The only exception is Fortis, but the deviation from parity for this twin was very small. This indicates that the announcement induces heavy trading, most likely also including arbitrage activity. Second, the volumes and the volatility in the volumes are much larger in the post-announcement period, in comparison with the 120 days before announcement. Apparently, the disappearance of noise trader risk attracts many investors, probably including arbitrageurs. Finally, the peaks in trading volume clearly coincide with changes in the deviations from parity. When the firm releases company-specific news that is

[22] The deviations for Dexia show that after a stable period the French share becomes undervalued and recover later. This can be explained as follows. On the 22nd trading day after the announcement of the unification, the French share is removed from the CAC40 index. This is likely to induce investors to sell the French share. Towards the unification date, it becomes clear that the bid will succeed and a 2.5% bonus is paid. For Merita/Nordbanken, the fluctuations are most likely driven by relatively low trading volumes of Merita due to the large amount of shares already tendered. For both twins the fluctuations are caused by the choice for a stock swap deal in which one of the twins disappears.

[23] The Datastream volume data shows some missing values. For each twin fewer than ten observations are missing. The only exception is ABB AG, for which roughly 80% of the volumes are missing.

value-relevant, we would expect volumes to increase without necessarily a resulting change in the deviation. Thus, a relation exists between the trading activity and the change in the price discrepancy. Arbitrageurs are a likely reason for this phenomenon.

A more compelling indication that active arbitrageurs correct price discrepancies that arise as the result of noise trading would be the absence of arbitrage profits. The remainder of this section contains an analysis of the risk and return characteristics of arbitrage strategies comparable to section 4. We present the results of the investment strategies for the six unified twins in the sample in Table 8. We consider the period starting five trading days after the unification announcement until the last trading day before the unification of the share structure.[24] The table presents the results of the same strategies as examined in section 4 for all 13 twins in the sample. The findings corroborate the observation from Figure 2 that after the announcement of the unification the price discrepancies between the two parts of the twin no longer show the large fluctuations that occur before the announcement. The 10/5 percent and 5/1 percent buy/sell threshold strategies produce a very limited number of arbitrage strategies. Weighted average returns are high on a monthly basis, but investment horizons are generally very short. Moreover, Merita/Nordbanken accounts for 3 out of 4 arbitrage positions in the 10/5 strategies. As mentioned in the previous section Bris, Goetzmann, and Zhu (2003) report that Finnish transfer taxes make shorting expensive. Figure 2 shows that the Finnish Merita is overpriced relative to Nordbanken in most of the post-announcement period. This feature explains the overpricing of Merita and thus the majority of the arbitrage opportunities.

The analysis of the unification of 6 of the 13 twins produces two clear results. First, the market instantaneously adjusts the relative stock prices in order to close the price discrepancy as soon as the unification is announced. Second, arbitrage opportunities essentially disappear in the post-announcement period. Since the main difference with the pre-announcement period is the removal of noise trader risk, the evidence indicates that noise traders deter arbitrage activity before the unification is announced.

[24] Our choice for discarding the first five days after the announcement is motivated by not willing to include the movement toward parity upon the unification announcement as an arbitrage strategy.

7. Conclusions

We study the limits of arbitrage in international equity markets by examining a sample of dual-listed companies (DLCs). A DLC is created by the de facto merger of two firms with different countries of incorporation. Each firm retains its own separate legal identity and its own set of shareholders, but is able to use the DLC structure to combine their operations. This is done by a set of arrangements that are designed to insure that the business is operated as if it were a single company. As part of the legal contracts, the shareholders of each company will get dividends based on a prescribed sharing of the cash flows created by the whole enterprise. In integrated and efficient equity markets, the stock prices of the twins should move together perfectly, as the stocks of both parent companies are perfect substitutes. DLCs. As DLCs do not involve fundamental risk, they constitute a unique natural experiment to empirically examine the proposition of Shleifer and Vishny (1997) that arbitrage in practice is limited as a result of noise trader risk in conjunction with arbitrageurs who are specialized professionals managing other people's capital.

We study the mispricing of 13 DLCs that were created until the second half of 2002. We find that the relative prices of all twins exhibit statistically significant and economically substantial deviations from theoretical parity. Average absolute price differentials range from around 2.5 to almost 12 percent, while maximum deviations reach values of 15 to nearly 50 percent. The deviations from parity show substantial deviation over time, assuming both negative and positive values for 11 out of 13 twins. This indicates that important mispricing exists in DLCs. Consistent with Froot and Dabora (1999), we find that the relative return of a twin is strongly affected by fluctuations in the domestic market indices. Employing the framework of Barberis, Shleifer, and Wurgler (2003), this can be interpreted as evidence of country-specific noise.

We analyze whether the existence of substantial price discrepancies imply exploitable arbitrage opportunities by designing and testing a number of trading rules. These arbitrage strategies produce economically large returns for all twins in the sample. Arbitrage in all DLCs combined yields excess returns of up to 10 percent per annum relative to the Fama-French three-factor model (incorporating transaction costs and margin requirements). However, arbitrage in DLCs involves considerable noise trader risk, because there is no identifiable date at which the twin prices will converge. Specialized arbitrageurs managing the capital of outside investors have limited horizons and are unable to close the price gap on their own. In addition, their portfolios are generally ill-diversified and their incentive contracts

make them risk-averse. Therefore, arbitrageurs are concerned about the idiosyncratic risk of their investments. We show that the returns of arbitrage strategies exhibit a large amount of idiosyncratic risk as the volatility of arbitrage returns is generally almost 50 percent higher than the volatility of the S&P 500. The risks associated with arbitrage strategies form an important obstacle to DLC arbitrage. Our results confirm Shleifer and Vishny's (1997) model of limited arbitrage, in which noise trader risk prevents specialized professional arbitrageurs from exploiting arbitrage opportunities.

The inference that noise trader risk constitutes an important impediment to arbitrage is confirmed in an analysis of the six DLCs that unified their share structure. Noise trader risk is practically absent after the unification announcement. In line with the implications of the reduced impact of noise traders, we show that there is a sharp move toward theoretical price parity at the unification announcements and trading volume increase. Profitable arbitrage opportunities become scarce after unification announcement. This corroborates our results.

