Corporate Management Review
Vol. 40 No. 1, 2020
pp. 35-75

Pairs trading in the Taiwan, Hong Kong, and China stock markets before and after short-selling deregulation
賣空限制解禁前後、配對交易策略獲利性在台港中股市的變化特徵

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Abstract: This research explores the performance of pair-trading strategies in the Taiwan, Hong Kong, and China stock markets. While their profitability in the China and Hong Kong markets is not as significant as that in the Taiwan market, the empirical results are robust to bankruptcy risk and different filters of pair trades during 1990/1/4~2017/6/30. The industry effect for financial pair trades prevails in the Hong Kong and the Taiwan markets, but its significant and positive profitability drops after those markets' short-selling deregulations appear. This study also notes that a lack of investor discipline raises a misleading comprehension for pair-trading profitability in the three markets.

Keywords: Pair trading, short-selling deregulation, distance filter, frequency filter, investor discipline.

摘要：根據 1990/1/4~2017/6/30 的實證數據，在考慮倒閉風險與不同的配對投組建構指標後，整體而言，陸股沒有配對交易的獲利特徵，而台股的獲利特徵則較港股與陸股來的明顯；特別是台股與港股金融區塊中的配對部位，顯示台灣與香港股市中存有產業效果。但是這些獲利性會隨著市場放空限制的解除而明顯下降，如此隱含隨著交易摩擦程度的下降，降低了交易者的賣方操作成本、提升了配對交易活動的強度與效率性，配對交易策略的獲利性也因此而降低。本文同時發現投資人若是出現投資紀律問題而長抱配對部位

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時，會產生額外的損失或是誤判配對交易的獲利前景。

關鍵詞：配對交易、賣空禁令的解除、誤差距離指標、纏繞次數指標、投資紀律

1. Introduction

In contrast to a simple buy-and-hold strategy that is initiated with one trading direction, a long-short strategy takes both short and long positions simultaneously. More investment opportunities become available under short-selling deregulation, without appealing to other financial products such as derivatives. Individual investors can create long-short portfolios for themselves in the spot markets, and institutional investors can implement more complicated strategies without much inventory of long positions beforehand, thereby lowering trading costs. The pair-trading strategy is one notable example of a long-short strategy. In fact, many financial groups like Fidelity International, Citibank, and JPMorgan Chase offer their customers explanations and suggested pair trades in order to execute such strategies. Some professional enterprises also exclusively provide different types of software or real-time services for pair trading, including Event Driven Investor Research Limited (2019), Mitre Media (2019), and Pair Trading Lab (2019).

Krauss (2017) academically reviews a large set of pair-trading literature consisting of more than one hundred studies and concludes that the specification applied by Gatev, Goetzmann, and Rouwenhorst (2006) is the most intensively researched and followed framework. Their methodology is based on detecting the time-varying distance between two price series to pick out stocks to buy and sell, which is termed the distance filter. Another representative study developed by Do and Faff (2010) picks out stocks to buy and sell according to the detection of intersection frequency between two price series, which is termed the frequency filter. Both the distance and frequency filters can be applied to formulate pair-trading strategies.

The reasoning underlying pair-trading strategies comes from the claim that if two stocks correlate with each other for some reasons ex ante, then a pair trade can be set up by a short position at a relatively high price and a long position at a relatively low price simultaneously. As long as the paired relationship reverts back to the long-term trend to some extent of close to it later on, then marking the two positions to market is profitable. This strategy was first developed by Nunzio Tartaglia's quantitative group at Morgan Stanley and was known on Wall Street in the 1980s (Gatev *et al.*, 2003).

Jegadeesh and Titman (1995) address that a market usually overreacts to idiosyncratic information and underestimates the impact from systematic information on individual positions at the early stage of information arrival. As the market gradually revises its biased sentiment, a reversion tendency of the price series occurs and results in profitability via reversal strategies. This is consistent with the viewpoint of Gatev *et al.* (2003, 2006) that even in an efficient market, the cointegrated relationship among price series can still be one source of pair-trading profitability.

Andrade *et al.* (2005) assert that uninformed traders make stock prices temporarily deviate from their normal levels. As transitional uninformed noises perish, the price series turn back to their regular paths. If we can find stocks that converge back to their original relationship, then profitability is expected through the implementation of long-short strategies. One example to filter out available pair trades is the industry boundary.

Based on the reasoning behind the converging tendency of price series, Gatev *et al.* (2006) test pair-trading strategies with daily data over 1962-2002. They use a distance filter between normalized historical price series to find profitable pair trades. Their findings present average annualized excess returns of up to 11% for self-financing portfolios of pair trades.

Papadakis and Wysocki (2007) examine the effects from earnings announcements and analysts' earnings forecasts on pair-trading profitability. With the same specification of Gatev *et al.* (2006) in the U.S. stock market during 1981-2006, they find average annualized excess returns of up to 7.67% and also find that changes in existing paired relationships are often triggered around the occurrences of accounting events. Pairs that begin to open their relationships after these accounting events are significantly less profitable than those pairs that begin to open in periods without these events.

Zebedeea and Kasch-Haroutounian (2009) empirically investigate paired relationships of stock returns on a microstructure basis for securities of U.S. airline firms. They find that the wider an asset's bid-ask spread is, the faster the asset will revert to the level of intra-day returns of other similar assets. This suggests that the adjustment speed of pair-trading returns is a function of asymmetric information.

Do and Faff (2010) formulate their strategy by a frequency filter to supplement the distance filter developed by Gatev *et al.* (2006). They find that a pair-trading strategy performs very well during the 1970s and 1980s, including the 1987 stock market crash. Nevertheless, a declining trend of pair-trading profitability in the U.S. stock market occurs. They also note that portfolios of pair trades from the financial and utility industries perform better than those from the industrial and transportation industries.

There are studies on pair trading for other countries aside from the U.S. market. Perlin (2009) applies daily, weekly, and monthly price data to test pair-trading profitability in the Brazil market. Based on the specification of Gatev *et al.* (2006), Perlin (2009) finds that the daily frequency is an intuitive selection and performs better. Bolgün *et al.* (2012) formulate their strategy by Turkdex futures contracts and a synthetic ETF with the algorithm of a constrained least squares regression. They discover an overall 9.01% return during 2005~2011 in the Turkey equities market.

