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The Risk and Return of Arbitrage in Dual-Listed Companies*

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Abstract. This paper evaluates investment strategies that exploit the deviations from theoretical price parity in a sample of 12 dual-listed companies (DLCs) in the period 1980–2002. We show that simple trading rules produce abnormal returns of up to almost 10% per annum adjusted for systematic risk, transaction costs, and margin requirements. However, arbitrageurs face uncertainty about the horizon at which prices will converge and deviations from parity are very volatile. As a result, DLC arbitrage is characterized by substantial idiosyncratic return volatility and a high incidence of large negative returns, which are likely to impede arbitrage.

JEL Classification: F30, G14, G15

1. Introduction

Arbitrage plays an important role in financial markets – it brings prices to fundamental value. However, there is a growing body of research that indicates that there are important impediments to arbitrage in financial markets. Empirical research has

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identified fundamental risk, transaction and holding costs, short-sale constraints, and idiosyncratic risk as potentially important barriers to arbitrage.[1]

We assess the performance of arbitrage strategies in dual-listed companies. A dual-listed company (DLC) structure (also referred to as a "Siamese twin") involves two companies incorporated in different countries contractually agreeing to operate their businesses as if they were a single enterprise, while retaining their separate legal identity and existing stock exchange listings. A well-known example is Royal Dutch/Shell. The shares of the DLC parents represent claims on exactly the same underlying cash flows. In integrated and efficient financial markets, stock prices of the twin pair should move in lockstep.[2]

Rosenthal and Young (1990) and Froot and Dabora (1999) show that significant mispricing in three DLCs has existed over a long period of time. Both studies conclude that fundamental factors (such as currency risk, governance structures, legal contracts, liquidity, and taxation) are not sufficient to explain the magnitude of the price deviations. Rosenthal and Young (1990) and Froot and Dabora (1999) do not investigate why arbitrage is not effective in bringing prices back to theoretical parity even though DLC shares are near-perfect substitutes and despite the fact that these are very large and liquid securities that can generally be arbitraged easily. We evaluate the risk and return of arbitrage strategies using a comprehensive sample of 12 DLCs during the period 1980–2002. Our analysis of investment strategies in DLCs is an important contribution to previous studies, because it allows us to uncover which impediments prevent arbitrage from eliminating the mispricing. In particular, our results indicate that there are limits to arbitrage due to idiosyncratic risk that inhibit arbitrageurs with capital and horizon constraints from closing the price gaps in DLCs.

For each DLC, we find large deviations from theoretical price parity. Mean absolute price discrepancies for individual twins range from roughly 4% to almost 12%. Deviations from parity reach values of over 15% for every single DLC in the sample and occasionally attain levels of up to 40%. Mispricing shows substantial variation over time for all DLCs.

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[1] Empirical studies include Pontiff (1996) and Gemmill and Thomas (2002) on closed-end funds; Mitchell, Pulvino, and Stafford (2002) on "negative stub value" situations; Lamont and Thaler (2003) on technology stock carve-outs; Mitchell and Pulvino (2001) and Baker and Savaşoglu (2002) on mergers and acquisitions.

[2] Many studies refer to DLCs as a textbook example of arbitrage opportunities. Recent references include Baker et al. (2008), Barberis and Thaler (2003), Brealey et al. (2006, chapter 13), Daniel et al. (2002), Ritter (2003), Shleifer (2000, chapter 2), and Thaler (1999).

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We design arbitrage strategies in DLCs based on the premise that convergence to theoretical parity occurs after large price discrepancies. We control for market frictions by taking into account realistic estimates of brokerage commissions, bid-ask spreads, short rebates, and capital requirements. Incorporating transaction costs and margin requirements, arbitrage in all DLCs combined generates abnormal returns of up to almost 10% per annum.

An important characteristic of DLC arbitrage is that the underlying shares are not convertible into each other. Hence, risky arbitrage positions must be kept open until prices converge. In contrast, arbitrage in cross-listed stocks involves the same underlying share, which allows for (almost) instantaneous arbitrage. Gagnon and Karolyi (2004) document the mechanics of arbitrage in cross-listed stocks and show that deviations between the prices of cross-listed stocks and stock prices in the home market are typically below 1%, which suggests that arbitrage succeeds in keeping the prices of cross-listed stocks at parity.

Since there is no identifiable date at which DLC prices will converge, arbitrageurs with limited horizons who are unable to close the price gap on their own face considerable uncertainty. In some cases, arbitrageurs would have to wait for almost nine years before prices have converged and the position is closed. In the short run, the mispricing might deepen. In these situations, arbitrageurs receive margin calls, after which they would most likely be forced to liquidate part of the position at a highly unfavorable moment and suffer a loss.

The substantial time-series variability of the deviations from parity results in a high volatility of arbitrage returns – almost all of which is idiosyncratic relative to well-known asset pricing models. The annualized idiosyncratic volatility is greater than 30% for all strategies and the daily 1% Value-at-Risk is around −4.0%. These findings suggest that idiosyncratic risk (and in particular the fat left tail of the return distribution) deters arbitrage in DLCs, consistent with the arguments of Shleifer and Vishny (1997) and Pontiff (2006).

Our results are robust to variations in the parameters of the arbitrage strategies and our transaction costs assumptions. We show that trading in different time zones and currencies cannot explain our results by running the same tests for several DLCs whose shares trade in the U.S. The unification of six of the DLCs to a single structure provides further evidence on the persistence of the mispricing. Since prices are almost certain to converge within a limited time period after the unification announcement, arbitrageurs no longer face horizon risk, which suggests that the mispricing should be eliminated immediately. Consistent with this conjecture, we observe a sharp movement toward parity around the announcement date for all six twins. Profitable arbitrage opportunities become scarce after unification announcement.

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2. Sample Description

2.1 THE STRUCTURE OF DUAL-LISTED COMPANIES

We investigate the limits of arbitrage in a sample of all 12 dual-listed companies that have existed for at least 12 months during the period 1980–2002.[3] DLCs are the result of a merger between two firms incorporated in different countries in which the firms agree to combine their activities and cash flows. At the same time, the corporations keep separate shareholder registries and identities and distribute the cash flows to their shareholders using a ratio laid out in the "equalization agreement." The equalization agreements are set up in such a way that equal treatment of both companies' shareholders in voting and cash flow rights is ensured under all circumstances. The contracts cover issues that determine the distribution of these legal and economic rights between the twin parents, including issues related to dividends, liquidation, and corporate governance. Baker & McKenzie (2001) and the Reserve Bank of Australia (2002) discuss the motivations to adopt a DLC structure instead of a regular merger.