Overall, we find there is prolonged mispricing of large, well-traded international equity securities. Arbitrage is not successful in eliminating this mispricing. Our findings are consistent with Shleifer and Vishny's (1997) thesis that noise trading deters arbitrage when arbitrageurs are specialized professional portfolio managers. We present evidence of inefficiencies in international financial markets involving assets that are perfect substitutes. Arbitrage may be even less effective in bringing prices to fundamental values for securities that do entail fundamental risk.

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Table 1
Description of the twins

This table presents an overview of all 13 dual-listed companies (DLCs) in the sample. The first column depicts the name of the DLC as well as the countries in which the parent companies are listed. The time differential between the two countries in hours is provided in parentheses. All twins are defined in such a way that the country of the first part of the twin is in an earlier time zone than the country of the second part of the twin. The second column presents information the structure of the DLC, while column 3 shows the date of the merger. For 6 of the 13 DLCs, column 4 and 5 give the date on which the unification of the share structure was announced and the last trading day before unification.

DLC *Country 1* / *Country 2* (time diff.)	**DLC type**	**Merger Date**	**Unification Announced**	**Unification Date**
Royal Dutch / Shell *Netherlands* / *United Kingdom* (-1)	Combined Entities Structure	02.15.1907	–	–
Unilever *Netherlands* / *United Kingdom* (-1)	Separate Entities Structure	1930	–	–
ABB *Switzerland* / *Sweden* (0)	Combined Entities Structure	01.01.1988	02.04.1999	06.25.1999
Eurotunnel *France* / *United Kingdom* (-1)	Stapled Stock Structure	04.18.1989	–	–
Smithkline Beecham *United Kingdom* / *United States* (-6)	Stapled Stock Structure	07.26.1989	02.20.1996	04.12.1996
Fortis *Netherlands* / *Belgium* (0)	Combined Entities Structure	12.12.1990	08.28.2000	12.14.2001
Elsevier / Reed International *Netherlands* / *United Kingdom* (-1)	Combined Entities Structure	01.01.1993	–	–
Rio Tinto *Australia* / *United Kingdom* (-10)	Separate Entities Structure	12.21.1995	–	–
Dexia *France* / *Belgium* (0)	Combined Entities Structure	11.19.1996	09.19.1999	11.26.1999
Merita / Nordbanken *Finland* / *Sweden* (-1)	Combined Entities Structure	12.15.1997	09.20.1999	03.24.2000
Zürich Allied / Allied Zürich *Switzerland* / *United Kingdom* (-1)	Combined Entities Structure	09.07.1998	04.17.2000	10.13.2000
BHP Billiton *Australia* / *United Kingdom* (-10)	Separate Entities Structure	06.29.2001	–	–
Brambles Industries *Australia* / *United Kingdom* (-10)	Separate Entities Structure	08.07.2001	–	–

Table 2
Summary statistics of the log deviations from parity (in %)

This table shows summary statistics of the log deviations from parity for all 13 DLCs in the sample. The columns present the mean, the mean of the absolute value, the standard deviation, the minimum, and the maximum value of the log deviations from parity (expressed in %) as well as the percentage of days in the sample period on which the log deviation was positive. For the unified DLCs the sample period ends 20 trading days before the unification announcement.

DLC	Mean	Abs	StDv	Min	Max	% pos
Royal Dutch / Shell 01.01.80–10.03.02	0.86	10.04	12.71	-36.22	19.83	68.5
Unilever 01.01.80–10.03.02	1.16	8.99	11.41	-39.07	29.10	62.2
ABB 01.01.88–01.07.99	-4.20	11.94	14.20	-48.77	17.77	45.2
Eurotunnel 04.18.89–10.03.02	-1.65	2.60	2.78	-10.87	17.67	25.7
Smithkline Beecham 07.26.89–01.22.96	7.94	8.10	4.09	-2.22	15.97	92.8
Fortis 12.12.90–07.31.00	-2.64	4.56	4.90	-17.10	13.79	30.5
Elsevier / Reed International 01.01.93–10.03.02	2.15	8.88	9.20	-14.73	17.58	55.6
Rio Tinto 12.21.95–10.03.02	1.90	4.11	4.76	-16.42	11.31	37.5
Dexia 11.19.96–08.20.99	-9.22	9.33	3.67	-17.66	5.15	1.8
Merita / Nordbanken 12.15.97–08.23.99	-7.01	7.07	3.19	-15.11	2.03	3.2
Zürich Allied / Allied Zürich 09.07.98–03.20.00	11.93	11.93	3.47	1.36	21.00	100
BHP Billiton 06.29.01–10.03.02	7.09	7.09	2.26	1.14	18.45	100
Brambles Industries 08.07.01–10.03.02	8.45	11.32	11.32	-18.62	29.15	74.3

Table 3
Log deviations from parity and market movements

This table reports regression estimates of the equation:

$$r_{A,t} - r_{B,t} = \alpha + \beta\left(r_{A,t-1} - r_{B,t-1}\right) + \sum_{i=0}^{1} \gamma_i^1 Index1_{t+i} + \sum_{j=-1}^{0} \gamma_j^2 Index2_{t+j} + \sum_{k=-1}^{1} \delta_k e.r._{t+k} + \varepsilon_t ,$$

where A and B represent the twin pair, $r_{A,t}$ and $r_{B,t}$ are the log returns at time t of the first and the second part of the DLC in their local currencies, respectively (Table 1 "Description of the DLCs" defines what the first and the second part is), *Index1* and *Index2* denote the log returns of the domestic market indices corresponding to the twin A and twin B, and *e.r.* represents the log changes in the exchange rate between the currencies of the first part en the second part of the twin. Columns depict the twin, the sample period, the adjusted R^2, the Durbin-Watson statistic, the degrees of freedom and the cumulative coefficients on all four independent variables in the regression. For the unified DLCs the sample period ends 20 trading days before the unification announcement. Frequency is daily. For the unified DLCs the sample period ends 20 trading days before the unification announcement. [a], [b], [c], indicate significance at the 10%, 5% and 1% level for Wald tests that the sum of all coefficients (lead/lag and current value) equals zero.