Jacobs and Weber (2015) apply the specification of Gatev *et al.* (2006) on 34 stock markets and claim profitable results of pair trading worldwide. Jacobs and Weber (2015) also state that the persistence of pair-trading profitability may be affected by the dynamics and interaction of news, investor attention, and limits to arbitrage in the U.S. market.

For the China and Hong Kong markets, Wang *et al.* (2013) follow Gatev *et al.* (2006) and note that a pair-trading strategy can yield a 1% monthly average return for pair-trading portfolios from the China Securities Index 300 during 2006 to 2009. Shao and Fan (2013) follow Gatev *et al.* (2006) with different setting of parameters. They find that the strategy performs better under a shorter formation period for pair trades from firms in the China Securities Index 300 during 2010 to 2013. Li *et al.* (2014) examine the pair-trading performance of 38 firms that are simultaneously listed on the China and Hong Kong exchanges. Their trading strategy yields an average annualized return of about 17.6% after the adjustment of systematic risk.

Hu *et al.* (2016) formulate a two-stage strategy by the cointegration method of distance estimation for 37 positions in the Shanghai Exchange 50 Index during 2010-2014. They find that their model outperforms the benchmark. Jacobs and Weber (2015) find that the average monthly pair-trading return in the China market is 0.665% with a significant t-statistic of 6.3 and 0.876% with a significant t-statistic of 8.43 in the Hong Kong market during 2000-2013.

For the Taiwan market, Andrade *et al.* (2005) formulate their portfolios by 647 listed companies during 1994-2002 and find an annualized return up to 10.18% based on the same specification of Gatev *et al.* (2003). Combining other countries' and Taiwan's data, Hong and Susmel (2013) construct pair-trading portfolios with 169 Asian shares listed in their local markets and their corresponding ADRs listed in the U.S. market during 2000/1~2011/12. Up to a 2.91% median return can be obtained within the settings of a 90-day holding period and a 60-day estimation period for the average firm.

During 2000/1~2013/12 and among 34 international markets, Jacobs and Weber (2015) find that 32 markets are equipped with positive average returns worldwide. While they find that the average monthly pair-trading return in the Taiwan market is insignificant at -0.058%, Wang *et al.* (2018) apply trading positions in the Taiwan 50 Index during 1990/1~2016/3 and find significant annualized mean returns of 1.84%~3.04%. They also claim that the deregulation on short-selling may diminish the profitability of a pair-trading strategy.

Gatev *et al.* (2006) and Do and Faff (2010) demonstrate positive and significant industry effects in the U.S. market. They show that portfolios of pair trades from the utility and financial industries are more profitable than those from other industries. They explain that utility companies face stable demand, low differentiation of product, and a general form of rate regulation. Financial companies are exposed by common macroeconomic factors such as interest rates and unemployment shocks. Hence, share prices within these two industries are more likely to move together and their pair trading is more profitable.

Worries over a financial crisis has resulted in a more restricted regulation environment of the financial industry worldwide (Basel Committee on Banking Supervision, 2010, 2011, 2013), which can be another important co-movement reason for financial price series. The discretionary degree of financial institutions tends to be much lower than in other industries. Once policy changes, share prices within the financial industry are more likely to move together and their pair trading is expected to be more profitable.

Empirical discrepancies in the literature may result from different markets, different periods, different filters of sample selection, different industries, or different parameters. However, factors underlying the robustness of empirical return statistics are important, which motivates this study to compare the levels of pair-trading profitability among the China, Hong Kong, and Taiwan stock markets under a unified and common specification.

Pair-trading investors have to hold enough long positions beforehand to establish a short position in a paired relationship under a short-selling restriction. The different deregulating processes in the China, Hong Kong, and Taiwan stock markets can provide comparative empirics to investigate the deregulation effects on pair trading in a more thorough sense. This is less discussed in the above pair-trading studies.

This study therefore applies the settings of Gatev *et al.* (2006, the distance filter) and Do and Faff (2010, the frequency filter) to formulate pair-trading strategies during 1990/1~2017/6 with additional considerations including bankruptcy risk, industry effect, and investor discipline. Empirical results from more than one stock market can help to clarify the effects resulting from short-selling deregulation.

The remainder of the paper is organized as follows. Section 2 provides the specification of the pair-trading strategy. Section 3 provides empirical results.

Finally, Section 4 concludes this study.

2. Empirical specifications

While the logic may be self-evident, the implementation of a pair-trading strategy is complicated. One different specification could result in a different empirical result (Göncü and Akyildirim, 2016) or the problem of data snooping (Gatev *et al.*, 2006). Thus, this study adopts the most cited empirical framework of Gatev *et al.* (2006) in that such a platform shares the commonality of specification in the literature (Andrade *et al.*, 2005; Papadakis and Wysocki, 2007; Perlin, 2009; Do and Faff, 2010; Jacobs and Weber, 2015; Krauss, 2017).

2.1 Samples

This study applies stock positions in the Shanghai Stock Exchange 50 Index (SSE50), the Hang Seng Index (HSI), and the FTSE TWSE Taiwan 50 Index (TW50) during 1990/1/4~2017/6/30. Data are collected from Datastream and the websites of the three exchanges. Daily frequency is applied as in the other most referenced studies in the literature (Gatev *et al.*, 2006; Perlin, 2009; Do and Faff, 2010; Jacobs and Weber, 2015; Krauss, 2017).

Note that the SSE50 consists of the largest, highly liquid, and most representative SSE-listed stocks in the Shanghai securities market (Shanghai Stock Exchange, 2017). HSI is the most widely quoted gauge of the Hong Kong stock market, which consists of the largest and most liquid stocks listed on the Main Board of the Hong Kong Stock Exchange (Hang Seng Indexes Company Limited, 2017). The TW50 comprises 50 of the most highly capitalized blue-chip stocks in the Taiwan market (FTSE Russell, 2017).

In terms of market value on 2017/6/30 or the last trading day of the sampling period of this study, the 50 stocks of SSE 50 together take up 44% of the 1,295 listed A-shares on the Shanghai Stock Exchange, the 50 stocks of HSI together take up 41% of the 1,746 listed companies on the Stock Exchange of Hong Kong, and the 50 stocks of TW50 together take up 69% of the 916 listed common stocks on the Taiwan Stock Exchange Corporation. These positions help avoid the bias of illiquidity on empirical results, which is a concern both academically and practically (Gatev *et al.*, 2006; Asparouhova *et al.*, 2010; Han and Lesmond, 2011). Because these positions are usually less restricted by short-selling regulation due to their larger trading volume, this helps facilitate the long-short formation of available pair trades for retailer and institutional investors in the spot markets.