DLCs can be structured in three ways (U.K. Panel on Takeovers and Mergers, 2002). The most common 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 the 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. There is a contractual agreement 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. Smithkline Beecham 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 I lists the structure used by each of the 12 DLCs in our sample as well as their date of merger. The two eldest twins are the Anglo-Dutch combinations Royal 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 1991, more

[3] Bedi et al. (2003) also describe a sample of DLCs, but they focus on the transition from a DLC to a unified structure. Scruggs (2007) uses data on two DLCs to construct a measure of noise trader risk.

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Table I. Description of the DLCs

This table presents an overview of all 12 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 on the structure of the DLC, while column 3 shows the date of the DLC creation. For 6 of the 12 DLCs, columns 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	Combined Entities			
Netherlands/*United Kingdom* (–1)	Structure	02.15.1907	10.28.2004	7.20.2005
Unilever	Separate Entities			
Netherlands/*United Kingdom* (–1)	Structure	1930	–	–
ABB	Combined Entities			
Switzerland/*Sweden* (0)	Structure	07.08.1991	02.04.1999	06.25.1999
Smithkline Beecham	Stapled Stock			
United Kingdom/*United States* (–5)	Structure	07.26.1989	02.20.1996	04.12.1996
Fortis	Combined Entities			
Netherlands/*Belgium* (0)	Structure	12.12.1990	08.28.2000	12.14.2001
Elsevier/Reed International	Combined Entities			
Netherlands/*United Kingdom* (–1)	Structure	01.01.1993	–	–
Rio Tinto	Separate Entities			
Australia/*United Kingdom* (–10)	Structure	12.21.1995	–	–
Dexia	Combined Entities			
France/*Belgium* (0)	Structure	11.19.1996	09.19.1999	11.26.1999
Merita/Nordbanken	Combined Entities			
Finland/*Sweden* (–1)	Structure	12.15.1997	09.20.1999	03.24.2000
Zürich Allied/Allied Zürich	Combined Entities			
Switzerland/*United Kingdom* (–1)	Structure	09.07.1998	04.17.2000	10.13.2000
BHP Billiton	Separate Entities			
Australia/*United Kingdom* (–10)	Structure	06.29.2001	–	–
Brambles Industries	Separate Entities			
Australia/*United Kingdom* (–10)	Structure	08.07.2001	–	–

than fifty years after the formation of the previous DLC, ABB, a Swiss-Swedish engineering group was created. This DLC set the stage for subsequent DLCs. Seven of the 12 pairs have a combined entities structure, four have a separate entities structure, and one has a stapled 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

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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 6 out of 12 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 used for the Smithkline Beecham twin, which are taken from Bloomberg. The Datastream World Market Index is used as the global market portfolio. Data on the 3-month Treasury Bill rate are from the website of the Federal Reserve Bank of St. Louis. We obtain daily returns on the Fama-French SMB and HML factors from Kenneth French's website.

3. Results

3.1 DEVIATIONS FROM THEORETICAL PARITY

Figure 1 depicts graphs of the log deviations of the relative price from theoretical parity for the eldest DLC (Royal Dutch/Shell) and the youngest DLC (Brambles) in our sample. Table II presents summary statistics of the price differentials for each twin. Log deviations from parity are often very large and they fluctuate considerably over time. The mean absolute price differential ranges from 4.11% (Rio Tinto) to 11.93% (Zürich Allied/Allied Zürich). For all of the twins, the deviation from theoretical parity exceeds 15% in absolute value at some point in time. For 5 (2) out of 12 twins, absolute price gaps amounting to 20% (35%) or more occur.

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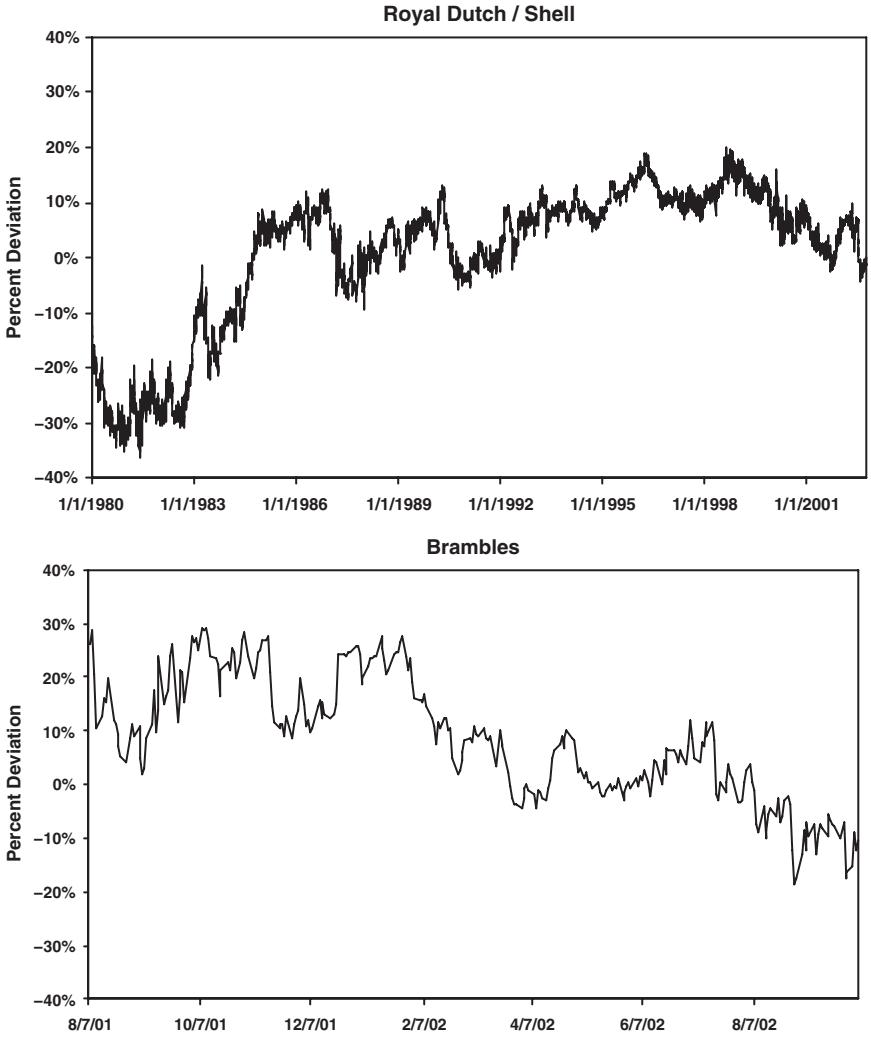

Figure 1. Log deviations from parity.
This figure shows the log deviations from theoretical parity (on a percentage basis) for 2 of the 12 dual-listed companies (DLCs) in the sample. The graphs of the log deviations for the other DLCs are available from the authors.