DLC	Sample period	R^2	DW	DOF	Lagged dep. var.	Index1	Index2	e.r.
Royal Dutch / Shell	01.01.80–10.03.02	0.242	2.03	5927	-0.231[c]	0.346[c]	-0.501[c]	-0.806[c]
Unilever	01.01.80–10.03.02	0.146	2.06	5927	-0.216[c]	0.170[c]	-0.560[c]	-0.595[c]
ABB	01.01.88–01.07.99	0.127	2.02	2867	-0.059[c]	0.667[c]	-0.484[c]	-0.430[c]
Eurotunnel	04.18.89–10.03.02	0.137	2.15	3501	-0.329[c]	0.285[c]	-0.145[b]	-0.916[c]
Smithkline Beecham	07.26.89–01.22.96	0.132	2.14	1527	-0.299[c]	0.086[a]	-0.248[c]	0.031
Fortis	12.12.90–07.31.00	0.104	1.99	2506	-0.163[c]	0.476[c]	-0.537[c]	-0.580[b]
Elsevier / Reed International	01.01.93–10.03.02	0.197	2.14	2534	-0.319[c]	0.331[c]	-0.417[c]	-0.772[c]
Rio Tinto	12.21.95–10.03.02	0.272	2.15	1760	-0.296[c]	0.431[c]	-0.741[c]	-0.524[c]
Dexia	11.19.96–08.20.99	0.100	2.18	708	-0.216[c]	0.290[c]	-0.324[c]	-0.319
Merita / Nordbanken	12.15.97–08.23.99	0.246	2.09	431	-0.371[c]	0.463[c]	-0.445[c]	-0.139
Zürich Allied / Allied Zürich	09.07.98–03.20.00	0.091	2.03	390	-0.153[c]	0.155	-0.354[b]	-0.928[c]
BHP Billiton	06.29.01–10.03.02	0.397	2.21	319	-0.280[c]	0.459[b]	-0.709[c]	-0.647[b]
Brambles Industries	08.07.01–10.03.02	0.288	2.00	293	-0.005	0.343	-0.866[c]	-0.567

Table 4
Arbitrage strategies with 10% buy threshold and 5% sell threshold

This table reports the returns of self-financing arbitrage strategies in individual twins. We consider arbitrage strategies that involve obtaining a long position in the relatively underpriced part of the twin and shorting an equal dollar amount in the relatively overpriced part of the twin from the viewpoint of an arbitrageur in the U.S. The arbitrageur maintains at most one arbitrage position at each point in time, only assumes a new position when the price discrepancy crosses the buy threshold and terminates the position when the price discrepancy crosses the sell threshold. Positions are also terminated after 1 year (260 trading days), no matter what the price discrepancy is at the time. Open positions at the end of the sample period are not taken into account. For positions that last less than 1 month (22 trading days), the investment proceeds are invested in the 3-month T-bill for the remainder of the month. The first (second) column depicts the number of arbitrage strategies that are long (short) in twin A, the first part of the DLC, and short (long) in twin B, the second part. In addition, the table presents the mean, median, minimum, and maximum number of days invested, the weighted average of the arbitrage returns expressed in % per month (where the weights are determined by the number of days for which each strategy is maintained), the median, minimum, and maximum return expressed in % per month, and the number of strategies interrupted because the maximum horizon is exceeded as well as the number of strategies with negative returns. For the unified DLCs the sample period ends 20 trading days before the unification announcement.

DLC	*# Long A Short B*	*# Short A Long B*	*Mean # Days*	*Median # Days*	*Min / Max # Days*	*Mean Return (w. % p.m.)*	*Median Return (% p.m.)*	*Min Return (% p.m.)*	*Max Return (% p.m.)*	*# Cut-Off*	*# Return < 0*
Royal Dutch / Shell	3	12	126.0	70	22 / 260	0.819	1.969	-0.562	7.181	5	2
Unilever	10	21	88.6	22	22 / 260	1.607	6.145	-1.165	14.777	5	4
ABB	13	6	67.5	22	22 / 260	2.257	5.348	-0.225	12.742	1	1
Eurotunnel	4	1	22.0	22	22 / 22	7.736	6.430	5.485	11.313	0	0
Smithkline Beecham	0	6	167.7	260	22 / 260	0.356	0.958	-0.381	5.753	3	1
Fortis	14	4	32.8	22	22 / 99	4.947	6.430	1.197	11.355	0	0
Elsevier / Reed International	6	7	116.2	80	22 / 260	1.032	1.568	-0.376	11.250	3	1
Rio Tinto	11	2	24.6	22	22 / 40	6.579	6.850	3.655	9.951	0	0
Dexia	4	0	124.5	46	22 / 260	1.245	1.399	-0.129	7.090	1	1
Merita / Nordbanken	4	0	55.3	22	22 / 148	2.823	4.172	0.747	10.324	0	0
Zürich Allied / Allied Zürich	0	3	133.0	123	22 / 254	1.345	1.573	0.846	5.826	0	0
BHP Billiton	0	5	23.0	22	22 / 27	5.880	5.391	4.346	8.387	0	0
Brambles Industries	1	4	30.6	22	22 / 65	4.349	5.552	2.447	7.760	0	0
Total	70	71	76.9	23	22 / 260	1.824	5.485	-1.165	14.777	18	10

Table 5
Arbitrage strategies with 10% buy threshold and 5% sell threshold with transaction costs and margin calls

This table reports the returns of arbitrage strategies in individual twins after taking account of transaction costs and margin requirements. The set-up of the arbitrage positions is described in Table 4. Transaction costs are composed of a commission of 25 basis points per transaction plus half of the bid-ask spread of 40 basis points. The latter estimate is the mean of the median bid-ask spread for all 13 DLCs in the sample. Data on bid-ask spreads are obtained from Datastream, but are generally not available over the full sample period. Returns are calculated assuming Regulation T initial and maintenance margin requirements. When margin calls are received, positions are partially liquidated such that maintenance margin requirements are satisfied. The first (second) column depicts the number of arbitrage strategies that are long (short) in twin A, the first part of the DLC, and short (long) in twin B, the second part. In addition, the table presents the mean, median, minimum, and maximum number of days invested, the weighted average of the arbitrage returns expressed in % per month (where the weights are determined by the number of days for which each strategy is maintained), the median, minimum, and maximum return expressed in % per month, the number of strategies interrupted because the maximum horizon is exceeded, the number of strategies with negative returns, and the number of strategies for which one or more margin calls are received. For the unified DLCs the sample period ends 20 trading days before the unification announcement.