2.2 The filters and the pair relationship

This study measures the degree of interconnection of any two stocks in a previous 250-trading-day period (formation period), picks out the pairs, and trades them in the subsequent 125-trading-day period (trading period). Since Krauss (2017) concludes that Gatev *et al.* (2006) is the most cited pair-trading literature and Do and Faff (2010) is another representative study in a similar vein, this study applies their measures or filters of closeness in the formation period to help pick out profitable pairs in the trading period. To be concise and without loss of generosity, this study takes the measure developed by Gatev *et al.* (2006) as the distance filter and the measure developed by Do and Faff (2010) as the frequency filter.

The distance filter SSD can be defined by Equation (1), where $P_{\cdot,t}$ denotes daily prices, and $N_{\cdot,t}$ denotes normalized prices of stocks i and j with their price averages $\overline{P}_{\cdot}$ and standard deviations $\widehat{S}_{\cdot}$ in the formation period. The difference series $D_{i,j,t}$ can thus be calculated. The sum of squared deviations $SSD_{i,j}$ quantifies the level of closeness between positions i and j. Intuitively, a smaller SSD implies a more interconnected relationship in the formation period and a stronger potential of converging to each other later on in the trading period.

In addition to the summation of squared distance between $N_{i,t}$ and $N_{j,t}$, which can measure the degree of closeness, the number or frequency of intersections between the two series during the formation period does as well. Do and Faff (2010) claim that this frequency filter can supplement the pair-trading strategy. Illustrated by the pair of Agricultural Bank of China (ABC) versus China Communications Construction (CCCC) in the formation period (2016/1/25~2017/1/6), ZC is the number of intersections between their

$$N_{i,t} = \frac{P_{i,t} - \bar{P}_i}{\widehat{S_i}}$$

$$N_{j,t} = \frac{P_{j,t} - \bar{P}_j}{\widehat{S_j}}$$

$$D_{i,j,t} = N_{i,t} - N_{j,t}$$

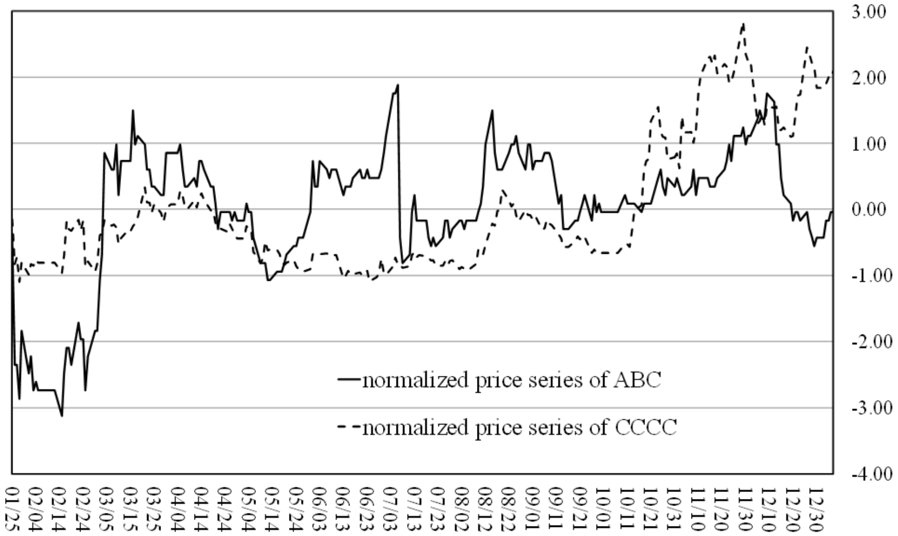
$$SSD_{i,j} \sum_{t=1}^{250}(D_{i,j,t})^2 = \sum_{t=1}^{250}(N_{i,t} - N_{j,t})^2 \quad (1)$$

normalized price series during the formation period. Equivalently, ZC is the number of intersections between the difference series $D_{i,j,t}$ and the horizontal zero axis in the formation period as demonstrated in Figure 1, which is 10.

Given a relationship between stocks i and j, once their normalized prices diverge out of some threshold in the trading period, a long-short position is initiated. Thereafter, the two positions are marked to market as some convergence condition meets. The divergence threshold is constructed by the standard deviation $\widehat{S_D}$ defined in Equation (2) and is computed by the normalized price spread series in the formation period.

$$\widehat{S_D} = \sqrt{\frac{\sum_{t=1}^{250}(D_t - \overline{D_t})^2}{249}} \quad (2)$$

When the absolute value of the normalized price spread, D_{ABS}, is two times larger than the standard deviation at a later time spot $t + k$, a long position with a relatively lower normalized price and a short position with a relatively higher normalized price are taken simultaneously, thus opening up a pair trade. The two positions are marked to market until their normalized price series intersect or cross over at some later time spot $t + k + h$, which closes this pair trade relationship. Equation (3) symbolically illustrates the open and close conditions for a paired relationship.



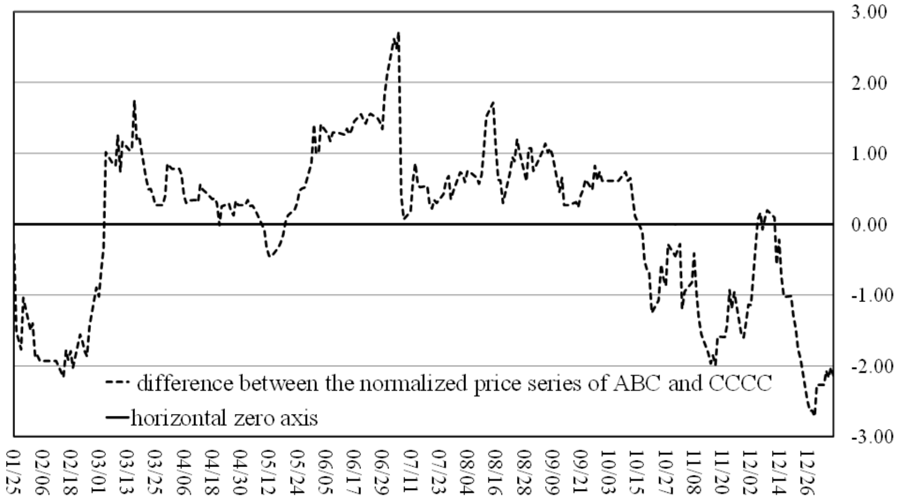


Figure 1
The pair trade relationship in the formation period (2016/1/25~2017/1/6) — Agricultural Bank of China (ABC) versus China Communications Construction (CCCC)[2]