The substantial time-series standard deviations depicted in the third column of Table II indicate that deviations from parity exhibit great variation over time for most twins. For all but two twins, the deviation from theoretical parity assumes both positive and negative values over the sample period. The price discrepancy changes from negative to positive (or vice versa) frequently for many twins. There is little indication that the price gap is smaller (or larger) for twins that were established

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

This table shows summary statistics of the log deviations from theoretical parity for all 12 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 *Sample period*	Mean	Abs	StDev	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						
07.08.1991–01.07.99	2.26	8.91	10.17	–20.47	17.77	64.4
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

later in the sample period. Price differentials are highly correlated for several twins. The correlation between the 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 deviations is 0.71. Price deviations of the Anglo-Australian twins Rio Tinto and BHP Billiton have a correlation of 0.57, but neither moves together with the deviations of Brambles Industries. The substantial correlations suggest that common factors may drive the price deviations of DLCs from specific countries.

3.2 COMOVEMENT WITH LOCAL MARKET INDICES

Following Froot and Dabora (1999), we run regressions of the relative returns on the stocks of the twin parents on the changes in the local market indices and the

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relevant currency changes. Estimation results, presented in Table III, show that the relative return differentials of all 12 twins exhibit strong comovement with local market indices. The signs of all coefficients on the domestic market returns are as predicted by the comovement effect and 22 out of 24 coefficients are statistically significant. The economic importance of the comovement effect is substantial and the R^2 of the regressions ranges from 10% to 40%. Other empirical studies also find evidence of comovement effects, see, e.g., Bodurtha et al. (1995), Chan et al. (2003), and Gagnon and Karolyi (2004).

3.3 ARBITRAGE STRATEGIES

Our main analysis concerns the performance of arbitrage strategies in the 12 DLCs in our sample. 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 this strategy is a zero-cost investment. However, in practice arbitrageurs must post collateral for this trade. We investigate the investment strategy from the perspective of U.S. arbitrageurs. We impose Regulation T initial margin requirements equal to 50% of the long market value and 50% of the short market value. Since some of the DLCs have never traded in the U.S., we bias our results against finding significant trading profits by having the arbitrageurs subject to the stricter U.S. shorting and margin rules. We assume that cash balances receive 5% per year and margin loans pay 5.5% annually. Daily returns are calculated on the basis of daily equity values. Following Mitchell et al. (2002), we assume that the short rebate is equal to 3% per year.[4]

We initially disregard currency risk in our analysis of DLC arbitrage, since we expect the impact of currency risk hedging on the arbitrage strategies to be negligible. Froot and Dabora (1999, p. 211) show that under reasonable assumptions about dividend payments and exchange rate volatility the impact of currency risk is very small. Additionally, implementing a currency hedging strategy is inexpensive, so currency risk is unlikely to materially affect our findings. We provide an investigation of the importance of risk due to currency differences in DLCs in section 5.1 below.

Our trading strategy requires the investors to specify three different parameters. First, we assume that investors set up an arbitrage position when the price

[4] These assumptions imply a borrowing fee of 200 basis points, which is considerably larger than the average lending fee estimates provided by Saffi and Sigurdsson (2007) for the countries in our sample. While these estimates are limited to the period 2004–2006, borrowing fees for the large and heavily traded stocks in our sample are likely to be significantly lower than the average over a large number of stocks in each country. Moreover, conversations with industry practitioners indicated that equity lending in the U.S. is available for many of the twin stocks. Section 5.3 reports that our results are insensitive to changes in the borrowing fee.

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Table III. Log deviations from parity and comovement
This table reports regression estimates of the equation:

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

where A and B represent the twin pair, $r_{A,t}$ and $r_{B,t}$ are the log returns on day t of the first and the second part of the DLC in their local currencies, respectively (Table I defines what the first and the second part is), *Index1* and *Index2* denote the log returns of the domestic market indices corresponding to twin A (country 1) and twin B (country 2), and *e.r.* represents the log changes in the exchange rate between the currencies of the first and the second part of the twin. In regressions of the return difference of twins for which there is no time difference only contemporaneous returns of the domestic market indices are incorporated. 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. [a], [b], and [c], indicate significance at the 1%, 5%, and 10% level for Wald tests that the sum of all coefficients (lead/lag and current value) is equal to zero. Newey-West standard errors are employed in order to correct for heteroskedasticity and autocorrelation.

DLC	Sample period	R^2	Durbin-Watson	Degrees of freedom	Lagged dep. variable	Market index country 1	Market index country 2	Exchange rate
Royal Dutch/Shell	01.01.80−10.03.02	0.242	2.03	5927	–0.231[a]	0.346[a]	–0.501[a]	–0.806[a]
Unilever	01.01.80−10.03.02	0.146	2.06	5927	–0.216[a]	0.170[a]	–0.560[a]	–0.595[a]
ABB	07.08.91−01.07.99	0.155	2.03	1952	–0.119[a]	0.433[a]	–0.399[a]	–0.509[a]
Smithkline Beecham	07.26.89−01.22.96	0.132	2.14	1527	–0.299[a]	0.086[c]	–0.248[a]	0.031
Fortis	12.12.90−07.31.00	0.104	1.99	2506	–0.163[a]	0.476[a]	–0.537[a]	–0.580[b]
Elsevier/Reed International	01.01.93−10.03.02	0.197	2.14	2534	–0.319[a]	0.331[a]	–0.417[a]	–0.772[a]
Rio Tinto	12.21.95−10.03.02	0.272	2.15	1760	–0.296[a]	0.431[a]	–0.741[a]	–0.524[a]
Dexia	11.19.96−08.20.99	0.100	2.18	708	–0.216[a]	0.290[a]	–0.324[a]	–0.319
Merita/Nordbanken	12.15.97−08.23.99	0.246	2.09	431	–0.371[a]	0.463[a]	–0.445[a]	–0.139
Zürich Allied/Allied Zürich	09.07.98−03.20.00	0.091	2.03	390	–0.153[a]	0.155	–0.354[b]	–0.928[a]
BHP Billiton	06.29.01−10.03.02	0.397	2.21	319	–0.280[a]	0.459[b]	–0.709[a]	–0.647[b]
Brambles Industries	08.07.01−10.03.02	0.288	2.00	293	–0.005	0.343	–0.866[a]	–0.567