DLC	*# Long A Short B*	*# Short A Long B*	*Mean # Days*	*Median # Days*	*Min/Max # Days*	*Mean Return (w.% p.m.)*	*Median Return (% p.m.)*	*Min Return (% p.m.)*	*Max Return (% p.m.)*	*# Cut-Off*	*# Return < 0*	*# Margin Calls*
Royal Dutch / Shell	3	12	126.0	70	22 / 260	0.492	1.460	-0.728	5.393	5	2	3
Unilever	10	21	88.6	22	22 / 260	1.134	4.346	-1.374	13.044	5	4	6
ABB	13	6	67.5	22	22 / 260	1.620	3.745	-0.393	10.993	1	1	2
Eurotunnel	4	1	22.0	22	22 / 22	6.016	4.690	3.745	9.615	0	0	0
Smithkline Beecham	0	6	167.7	260	22 / 260	0.147	0.680	-0.464	3.976	3	2	2
Fortis	14	4	32.8	22	22 / 99	3.760	4.677	0.805	9.589	0	0	0
Elsevier / Reed International	6	7	116.2	80	22 / 260	0.694	1.095	-0.573	9.552	3	1	1
Rio Tinto	11	2	24.6	22	22 / 40	5.054	5.140	2.539	8.250	0	0	0
Dexia	4	0	124.5	46	22 / 260	0.917	1.179	-0.318	5.385	1	1	1
Merita / Nordbanken	4	0	55.3	22	22 / 148	2.150	2.885	0.513	8.627	0	0	0
Zürich Allied / Allied Zürich	0	3	133.0	123	22 / 254	1.062	1.249	0.712	4.058	0	0	0
BHP Billiton	0	5	23.0	22	22 / 27	4.238	3.703	2.930	6.705	0	0	0
Brambles Industries	1	4	30.6	22	22 / 65	3.106	3.830	0.764	6.056	0	0	0
Total	70	71	76.9	23	22 / 260	1.304	3.830	-1.374	13.044	18	11	15

Table 6
Summary of simulated arbitrage strategies before unification

This table reports the returns of combined arbitrage strategies in all twins after taking account of transaction costs and margin requirements. The set-up of the arbitrage positions is described in Table 4. Transaction costs are composed of a commission of 25 basis points per transaction plus half of the bid-ask spread of 40 basis points. The latter estimate is the mean of the median bid-ask spread for all 13 DLCs in the sample. Returns depicted in this table are calculated assuming Regulation T initial and maintenance margin requirements. When margin calls are received, positions are partially liquidated such that maintenance margin requirements are satisfied. The final two rows assess the impact in a change in the bid-ask spread assumption to, respectively, 30 and 50 basis points for one of the trading rules. The first (second) column depicts the number of arbitrage strategies that are long (short) in twin A, the first part of the DLC, and short (long) in twin B, the second part. In addition, the table presents the mean, median, minimum, and maximum number of days invested, the weighted average of the arbitrage returns expressed in % per month (where the weights are determined by the number of days for which each strategy is maintained), the median, minimum, and maximum return expressed in % per month, the number of strategies interrupted because the maximum horizon is exceeded, the number of strategies with negative returns, and the number of strategies for which one or more margin calls are received. For the unified DLCs the sample period ends 20 trading days before the unification announcement.

Buy Threshold / Sell Threshold / Horizon	*# Long A Short B*	*# Short A Long B*	*Mean # Days*	*Median # Days*	*Min/Max # Days*	*Mean Return (w.% p.m.)*	*Median Return (% p.m.)*	*Min Return (% p.m.)*	*Max Return (% p.m.)*	*# Cut-Off*	*# Return < 0*	*# Margin Calls*
5% / 1% / 1 month	193	189	22.0	22	22 / 22	0.601	0.584	-15.154	13.472	245	183	6
5% / 1% / 3 months	135	127	41.5	32	22 / 65	0.942	2.396	-6.726	13.472	96	82	16
5% / 1% / 12 months	111	98	70.1	22	22 / 260	1.191	3.082	-0.992	13.472	21	17	21
5% / 1% / ∞	106	85	100.8	22	22 / 2321	1.008	3.211	-0.124	13.472	0	1	22
10% / 5% / 1 month	121	183	22.0	22	22 / 22	0.582	0.108	-23.523	13.044	219	144	3
10% / 5% / 3 months	88	111	44.5	50	22 / 65	1.197	2.311	-7.650	13.044	89	58	10
10% / 5% / 12 months	70	71	76.9	23	22 / 260	1.304	3.830	-1.374	13.044	18	11	15
10% / 5% / ∞	65	61	92.3	22	22 / 1322	1.352	4.149	0.098	13.044	0	0	11
Bid-ask spread level												
10% / 5% / 12 months / 30 bp	70	71	76.9	23	22 / 260	1.360	4.022	-1.354	13.237	18	11	15
10% / 5% / 12 months / 50 bp	70	71	76.9	23	22 / 260	1.247	3.637	-1.393	12.850	18	11	15

Table 7
Portfolio regression results for the simulated arbitrage strategies before unification

This table reports regression estimates of the equation:

$$rp_t - rf_t = a + b(rm_t - rf_t) + sSMB_t + hHML_t + e_t,$$

where rp_t represents the daily returns (expressed in % per month) on a portfolio consisting of all the individual positions in the twins for the arbitrage strategies presented in Table 6, rf_t is the 3-month Treasury Bill yield, rm_t is the return on the S&P 500 index, and SMB_t and HML_t are the daily returns on the Fama-French mimicking portfolios for the size and book-to-market effects, respectively. Portfolio returns are calculated after transaction costs and Regulation T initial and maintenance margin requirements are imposed. Columns present the arbitrage strategy analyzed, the number of individual investment positions generated by this strategy, the estimates of regression coefficients *a*, *b*, *s*, and *h* (*t*-statistics that are robust to serial correlation and heteroskedasticity in parentheses), the adjusted R^2 (number of observations in parentheses), the annualized abnormal return of the portfolio (based on the estimate of *a*), the standard deviation of portfolio returns, and for comparison purposes, the standard deviation of S&P 500 returns over the same period. [a], [b], [c], indicate significance at the 10%, 5%, and 1% level.