[2] The 10 intersection time points of the two normalized price series in the formation period occur at 2016/3/4, 4/21, 4/22, 5/10, 5/19, 10/17, 12/5, 12/7, 12/8, and 12/12.

$$\begin{aligned} &\text{open condition: } D_{ABS,t+k} > 2 \times \widehat{S_D} \\ &\text{close condition: } D_{ABS,t+k+h} = 0 \\ &\text{where } D_{ABS,t} = \left|N_{i,t} - N_{j,t}\right| \\ &\qquad k, h > 0 \end{aligned} \tag{3}$$

After the close of the pair trade and before the end of the trading period, the pair of stocks may experience other open and close opportunities recursively. Note that if the pair trade is still in the open status at the end of the trading period, then it will be marked to market automatically to maintain investor discipline.

2.3 Reinvestment mechanisms and pair trading

After a complete open-close operation, the next pair trade might be initiated again within the trading period or might be marked to market automatically by the end of the trading period. To be more practical and conservative, the 100% initial margin requirement for the short position is applied, the open, close, and marking-to-market operations are executed in the next trading day, and the clearing price of a position at a bankruptcy or delisting condition will be zero.

For those pairs with several open-close operations in the same trading period, additional cash flows from the last long and short positions can be reinvested in the next long and short positions accordingly or equally. Gatev *et al.* (2006) note that if long positions in pair trades contribute to the profitability a lot more, then the bankruptcy risk will diminish the robustness of pair-trading profitability. In contrast, short positions do not suffer bankruptcy risk and thereby help the profitability. A comparison of the empirical results based on the two allocation settings helps identify the role played by bankruptcy risk.

3. Empirical results

As illustrated in Table 1, *GGR* denotes the portfolio specified by Gatev *et al.* (2006) that consists of pairs by matching only one partner for each stock separately, which minimizes their *SSD*. The pair-trading strategy is not profitable during the whole sampling period, because the average returns of all pairs in the three markets are insignificant at the 10% level. Only the portfolio *GGR* in the Taiwan market provides a significant and positive average return, which is 1.19% at a 0.45% significance level. While the average returns of *GGR* in the China and the Hong Kong markets are both positive, they are very insignificant.

Figure 2 exhausts the relationship between the average return and the number of pairs with the smallest *SSD* values, meaning the portfolios are formulated by the distance filter. Note that the three markets are equipped with the same maximum number of available pairs, 1,225, because the numbers of stocks are 50 uniformly in their representative indices. It can be observed that with more pairs, the average returns of the three markets converge to some levels in a stable or obvious sense. The pair-trading strategy seems to perform best in the Taiwan market, then China, and then Hong Kong.

Such stable or obvious patterns in Figure 2 might be not reliable. Figure 3 demonstrates the relationship between the p-value of t-statistics for the average return of pair trades and the number of pair trades with the smallest *SSD* values. It can be observed that most portfolios with different numbers of pairs are not significant at the 10% level. Specifically, the average returns of all the 1,225 portfolios are insignificant at the 10% level in the China market. The average pair-trading return becomes insignificant at the 10% level in the Hong Kong market except for first 16 portfolios.

We note that even though the average returns of some portfolios in the Taiwan market are positive and significant at the 10% level, only 8 portfolios out of the total 1,225 ones are qualified as significant within the 5% level. Therefore, pair-trading profitability is weak in terms of average statistics during the whole sampling period.

The above results imply that other factors can be taken into consideration for the robustness of pair-trading profitability in the three markets under a unified and comparable manner. The following subsections provide empirical

Table 1

Basic statistics of pair-trading returns

	China market		Hong Kong market		Taiwan market	
	all trade pairs	*GGR*	all trade pairs	*GGR*	all trade pairs	*GGR*
Average return	0.53%	0.25%	-0.77%	0.17%	0.73%	1.19%
t-statistic	0.59	0.22	-0.97	0.19	1.65	2.95
p-value	55.94%	82.67%	33.44%	85.09%	10.44%	0.45%
Standard error	5.99%	7.49%	7.27%	8.12%	3.42%	3.13%

Notes: Following the information in a previous formation period (a 250-trading-day period), this study conducts pair trading in the subsequent trading period (a 125-trading-day period) on a daily basis. All available pairs without an industry boundary are applied during 1990/01~2017/06. The reinvestment mechanism in the same trading period allocates the accumulated total cash flow equally between the long and short positions in the next open operation. *GGR* denotes the portfolio specified by Gatev *et al*. (2006) that consists of only one matching partner for each stock by finding the security that minimizes *SSD*.

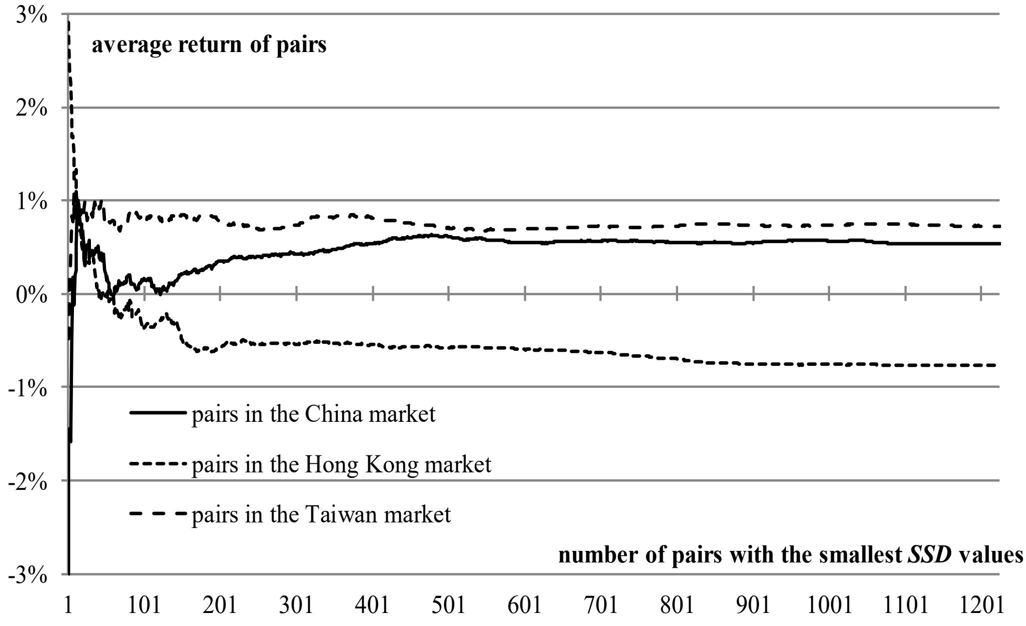


Figure 2

The average return of trade pairs and the number of trade pairs with the smallest *SSD* values during 1990/01~2017/06