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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 can 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 (in order to arrive at a conservative estimate of arbitrage profits) and we discard any open positions at the end of the sample period. We also 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. This assumption prevents investment strategies with modest daily returns, but very short durations from having a large influence on the results. We use daily closing prices to assess the profitability of the strategy. 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. The establishment of a new arbitrage position is conditional on the prices observed on the previous day, which makes our trading rules feasible in practice.

Our analysis incorporates transaction costs and maintenance margin requirements. Based on conversations with a number of large investment firms, we use the (conservative) assumption that arbitrageurs pay a commission of 25 basis points per transaction. In addition, setting up an arbitrage position involves a cost 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 24 twin stocks in the sample. The main reason for using the median bid-ask spread is that the bid-ask spread data from Datastream are not sufficiently reliable. Data on spreads are only available for a small part of the sample period (for most stocks data are not available before the late 1990s) and exhibit frequent missing values and outliers. A bid-ask spread of 40 basis points is realistic in comparison with trading cost estimates provided by Chiyachantana et al. (2004), Froot and Perold (1997), Hupperets and Menkveld (2002), and the annual Elkins/McSherry trading costs survey. (Unreported results show that using the average bid-ask spread for each individual DLC as an estimate for the variable transaction costs yields similar findings.) Our analysis abstracts from the costs of doing the currency translation. These transactions costs are generally only a few basis points and are unlikely to have a significant impact on our results.

The arbitrageur receives a margin call if twin prices move such that the position reaches the minimum required maintenance margin of 25% for long positions and 30% for short positions (following NYSE and Nasdaq regulations). After a margin call, the arbitrageur responds by partially liquidating the position. That is, the arbitrageur unwinds the smallest possible fraction of the long and the short position that generates enough additional equity in the account to satisfy the margin

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requirements. The partial liquidation leads to a negative return on that day, as the mispricing has deepened. The account is marked to market each day.

Table IV reports the results of an investment strategy with a buy threshold of 10%, a sell threshold of 5%, and a maximum horizon of one year (260 trading days). Over the sample period 1980–2002, a U.S. arbitrageur would have set up 136 positions in the DLCs in the sample, indicating notable arbitrage activity. For example, the strategy would have generated positions in Royal Dutch/Shell lasting roughly seven and a half years in total, or one third of the sample period. There is a significant amount of variation in the investment horizon across the arbitrage positions. All 12 twins generate at least one arbitrage strategy that lasts shorter than one month (22 trading days), while in total 18 arbitrage positions (distributed over six twins) are interrupted after one year.

Following the arbitrage strategy for all twins in the sample would have yielded an average return of 1.18% per month (14.2% per annum). Returns exhibit considerable dispersion, both across twins and for each individual DLC. Median returns for individual twins vary between 0.14% to over 5% per month. Roughly 9% of the positions (11 out of 127) produce negative investment returns. Negative returns 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 16.5% (i.e., 12 times the reported return of −1.374% on a monthly basis) of the arbitrageur's total invested capital. More than 10% of the 127 investment strategies result in one or more margin calls. Most of these investments receive a number of subsequent margin calls forcing the arbitrageur to partially liquidate the position, as the mispricing deepens for several days in a row.

In order to determine the sensitivity of our return calculations to the thresholds and the horizon, we present returns for buy/sell thresholds of 10%/5% and 5%/1% and horizons of one month, three months, and one year, as well as unlimited horizon results in Table V. The table presents the results of eight different trading rules aggregated over all twins. All strategies produce a considerable number of arbitrage positions (ranging from 112 to 309 positions) and weighted-average monthly returns of up to 1.238% per month. The number of strategies decreases with the investment horizon, as long horizons prevent other positions from being set up in the same period. For the unlimited horizon strategies in particular, investment horizons of individual arbitrage positions exhibit substantial variation. Although the majority of investments last only one month, the average horizon is about 4.5 (6) months for the 10%/5% (5%/1%) case 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 occurs leads to negative returns. For instance, for the strategies with a maximum horizon of one month, more than half of the arbitrage positions result in a negative return. The losses may be very large for individual arbitrage positions (up to 23% of

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

This table reports the returns of arbitrage strategies that involve obtaining a long position in the relatively underpriced part of the twin and shorting an equal dollar amount in the other part of the twin. At most one arbitrage position is maintained at each point in time. Positions are initiated (terminated) when the absolute price deviation crosses the buy (sell) threshold. Positions are also terminated after 1 year (260 trading days), no matter what the price deviation 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. Transaction costs are composed of a commission of 25 basis points per transaction plus half of the bid-ask spread of 40 basis points. 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 positions 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 position 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	5	5	96.7	77	22/260	0.920	3.607	–0.393	6.960	1	1	1
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	58	69	82.0	25	22/260	1.180	3.703	–1.374	13.044	18	11	14

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Table V. Summary of arbitrage strategies

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 IV. The first (second) column depicts the number of arbitrage positions 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 position 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	135	174	22.0	22	22/22	–0.009	–0.560	–15.154	11.704	218	170	4
5%/1%/3 months	93	112	44.6	50	22/65	0.558	1.653	–6.726	11.704	89	77	13
5%/1%/12 months	73	83	83.4	32	22/260	0.892	2.487	–0.992	11.704	21	17	19
5%/1%/∞	68	70	126.8	23	22/2321	0.780	2.878	–0.124	11.704	0	1	20
10%/5%/1 month	107	181	22.0	22	22/22	0.432	0.074	–23.523	13.044	215	140	3
10%/5%/3 months	75	109	46.0	62	22/65	1.064	1.815	–7.650	13.044	88	57	9
10%/5%/12 months	58	69	82.0	25	22/260	1.180	3.703	–1.374	13.044	18	11	14
10%/5%/∞	53	59	100.1	22	22/1322	1.238	4.081	0.098	13.044	0	0	10

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total capital for some strategies). Moreover, transaction costs have a more negative impact on returns for short horizon strategies. Imposing a maximum horizon of only one month with buy/sell thresholds of 5%/1% leads to negligible arbitrage returns as a result of very high transaction costs. 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.