Buy Threshold / Sell Threshold / Horizon	*# Investments*	*a*	*b*	*s*	*h*	*Adj. R^2 (n)*	*Annualized Abnormal Return*	*Standard Deviation*	*Standard Deviation S&P 500*
5% / 1% / 1 month	382	0.203 (0.811)	0.093 (1.774)	0.087 (1.001)	-0.017 (-0.313)	0.004 (8404)	2.4%	33.9%	23.1%
5% / 1% / 3 months	262	0.544[c] (2.593)	0.093[b] (2.057)	0.092 (1.256)	-0.021 (-0.400)	0.004 (10873)	6.5%	34.0%	23.3%
5% / 1% / 12 months	209	0.770[c] (4.343)	0.091[b] (2.287)	0.093 (1.466)	0.013 (0.297)	0.003 (14647)	9.2%	33.2%	22.5%
5% / 1% / ∞	191	0.555[c] (3.980)	0.083[b] (2.487)	0.048 (0.944)	0.000 (0.001)	0.003 (19260)	6.7%	31.5%	22.0%
10% / 5% / 1 month	304	0.159 (0.579)	0.071[b] (2.037)	-0.031 (-0.684)	0.011 (0.216)	0.003 (6691)	1.9%	31.4%	24.0%
10% / 5% / 3 months	199	0.748[c] (3.192)	0.072[b] (2.385)	-0.006 (-0.138)	0.019 (0.450)	0.003 (8859)	9.0%	31.1%	23.2%
10% / 5% / 12 months	141	0.846[c] (4.049)	0.062[b] (2.308)	-0.018 (-0.489)	0.022 (0.587)	0.002 (10847)	10.1%	31.1%	22.9%
10% / 5% / ∞	126	0.862[c] (4.257)	0.066[b] (2.327)	-0.013 (-0.349)	0.002 (0.045)	0.002 (11635)	10.3%	31.2%	22.3%

Table 8
Summary of simulated arbitrage strategies after unification

This table reports the returns of combined arbitrage strategies in all unified twins after taking account of transaction costs and margin requirements. The set-up of the arbitrage positions is described in Table 4. The sample period starts 5 trading days after the unification announcement and ends at the unification date. Transaction costs, which are composed of a commission of 25 basis points per transaction plus half of the bid-ask spread of 40 basis points. The latter estimate is the mean of the median bid-ask spread for all 13 DLCs in the sample. Returns depicted in this table are calculated assuming Regulation T initial and maintenance margin requirements. When margin calls are received, positions are partially liquidated such that maintenance margin requirements are satisfied. The first (second) column depicts the number of arbitrage strategies that are long (short) in twin A, the first part of the DLC, and short (long) in twin B, the second part. In addition, the table presents the mean, median, minimum, and maximum number of days invested, the weighted average of the arbitrage returns expressed in % per month (where the weights are determined by the number of days for which each strategy is maintained), the median, minimum, and maximum return expressed in % per month, the number of strategies interrupted because the maximum horizon is exceeded, the number of strategies with negative returns, and the number of strategies for which one or more margin calls are received.

Buy Threshold / Sell Threshold / Horizon	*# Long A Short B*	*# Short A Long B*	*Mean # Days*	*Median # Days*	*Min/Max # Days*	*Mean Return (w.% p.m.)*	*Median Return (% p.m.)*	*Min Return (% p.m.)*	*Max Return (% p.m.)*	*# Cut-Off*	*# Return < 0*	*# Margin Calls*
5% / 1% / 1 month	2	2	22.0	22	22 / 22	3.945	0.776	0.411	9.490	2	0	0
5% / 1% / 3 months	2	1	33.7	22	22 / 57	4.034	5.101	1.516	9.490	0	0	0
5% / 1% / 12 months	2	1	33.7	22	22 / 57	4.034	5.101	1.516	9.490	0	0	0
5% / 1% / ∞	2	1	33.7	22	22 / 57	4.034	5.101	1.516	9.490	0	0	0
10% / 5% / 1 month	0	1	22.0	22	22 / 22	5.958	5.958	5.958	5.958	0	0	0
10% / 5% / 3 months	0	1	22.0	22	22 / 22	5.958	5.958	5.958	5.958	0	0	0
10% / 5% / 12 months	0	1	22.0	22	22 / 22	5.958	5.958	5.958	5.958	0	0	0
10% / 5% / ∞	0	1	22.0	22	22 / 22	5.958	5.958	5.958	5.958	0	0	0

Figure 1
Log deviations from parity

This figure shows on a percentage basis the log deviations from theoretical parity for all 13 dual-listed companies (DLCs) in the sample. For the unified DLCs the sample period ends 20 trading days before the unification announcement.