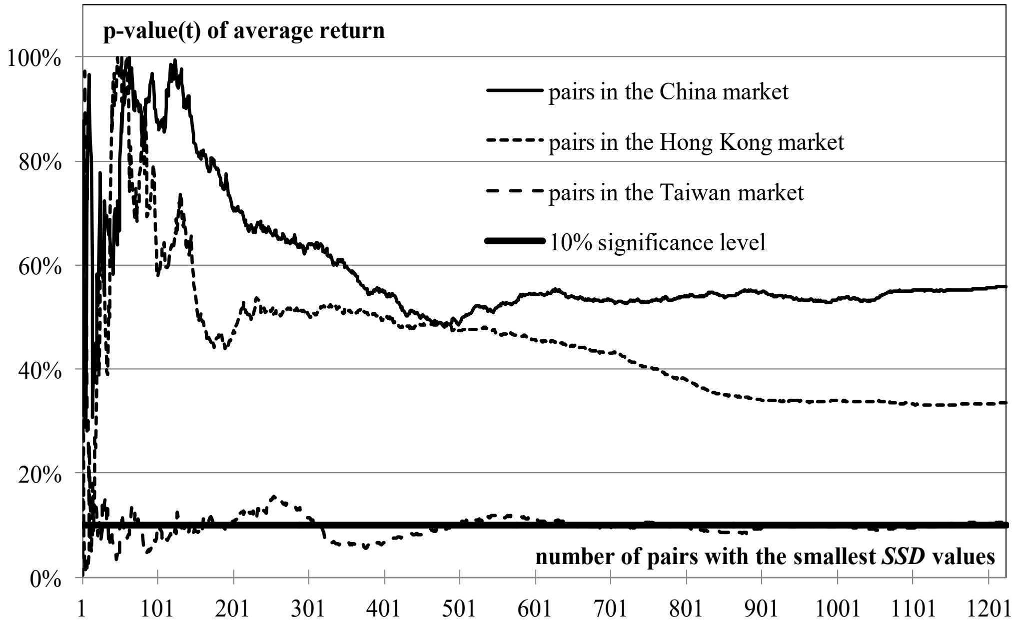


Figure 3
The p-value of t-statistics for the average return of trade pairs and the number of trade pairs with the lowest SSD values

results on bankruptcy risk, the distance or frequency filter, the industry groups, and the effect from short-selling deregulation. We also explore the length of trading period, which relates to investor discipline.

3.1 Reinvestment mechanisms, bankruptcy risk, and pair trading

Several open-close operations may occur during a trading period for a pair of stocks that result in additional cash flows for reinvestment. The accumulated total cash flow can be allocated equally between the long and short positions in the next open operation. Alternatively, it can be implemented by separately allocating the cash flows accumulated from the last long and short positions to the next open operation.

Gatev *et al.* (2006) note that if pair-trading profitability is dominated consistently by the operation of one single direction, then the empirical results based on the two settings will be distinctly different from each other, because of the compounding or reinvesting effect. If the profitability of pair trading is generated by the long and short positions randomly or evenly, then the empirical results based on the two reinvestment mechanisms should not differ from each other to a noticeable extent, implying that the pair-trading profitability is immune to bankruptcy risk.

Table 2 demonstrates the statistics given the two different mechanisms. It can be observed that the statistics in Panel A and Panel B do not differ from each other in a clear sense. The different reinvestment mechanism or bankruptcy risk does not alter the conclusion of weak pair-trading profitability in terms of average statistics during the whole sampling period for these three markets.

Table 2
Statistics of pair-trading returns in the three stock markets given different reinvestment mechanisms

	China market		Hong Kong market		Taiwan market	
	all trade pairs	*GGR*	all trade pairs	*GGR*	all trade pairs	*GGR*
Panel A: allocate total cash flow equally between the long and short positions						
Average return	0.53%	0.25%	-0.77%	0.17%	0.73%	1.19%
t-statistic	0.59	0.22	-0.97	0.19	1.65	2.95
p-value	55.94%	82.67%	33.44%	85.09%	10.44%	0.45%
Standard error	5.99%	7.49%	7.27%	8.12%	3.42%	3.13%
Panel B: allocate accumulated cash flows from last long and short positions separately						
Average return	0.88%	0.44%	-0.69%	0.15%	0.73%	1.15%
t-statistic	1.14	0.48	-0.91	0.18	1.66	2.95
p-value	26.17%	63.29%	36.52%	86.14%	10.25%	0.46%
Standard error	5.13%	6.08%	6.96%	8.05%	3.43%	3.01%

Notes: Following the information in a previous formation period (a 250-trading-day period), this study conducts pair trading in the subsequent trading period (a 125-trading-day period) on a daily basis. All available pairs without an industry boundary are applied during 1990/01~2017/06. GGR denotes the portfolio specified by Gatev *et al.* (2006) that consists of only one matching partner for each stock by finding the security that minimizes SSD.

Given the same composition of pairs for each portfolio and within the same sampling period, Figure 4 shows the p-values of t-statistics for the equality test of average returns between the two reinvestment mechanisms. We can see that bankruptcy risk does not result in any significant difference. The p-values for all of the enumerated portfolios with different numbers of pairs in the three markets are overall insignificant to a large extent.

The equality test of variances between the two reinvestment mechanisms is similarly overall insignificant to a large extent across all of the enumerated portfolios according to Figure 5. Therefore, bankruptcy risk does not affect the robustness of pair-trading profitability in terms of the first and second moments of return statistics. The following empirical specification applies the setting of equal allocation as the reinvestment mechanism.