Taken as a whole, the results presented in Tables IV and V suggest that investment strategies in the 12 DLCs in our sample produce significant arbitrage returns. Arbitrage in DLCs is not risk-free, however. Uncertainty over the time to convergence is large, and arbitrageurs regularly receive a sequence of margin calls. In addition, imposing a maximum horizon leads to a large fraction of positions that yield (potentially large) negative returns.

4. Arbitrage Risk and the Limits of Arbitrage

This section presents an analysis of the risk of the arbitrage strategies in DLCs. As a starting point of the analysis we measure abnormal arbitrage returns after correcting for systematic risk. Table VI displays estimates of the abnormal return (alpha) relative to the Fama-French three-factor model for all eight investment strategies described in Table V. Alphas 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 are constructed by pooling the daily returns on the individual investment positions after incorporating transaction costs and maintenance margin requirements. Out of the eight strategies analyzed, five produce alphas that are statistically significant at the 5% level or better. Average alphas on these strategies range from 3.7% to 8.9% on an annual basis. Only strategies with a very short maximum horizon do not generate positive alphas. Inspired by Jorion and Schwartz (1996) and Foerster and Karolyi (1999), we also compute alphas relative to an International Asset Pricing Model (IAPM) that includes the global market portfolio and the local market portfolios corresponding to each of the twin parents. The IAPM alphas reported in Table VI are very similar to the alphas of the Fama-French three-factor model with values of up to 9.5%.

Although abnormal returns on simple DLC arbitrage strategies seem economically large, DLC arbitrage is characterized by a high degree of uncertainty about convergence of the mispricing. Some of the DLCs have existed for a very long time. As shown in section 3, price discrepancies in DLCs are very volatile and often assume large values for prolonged periods of time. As a result, arbitrage positions can

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Table VI. Abnormal returns and risk of arbitrage strategies

This table reports the abnormal returns of the arbitrage strategies presented in Table V, obtained as the intercept (alpha) in two different regression models of the daily excess returns (expressed in % per month) on all the individual positions in the twins for all eight arbitrage strategies: (i) the Fama-French three-factor model (FF 3-F) including the (excess) returns on the S&P 500 index, the SMB and the HML portfolio and (ii) an International Asset Pricing Model (IAPM) including the excess returns on the global market portfolio and two domestic market portfolios corresponding to each of the twin parents. Arbitrage 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 (total number of days invested in parentheses), the estimates of the Fama-French alpha and the IAPM alpha expressed in % per month (factor loadings are suppressed to conserve space), the annualized abnormal return of the portfolio (based on both estimates of alpha), the volatility (σ) of excess arbitrage returns, the volatility (σ) of abnormal returns on the S&P 500 over the same period (for comparison purposes), the idiosyncratic volatility (σ_ε) relative to the FF 3-F model and the IAPM, and finally the skewness, the kurtosis, and the 1% Value-at-Risk of the arbitrage return distribution. [a], [b], and [c], indicate significance at the 1%, 5%, and 10% level.

Buy Threshold/Sell Threshold /Horizon	*# Investments (# Days)*	*FF 3-F Alpha*	*Annualized Abnormal Return*	*IAPM Alpha*	*Annualized Abnormal Return*	σ	σ *S&P* 500	*FF 3-F* σ_ε	*IAPM* σ_ε	*Skewness*	*Kurtosis*	*1% VAR*
5%/1%/1 month	309 (6,798)	–0.415	–5.0%	–0.416	–5.0%	34.6%	23.6%	34.5%	34.4%	0.46	12.4	–4.6%
5%/1%/3 months	205 (9,148)	0.159	1.9%	0.126	1.5%	34.5%	23.8%	34.4%	34.3%	0.40	11.6	–4.5%
5%/1%/12 months	156 (13,019)	0.457[b]	5.5%	0.447[b]	5.4%	33.5%	22.6%	33.4%	33.3%	0.34	11.0	–4.2%
5%/1%/∞	138 (17,505)	0.310[b]	3.7%	0.333[b]	4.0%	31.6%	22.1%	31.5%	31.4%	0.29	10.8	–4.0%
10%/5%/1 month	288 (6,339)	0.011	0.1%	0.033	0.4%	31.0%	24.0%	30.9%	30.9%	0.23	8.9	–3.8%
10%/5%/3 months	184 (8,462)	0.610[a]	7.3%	0.643[a]	7.7%	30.7%	23.2%	30.7%	30.7%	0.23	8.3	–3.8%
10%/5%/12 months	127 (10,422)	0.718[a]	8.6%	0.752[a]	9.0%	30.7%	22.9%	30.6%	30.7%	0.35	9.6	–3.7%
10%/5%/∞	112 (11,210)	0.745[a]	8.9%	0.790[a]	9.5%	30.9%	22.2%	30.8%	30.8%	0.41	10.2	–3.8%

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have very long horizons (up to nine years for the strategies depicted in Table V). During this time, mispricing may worsen significantly. This leads to negative arbitrage returns in the short run even though expected returns are positive over the full horizon. As an example, the price deviation of Unilever NV/PLC "converged" from –10.2% to –4.9% between January 7, 1980 and May 9, 1983, but the mispricing worsened dramatically between these dates, reaching –39.1% on August 18, 1981. Several theoretical studies, e.g., De Long et al. (1990), Shleifer and Summers (1990), and Shleifer and Vishny (1997), suggest that rational arbitrageurs are concerned about possible adverse price movements in the short run, even when they know that prices will converge eventually.