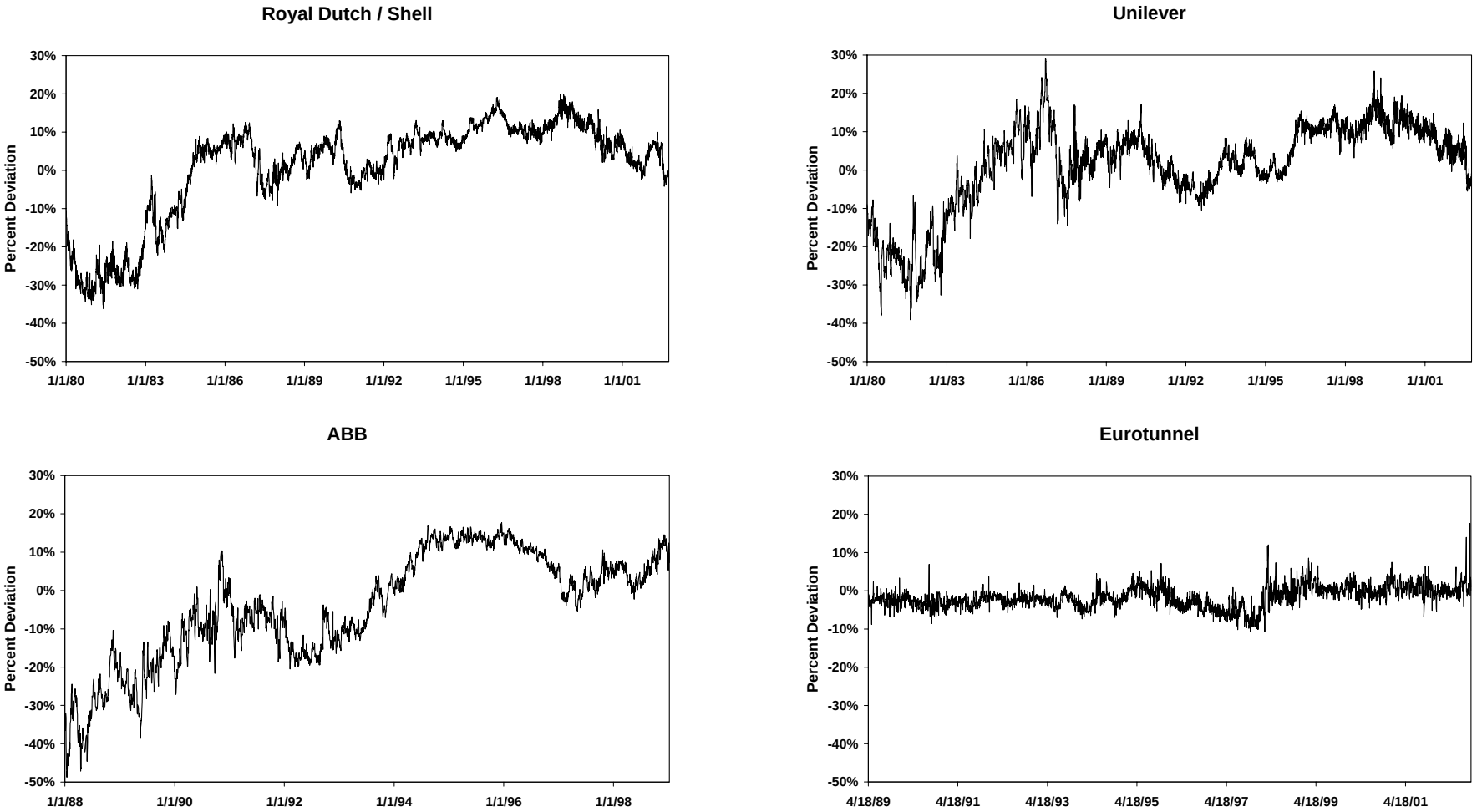
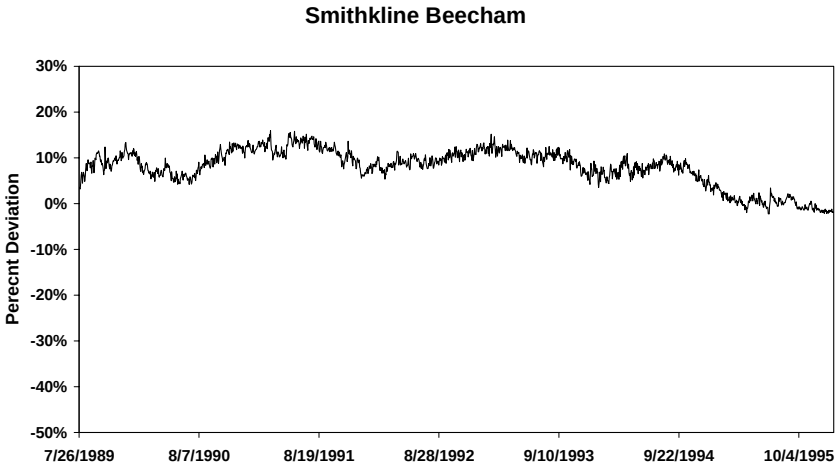
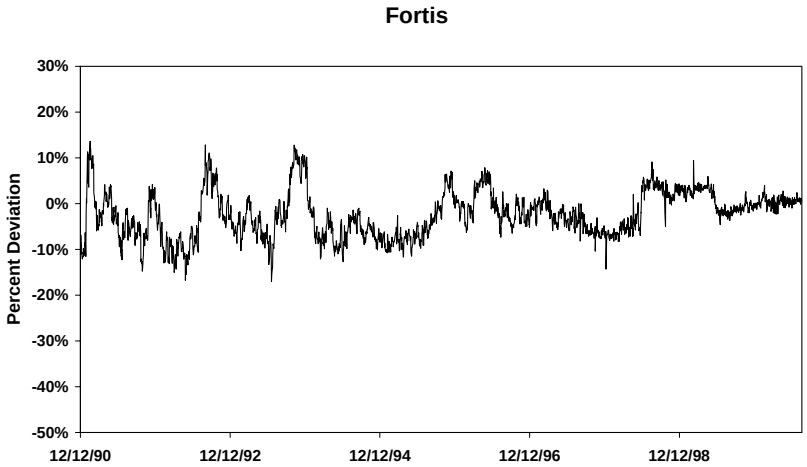
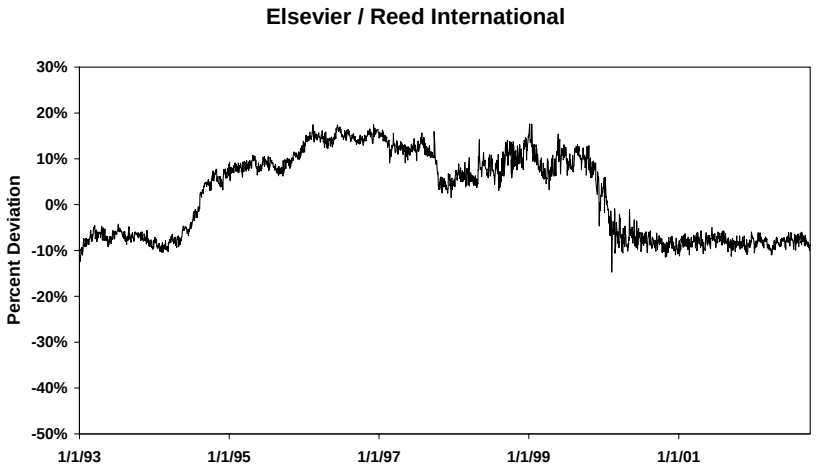


Figure 1 – *continued*
Log deviations from parity

This figure shows on a percentage basis the log deviations from theoretical parity for all 13 dual-listed companies (DLCs) in the sample. For the unified DLCs the sample period ends 20 trading days before the unification announcement.