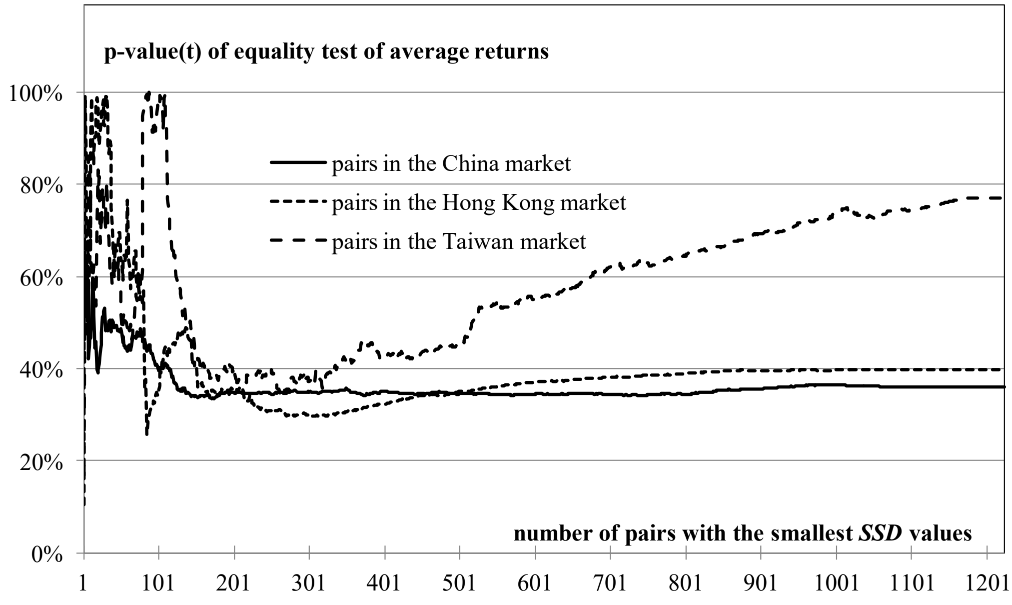


Figure 4
The p-value of t-statistics for the equality test of average returns between two reinvestment mechanisms and the number of trade pairs with the lowest SSD values during 1990/01~2017/06

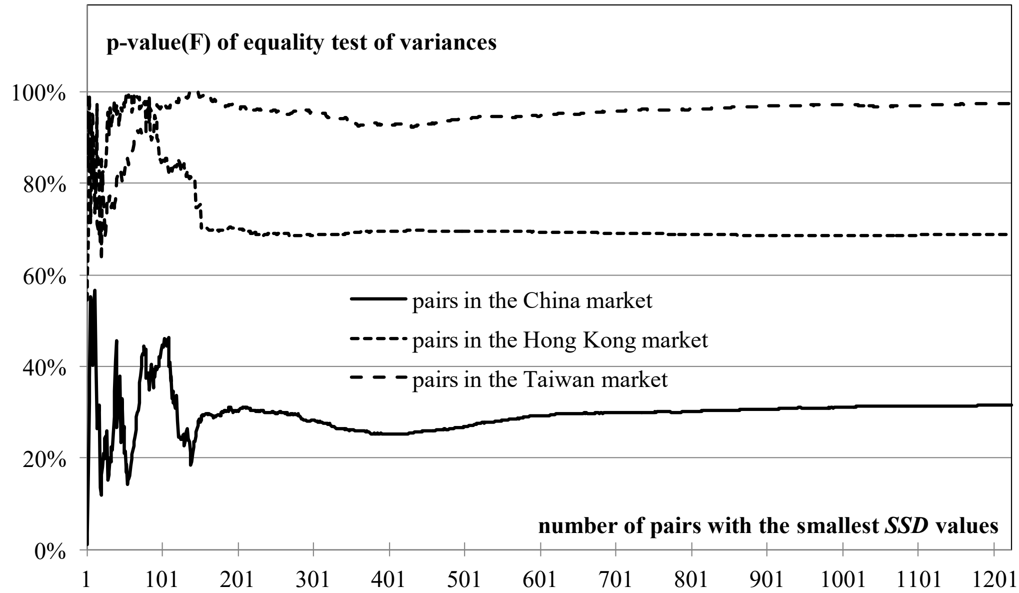


Figure 5
The p-value of F-statistics for the equality test of variances between two reinvestment mechanisms and the number of trade pairs with the lowest SSD values during 1990/01~2017/06

3.2 Distance filter, frequency filter, and pair trading

Gatev *et al.* (2006) apply the distance filter or the sum of squared deviations (*SSD*). Do and Faff (2010) utilize the frequency filter or the number of zero crossings (*ZC*) to quantify the degree of closeness between two normalized price series during their paired relationship. Both a larger *ZC* and a smaller *SSD* mean a closer paired relationship in the formation period and a stronger potential or expectation of pair-trading profitability in the trading period.

Gatev *et al.* (2006) choose only one matching partner with the smallest *SSD* value for each stock to formulate their particular portfolio *GGR*. *GGR* in our study only consists of 50 pairs, because the number of stocks for each market is uniformly 50 in the three representative indices. Our study also choose pairs with the 50 smallest *SSD* values from the 1,225 available pairs to formulate the portfolio *SSD*(50). Thus, even with the same number of pairs, the compositions of the two portfolios may not be the same.

Table 3 summarizes the return statistics of representative portfolios filtered by different ways for each market. *GGR* and *DF* denote the portfolios that choose only one matching partner for each stock with the smallest *SSD* value and with the largest *ZC* value. Both *GGR* and *DF* consist of 50 pairs. *GD* denotes the portfolio consisting of pairs from the intersection of *GGR* and *DF*, implying that the number of qualified pairs may be less than 50. Any pair in this portfolio is ranked within the top 50 either by the filter *SSD* or the filter *ZC*.

From the pool of 1,225 available pairs for each market, *SSD*(50) and *ZC*(50) denote the portfolios that choose pairs with the 50 lowest SSD values and the 50 largest *ZC* values, respectively. *SZ*(50) denotes the portfolio consisting of the first 50 pairs with the smallest *SSD* values and with the largest *ZC* values simultaneously, which implies that a pair in this portfolio may not be ranked within the top 50 either by the filter *SSD* or by the filter *ZC*.

According to Panel A in Table 3, only in the Taiwan market does the distance filter *SSD* help to formulate profitable portfolio *GGR*, which has an average return of 1.19% within a 0.45% significance level. The frequency filter *ZC* takes effect only in the Taiwan market for portfolio *DF*, which has an average return of 0.99% within a 3.60% significance level according to Panel B.