Table VI presents estimates of the total volatility (σ) and the idiosyncratic volatility (σ_ε) of returns for the DLC investment strategies as well the total volatility of the S&P 500 over the same period. Annualized standard deviations of arbitrage returns range from 31.0% to 34.6% for different strategies. The idiosyncratic risk of arbitrage returns relative to both the Fama-French three-factor model and the IAPM discussed above are almost identical to the standard deviation of arbitrage returns. It is remarkable that only a marginal fraction of the time-series variation in arbitrage returns can be attributed to variation in the benchmark factors included in widely used asset pricing models. Both the total and the idiosyncratic volatility of arbitrage returns are much larger than the annualized volatility of the S&P 500, which lies between 22.1% and 24.0%. Hence, the volatility of DLC arbitrage consistently exceeds the risk of investing in the S&P 500 by almost 50%. This is especially striking in light of the fact that our arbitrage strategies involve hedged long-short positions.[5]

The final three columns of Table VI indicate that the distribution of arbitrage returns exhibits positive skewness and high kurtosis (i.e., fat tails). Arbitrage in DLCs is associated with substantial downside risk. The daily 1% Value-at-Risk of around –4% for all strategies indicates that the arbitrageur can be expected to regularly suffer a large single-day loss.

Taken together, our findings indicate that although arbitrage strategies in DLCs have negligible fundamental risk and low systematic risk, they are characterized by high idiosyncratic risk (including a high frequency of extreme returns) and uncertainty about the horizon at which convergence takes place. We interpret the evidence as being consistent with idiosyncratic risk deterring arbitrage activity and impeding efficient pricing.

[5] The volatility of arbitrage positions in DLCs is also much higher than the volatility of hedge fund returns. Agarwal et al. (2007) report that the volatility of monthly returns amounted to 4.4% on average for 3,924 hedge funds over 1994–2002.

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5. Robustness

5.1 DO TIME ZONE AND CURRENCY DIFFERENCES MATTER?

The two parent companies of the twins Royal Dutch/Shell, Unilever, ABB, Elsevier/Reed International, Rio Tinto, Zürich Allied/Allied Zürich, and BHP Billiton have all traded on a U.S. stock market during at least part of the sample period. The U.S. share prices of these twins can be used to investigate whether their mispricing can in part be explained by differences in time zones and currencies, as all U.S. listed shares trade within the same time zone and in U.S. dollars. Data on share prices in the U.S. are obtained from Datastream, except for the ADR prices of ABB AG/AB and BHP Billiton Ltd/PLC, which are taken from Bloomberg. We compute log deviations from parity on the basis of the U.S. prices and analyze arbitrage opportunities on the basis of these price differentials. Detailed results of the analyses of the ADR data are available from the authors.

ADR prices closely follow the prices of the ordinary shares for all DLC parents. This implies that differences between the log deviations from parity based on the ADR prices and those based on the ordinary share prices are minor and most correlations are nearly equal to 1. Some of the DLCs exhibit a slightly lower correlation between ADR and ordinary share price discrepancies, which can be explained by the infrequent trading of some of the ADRs and because the ADR of ABB AB is on the B share, which carries 1/10th of the votes of the A share.

Relative returns on the ADRs of the twin parents also exhibit comovement with the relative returns in the home markets. Moreover, both the number of arbitrage positions established in the twin ADRs and the returns on these positions are very similar to the results reported in Table V. These findings indicate that arbitrage in the ADRs of DLCs is equally profitable as arbitrage in the ordinary shares. Overall, the evidence demonstrates that time zone and currency differences do not play a role in the mispricing of DLCs.

5.2 ALTERNATIVE HYPOTHESES FOR DLC MISPRICING

This section discusses whether the mispricing observed in the 12 DLCs in our sample can be explained by contractual shortcomings in the equalization agreements, taxation, corporate governance issues, or short-sales constraints.

The relative pricing of the shares of the twin parents depends crucially on the effectiveness of the equalization agreements. It is impossible to rule out that observed deviations from theoretical price parity in part arise from (perceived) contractual shortcomings. On the other hand, we have elaborately reviewed academic and applied research and find little indication that investors face uncertainty about the parity of the twin stocks' fundamental value. The legal structures of DLCs have

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been scrutinized from several perspectives. In the academic finance literature, Rosenthal and Young (1990) and Froot and Dabora (1999) do not find defects in the agreements that can explain the mispricing. An internal document of Merrill Lynch (2002) investigates arbitrage opportunities and discusses the legal structure without pointing at any type of fundamental risk. Legal scholars (Schmidt, 1999; Wymeersch, 2000; PLC, 1993), global law firms (Allens Arthur Robinson, 2001; Baker & McKenzie, 2001; Lovells, 2001; Cleary Gottlieb Steen & Hamilton, 2003; Herbert Smith, 2003), and regulators (Reserve Bank of Australia, 2002; U.K. Panel on Takeovers and Mergers, 2002) have investigated the contractual features and conclude that the equalization agreements are an effective instrument in cross-border mergers.

Dividend taxation could be a potential explanation for the price deviations in DLCs, since the equalization agreements do not aim to adjust dividend payments for tax differences across countries and investors. Analyzing dividend taxation in DLCs is very complex, because taxation differs across different groups of investors in different countries in a myriad of ways. We provide three pieces of evidence based on which we expect that taxation is not a main determinant of the mispricing. First, Froot and Dabora (1999) conclude that tax-induced investor heterogeneity cannot explain the mispricing, because for each of the three twins in their sample at least one group of Dutch, U.K., and U.S. investors is tax-indifferent and because the deviations from parity are too large relative to observed taxation differences for other groups. Second, if dividend taxation matters for relative twin prices, we would expect to observe different ex-dividend day effects for the twin shares of a DLC (see, e.g., Elton and Gruber, 1970; Elton et al., 2005). However, in an event study of all 34 dividend payment observations where both parents go ex-dividend on the same date (not reported), we detect only one significant change in the price deviation on the ex-dividend day. This finding suggests that dividend taxation does not materially affect the deviation from parity. Third, the time-series volatility of the deviations from parity we document in section 3 is much larger than can be explained by occasional taxation changes. We investigate the abolition of the U.K. Advanced Corporation Tax (arguably the most important regulatory tax change during our sample period, see Financial Times, 1997). If dividend taxation matters, we should observe that U.K. parents decline in value relative to the parents in other countries after the abolition. In an (unreported) event study, we find no evidence of a significant effect on the price deviations.