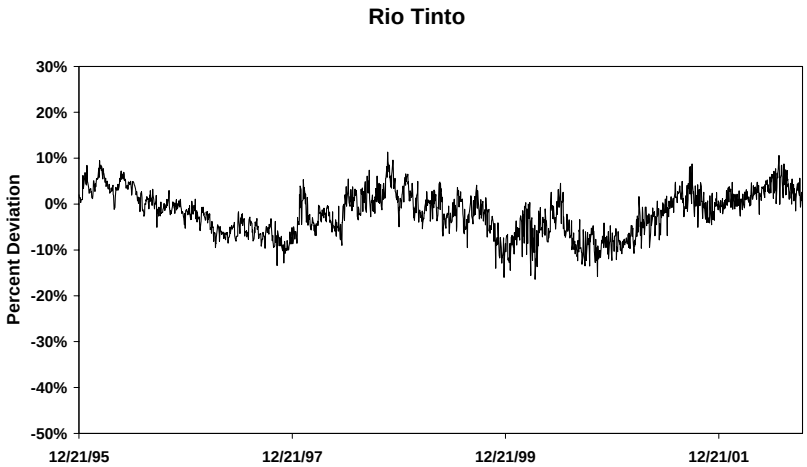
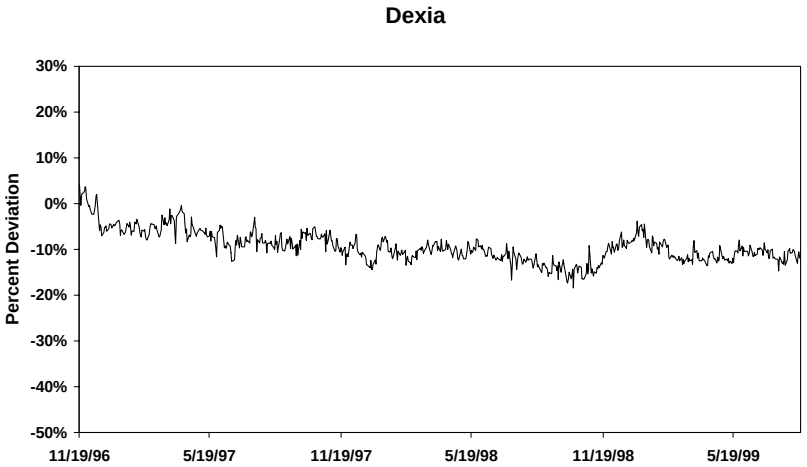
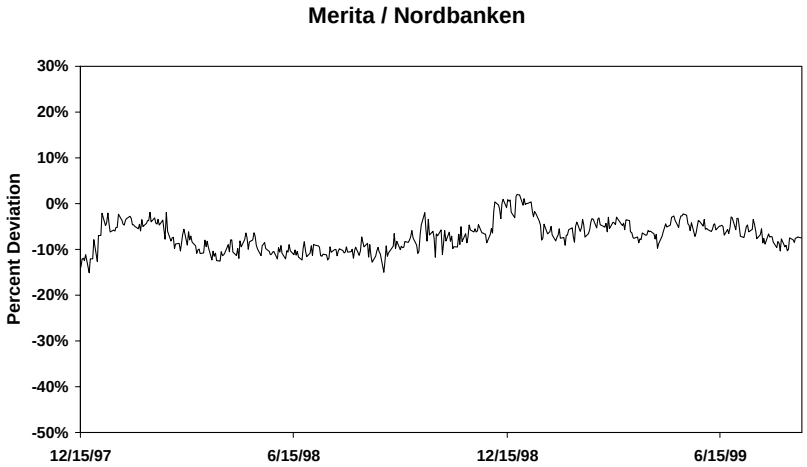
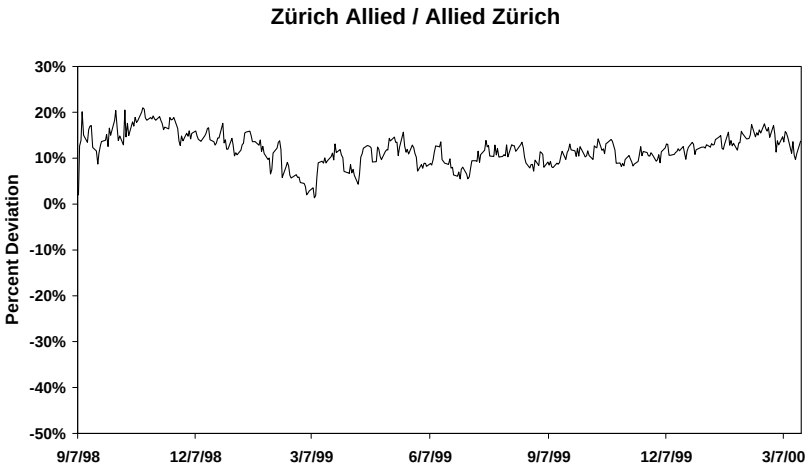


Figure 1 – *continued*
Log deviations from parity

This figure shows on a percentage basis the log deviations from theoretical parity for all 13 dual-listed companies (DLCs) in the sample. For the unified DLCs the sample period ends 20 trading days before the unification announcement.







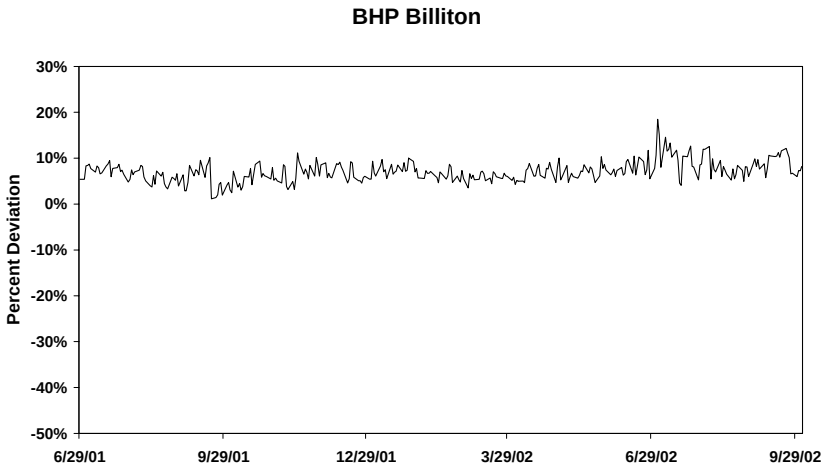


Figure 1 – *continued*
Log deviations from parity

This figure shows on a percentage basis the log deviations from theoretical parity for all 13 dual-listed companies (DLCs) in the sample. For the unified DLCs the sample period ends 20 trading days before the unification announcement.