Other enumerated portfolios filtered by the distance or frequency filter separately or double filtered by *SSD* and *ZC* simultaneously cannot provide positive and significant average returns as shown in Panel C in the three markets. Therefore, the pair-trading profitability remains weak in terms of average statistics during the whole sampling period with different filters.

To clarify the effect from the number of pairs in a portfolio, Figure 6 exhausts the relationship between the average return and the number of pairs filtered by smaller *SSD*, larger *ZC*, and double filtered by the two measures. It can be observed that none of the three markets is equipped with a stable or clear pattern that can differentiate the superiority among the three filtering methods. Therefore, the following empirical work applies the filter *SSD* for parsimonious sake.

Table 3

Statistics of pair-trading returns given different filters of trade pairs

	China market		Hong Kong market		Taiwan market	
Panel A: trade pairs filtered by the sum of squared deviations, the distance filter *SSD*.						
	GGR	*SSD*(50)	*GGR*	*SSD*(50)	*GGR*	*SSD*(50)
Average return	0.25%	0.21%	0.17%	-0.03%	1.19%	0.77%
t-statistic	0.22	0.21	0.19	-0.04	2.95	1.69
p-value	82.67%	83.23%	85.09%	96.60%	0.45%	9.63%
Standard error	7.49%	6.58%	8.12%	5.74%	3.13%	3.53%
Panel B: trade pairs filtered by the number of zero crossings, the frequency filter *ZC*.						
	DF	*ZC*(50)	*DF*	*ZC*(50)	*DF*	*ZC*(50)
Average return	-0.04%	0.35%	-1.05%	-0.77%	0.99%	0.56%
t-statistic	-0.02	0.28	-1.12	-1.07	2.15	1.13
p-value	98.55%	77.95%	26.40%	28.70%	3.60%	26.49%
Standard error	12.93%	8.25%	8.59%	6.61%	3.56%	3.84%
Panel C: trade pairs double filtered by *SSD* and *ZC*.						
	GD	*SZ*(50)	*GD*	*SZ*(50)	*GD*	*SZ*(50)
Average return	2.77%	0.46%	2.74%	-0.14%	0.36%	0.24%
t-statistic	2.06	0.39	0.83	-0.22	0.27	0.40
p-value	5.09%	69.94%	41.27%	82.46%	78.64%	69.34%
Standard error	6.59%	7.84%	21.68%	5.67%	9.12%	4.61%

Notes: Following the information in a previous formation period (a 250-trading-day period), this study conducts pair trading in the subsequent trading period (a 125-trading-day period) on a daily basis. All available pairs without an industry boundary are applied during 1990/01~2017/06. The reinvestment mechanism in the same trading period allocates the accumulated total cash flow equally between the long and short positions in the next open operation. *GGR* and *DF* denote the portfolios that choose only one matching partner for each stock with the smallest SSD value and with the largest *ZC* value. *GD* denotes the portfolio consisting of pairs from the intersection of *GGR* and *DF*. *SSD*(50) and *ZC*(50) denote the portfolios that choose pairs with the 50 lowest *SSD* values and the 50 largest *ZC* values, respectively. *SZ*(50) denotes the portfolio consisting of the first 50 pairs with the smallest *SSD* values and with the largest *ZC* values simultaneously.

3.3 Industry effect and pair trading

Gatev *et al.* (2006) and Do and Faff (2010) demonstrate significant industry effects in the U.S. market. They find that portfolios of pair trades from the utility