Corporate governance issues or the threat of contract renegotiation could also be relevant explanations for the mispricing. However, the governance structures and contracts are rarely changed, while the mispricing is very volatile and 10 out of 12 twins show both positive and negative price deviations. Second, we are not aware of any case in which doubts about the governance structure or the equalization agreements have been raised. Third, we collect announcement dates (if available)

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of significant changes in blockholdings (identified on the basis of 20-F filings and annual reports) over the period 1991–2002 and find little evidence of a systematic relation with the magnitude and sign of the price deviations.

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 exhibits important imperfections for a sample of U.S. tech stocks. Bris et al. (2007) document short-sale restrictions in international equity markets. For example, in Belgium there is no organized market for stock lending and borrowing, while in Sweden shorting has only been allowed since 1991. In Finland shorting started in 1998, but transfer taxes make it expensive. Although 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), for most firms in the sample it is implausible that short-sale 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.

5.3 TRADING PARAMETERS

Figure 2 displays the alphas of arbitrage strategies in DLCs relative to the Fama-French three-factor model as a function of the buy and the sell thresholds. (We obtain similar results when Sharpe ratios instead of alphas are used as the performance measure.) The benchmark arbitrage strategy has a buy threshold of 10%, a sell threshold of 5%, and a maximum horizon of one year. This strategy produces an alpha of 0.718% per month (8.6% per annum) and is indicated by a black dot in the graph. Figure 2 shows that the abnormal return on our benchmark strategy is not exceptional. Both a strategy with a buy/sell threshold of 10%/6% and a strategy with a buy/sell threshold of 9%/5% yield a higher alpha. These strategies also generate a higher number of arbitrage positions. Moreover, strategies with a buy threshold between 14% and 18% are considerably more profitable as well. In particular, a strategy with a buy threshold of 18% and a sell threshold of 10% has an abnormal return of almost 15% per annum. This strategy generates only 24 arbitrage positions, however. The number of positions varies from up to 300 for thresholds that are relatively low and close together and falls below 100 for buy thresholds that are much higher than sell thresholds. The fact that alphas increase with the buy threshold (for a given difference between buy and sell thresholds) suggests that relative prices have a greater tendency to move toward parity when the price gap is larger.

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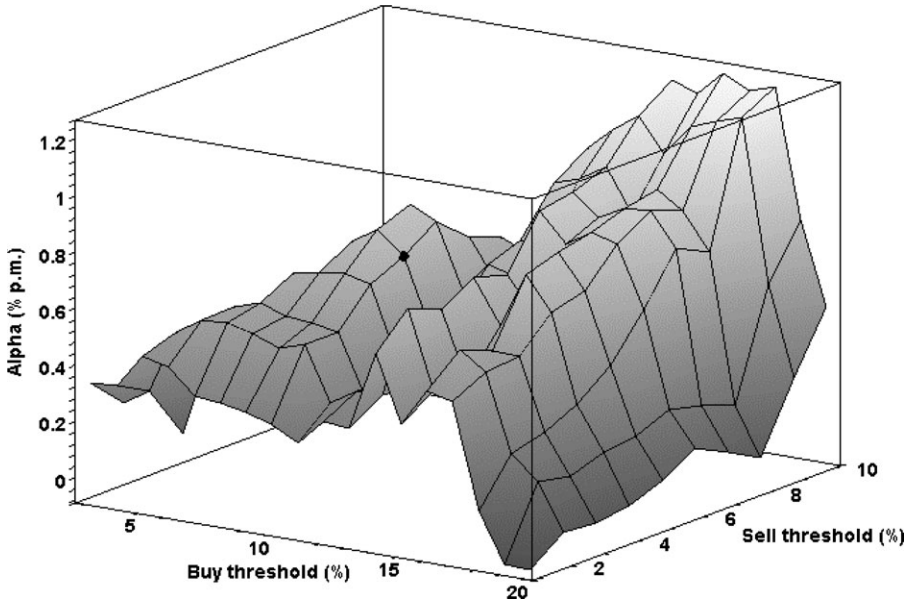

Figure 2. Sensitivity analysis of arbitrage strategies.
This figure shows the sensitivity of the abnormal returns (alphas) – relative to the Fama-French three-factor model and after taking account of transaction costs and margin requirements – of the arbitrage strategies in all twins with respect to buy and sell thresholds. The benchmark arbitrage strategy has a buy (sell) threshold of 10% (5%) and a maximum horizon of one year. This strategy is indicated by a black dot in the graph. The set-up of the arbitrage positions is described in Tables IV and V.

Our assumptions on trading costs and interest rates do not have a large effect on the abnormal returns of the arbitrage strategies. When the commission is increased from 25 to 50 basis points, the alpha decreases to 0.453% per month. Similarly, when we assume that the bid-ask spread is 80 instead of 40 basis points, we find an alpha of 0.506% per month. Reducing the short rebate to 1% per year leads to a drop in the alpha to 0.562% per month. As a final analysis, we impose an additional delay of one trading day before the arbitrageur acts on signals derived from the crossing of buy/sell thresholds. This quite restrictive assumption moderates the alpha to a still healthy 0.382% per month.

5.4 UNIFICATIONS

An interesting feature of our sample is that six twins have chosen to end the DLC structure and have unified their shares. (We do not analyze the unification of Royal Dutch/Shell in 2005 as it falls outside of our sample period.) In the period between the announcement and the actual unification, horizon risk is negligible

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because prices will certainly converge within a set and limited amount of time (subject to governmental or shareholder objections). Thus, if uncertainty about the horizon is an important impediment to arbitrage, we expect prices to converge to parity instantaneously. Furthermore, price discrepancies and arbitrage opportunities should be absent after the unification announcement.

The final two columns of Table I display the dates of the announcement of the unification and the actual unification dates. Several reasons for unification were mentioned by the twins. Four of the six DLCs explicitly stated that the premiums or discounts were undesirable. Other motivations include greater liquidity (mentioned by four twins), enhanced access to capital markets (four), elimination of investor confusion caused by the complicated structure (three), greater presence and weighting in certain indices (two), and a broader shareholder base (two).

Unifications 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. 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. In addition to choosing either of these structures, some firms provide incentives to specific shareholders. For example, Allied Zürich holders received 40 pence a share as compensation for having to hold a company with a primary listing in Switzerland and for no longer owning a company that was part of the FTSE 100 index.