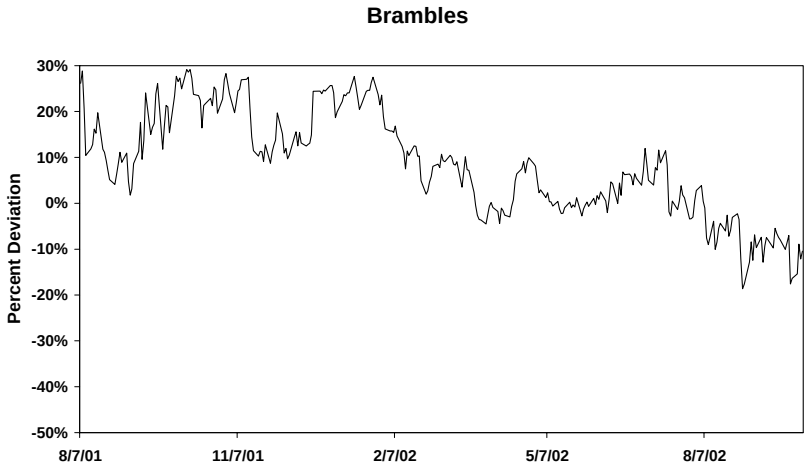


Figure 2
Log deviations from parity and trading volumes around the unification announcement

This figure shows a percentage basis the log deviations from theoretical parity as well as the relative trading volumes for all 6 unified DLCs over the period starting 120 days before the unification announcement (day 0) till the last trading day before unification. Trading volumes are measured relative to the average volume over the period from 120 to 21 days before the announcement. The dotted (solid) line reflects relative trading volume in the first (second) part of the twin (left scale) and the thick solid line presents deviations from parity (right scale).

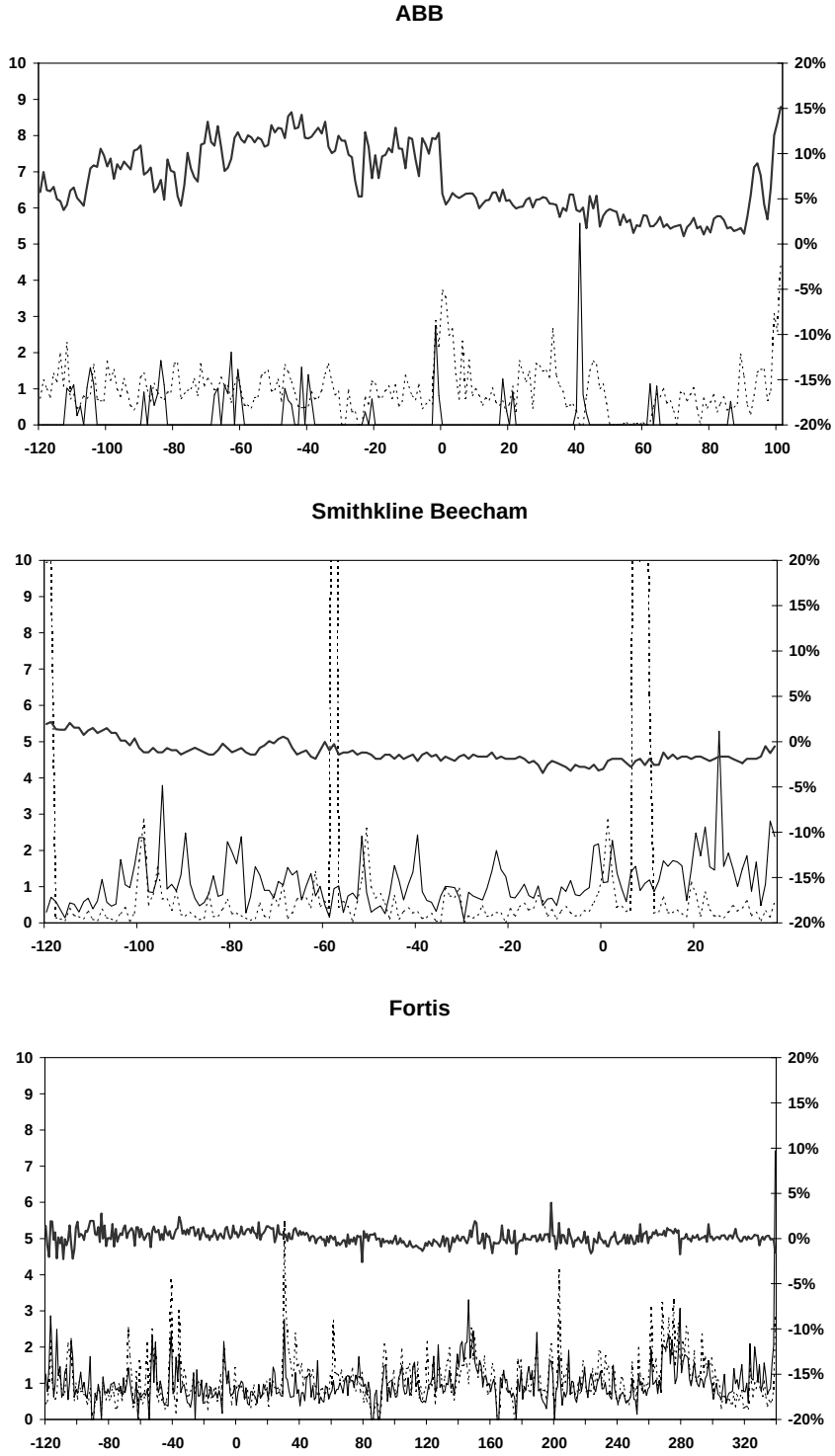


Figure 2 – *continued*
Log deviations from parity and trading volumes around the unification announcement

This figure shows a percentage basis the log deviations from theoretical parity as well as the relative trading volumes for all 6 unified DLCs over the period starting 120 days before the unification announcement (day 0) till the last trading day before unification. Trading volumes are measured relative to the average volume over the period from 120 to 21 days before the announcement. The dotted (solid) line reflects relative trading volume in the first (second) part of the twin (left scale) and the thick solid line presents deviations from parity (right scale).