Figure 3 shows the development of the log deviations from parity of Dexia and Zürich Allied/Allied Zürich starting 120 trading days before the announcement date (date 0) up to the last trading day of the twin shares. The graphs show that the mispricing is eliminated virtually instantaneously. For Dexia, the deviation changes from –9.22% to –0.14% in a single day. For Zürich Allied/Allied Zürich, the deviation is reduced from 8.29% to 1.91% in one day and to 0.34% in two days. Similar changes in the price deviations occur for Merita/Nordbanken (from –5.44% to –0.13% in one day) 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 these price discrepancies is consistent with the incentives provided to ABB AG shareholders and U.S. Smithkline Beecham shareholders. (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. Smithkline Beecham paid holders of the equity units US$0.225 per share or US $1.125 per unit to redeem the preferred stock that was part of the unit.) These results suggest that the financial markets are aware of the mispricing of the DLCs and that a correction to prices occurs within one or two days.

During the period between the announcement and the actual unification, the deviations from parity remain relatively stable for ABB, Smithkline Beecham,

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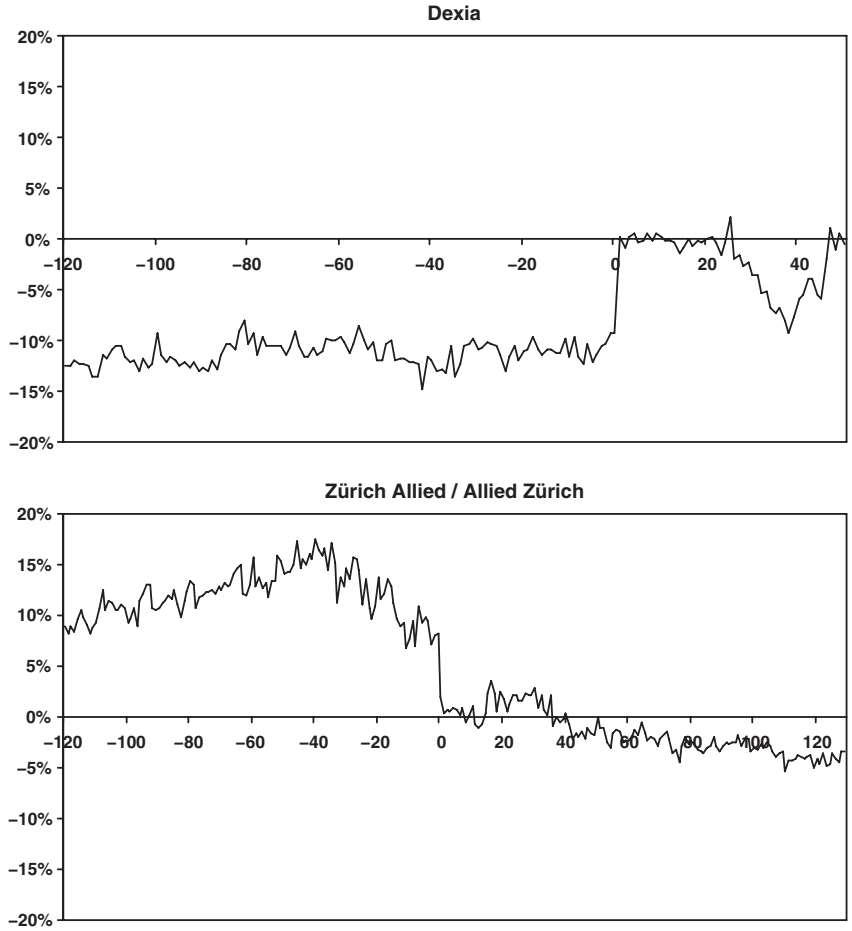

Figure 3. Log deviations from parity around the unification announcement.
This figure shows the log deviations from theoretical parity (on a percentage basis) for two of the six unified DLCs over the period starting 120 days before the unification announcement (day 0) till the last trading day before unification. The graphs of the log deviations for the other unified DLCs around the unification announcement date are available from the authors.

Fortis, and Zürich Allied/Allied Zürich. Two twins, Dexia and Merita/Nordbanken, exhibit considerable swings, however. This phenomenon can be explained by the stock swap structure of these unifications. In the case of Dexia, the French share becomes undervalued after a stable period and recovers later. 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.

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We examine whether the trading rules discussed in section 3 yield different results in the post-announcement period. Unreported results show that after the announcement of the unification, the 10%/5% and 5%/1% buy/sell threshold strategies produce a total of only one and four arbitrage positions, respectively. Some arbitrage returns are high on a monthly basis, but investment horizons are generally very short. Moreover, Merita/Nordbanken accounts for the only position in the 10%/5% strategy and for three out of four arbitrage positions in the 5%/1% strategy. These positions require shorting the shares of Merita, the Finnish parent. As mentioned in section 5.2, Finnish transfer taxes make shorting expensive and little used.

The main difference of the post-announcement period compared with the pre-announcement period is that there is far less uncertainty over the arbitrage horizon, which reduces concerns about adverse price movements in the short run. Our analysis of the six unifications provides further evidence suggesting that this type of uncertainty deters arbitrage activity in the period before the unification announcement.

6. Conclusions

We examine the risk and return of arbitrage strategies in a sample of 12 dual-listed companies (DLCs). In contrast to previous empirical studies on the risk and return characteristics of arbitrage strategies, our analysis involves situations in which fundamental risk, transaction costs, and short-sale constraints do not form important barriers to arbitrage.

We find that the relative prices of all twins exhibit statistically significant and economically large deviations from theoretical parity. The deviations from parity show substantial variation over time. Arbitrage in DLCs produces abnormal returns of up to almost 10% per annum (taking into account transaction costs and margin requirements). However, DLC arbitrage involves considerable uncertainty, as there is no identifiable date at which the twin prices will converge. We show that arbitrage strategies exhibit a large amount of idiosyncratic risk and a distribution with a fat left-tail. The idiosyncratic volatility of arbitrage returns lies in the range of 30–35% for all strategies, which is close to 50% higher than the total volatility of the S&P 500.

Overall, we find that there is prolonged mispricing of large, well-traded international equity securities. Arbitrage is not successful in eliminating this mispricing. We interpret our findings as evidence in support of studies that emphasize the importance of idiosyncratic risk as an impediment to arbitrage, e.g., Shleifer and Vishny (1997) and Pontiff (2006).

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