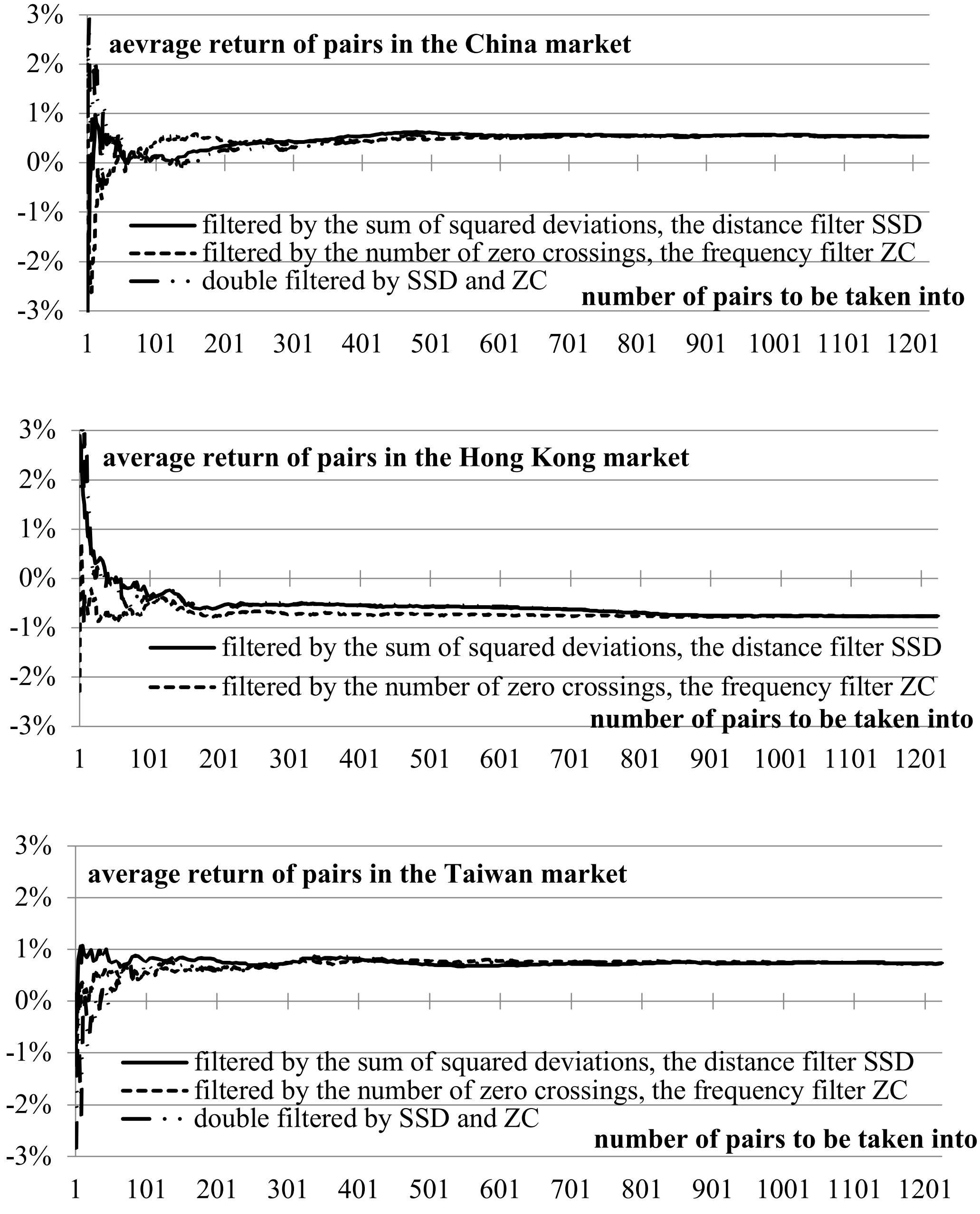


Figure 6
The average return of trade pairs and the number of trade pairs filtered by different measures during 1990/01~2017/06

and financial industries are more profitable than those from other industries. They explain that utility companies face stable demand, low differentiation of product, and a general form of rate regulation. Financial companies are exposed by common macroeconomic factors such as interest rates and unemployment shocks. Hence, share prices within these two industries are more likely to move together and their pair trading is more profitable.

Note that the China, Hong Kong, and Taiwan stock markets are equipped with unique structures in their industry compositions. For instances, fundamental and resource companies take the largest pie in the Shanghai Stock Exchange 50 Index (SSE50). Fundamental, resource, and financial companies take the highest percentage in the Hang Seng Index (HSI). For Taiwan, its electronics companies make up a large part of the FTSE TWSE Taiwan 50 Index (TW50).

A classification that is too detailed may deteriorate the availability of stocks within one group, and thus this study constructs only three industry groups for each market and takes their unique industry groups into the categorization. They include the group of financial stocks for all three markets, the group of fundamental and resource stocks for the China and Hong Kong markets only, the group of electronics stocks for the Taiwan market only, and the group of the rest of stocks for all three markets.

Each stock is attributed to one industry group exclusively by the keywords or phrases appearing in the company’s name or its industry description stated in Wikipedia. There are 25, 14, and 13 firms categorized in the financial groups for the three markets, because their names or their industry descriptions involve keywords or phrases including bank, banking, financial service, etc. Similarly, if a firm’s name or industry description involves keywords including steel, petroleum, utility, transportation, automotive, mining, etc., then it is attributed to the group of fundamental and resource stocks. There are 21 and 33 stocks categorized in this type of industry group for the China and Hong Kong markets respectively.

We note that the 21 electronics firms are very important and unique in TW50. Thus, this study categorizes them into a special industry group exclusively for the

Taiwan market. Finally, except for those stocks already categorized into the financial, fundamental and resource, and electronics groups in the three markets, those remaining stocks in SSE50, HIS, and TW50 are categorized into the groups of other for the three markets.

Table 4 summarizes the average return statistics of different industry groups in the three markets. None of the three industry groups in the China market provide significant and positive average returns, but the average returns of financial pair trades in the Hong Kong and the Taiwan markets are positive and significant within the 5% level, bringing respective average returns of 2.07% and 1.53% at significance levels of 2.59% and 1.19%. This is consistent with the argument that financial companies are exposed by common systematic risk factors or regulated by the government in a more frequent or homogenous way.

Table 4

Statistics of pair-trading returns for different industry groups

	China market	**Hong Kong market**	**Taiwan market**
	financial trade pairs	financial trade pairs	financial trade pairs
Average return	0.26%	2.07%	1.53%
t-statistic	0.12	2.27	2.60
p-value	90.21%	2.59%	1.19%
Standard error	13.05%	8.36%	4.48%
	fundamental or resource trade pairs	fundamental or resource trade pairs	electronics trade pairs
Average return	1.26%	-0.87%	0.22%
t-statistic	1.47	-0.91	0.35
p-value	14.91%	36.44%	72.89%
Standard error	5.40%	8.84%	4.63%
	other trade pairs	other trade pairs	other trade pairs
Average return	0.56%	-10.79%	0.51%
t-statistic	0.29	-1.60	1.04
p-value	77.14%	11.83%	30.03%
Standard error	10.64%	43.30%	3.75%

Notes: Following the information in a previous formation period (a 250-trading-day period), this study conducts pair trading in the subsequent trading period (a 125-trading-day period) on a daily basis during 1990/01~2017/06. The reinvestment mechanism in the same trading period allocates the accumulated total cash flow equally between the long and short positions in the next open operation.

Figure 7 demonstrates the relationship between the average return and the number of pairs within different industry groups. We see that some industry effects exist in the three markets. They are the fundamental or resource industry group for the China market, and the financial industry groups for the Hong Kong and Taiwan markets. Nevertheless, some delicate facts remain to be clarified. Figure 8 supplements the analyses on this argument.

In the China market, pairs from the fundamental or resource industry group outperform other groups as shown in Figure 7. However, the average returns of portfolios formulated by different number of pairs in this group are unanimously insignificant as shown in Figure 8. In contrast, all of the average returns of portfolios formulated by different number of financial pairs are significant as shown in Figure 8, implying that the financial industry effect exists in the Hong Kong and Taiwan markets.

3.4 Short-selling deregulation, industry effect, and pair trading

In addition to different types of risk preference (Wang *et al.*, 2016) and trading experience (Lin and Yang, 2016), a short-selling restriction makes pair-trading investors have to hold enough long positions beforehand to establish a short position in a pair trade relationship. After deregulation of such a restriction, both institutional and individual investors are able to implement their pair-trading strategies at lower costs. The literature finds that regulators around world tend to impose suspensions or constraints on short sales to mitigate potential damages to markets during crises.

These policies are counter-intuitively detrimental or neutral for liquidity, slowing down price discovery and failing to support prices (Diether *et al.*, 2009; Beber and Pagano 2013; Boehmer *et al.*, 2013). Kolasinski *et al.* (2013) suggest that such restrictions will not reduce informed short selling and may actually increase the proportion of informed short sellers. Moreover, relaxing these constraints is not associated with an increase in either price instability or the occurrence of extreme negative returns (Saffi and Sigurdsson, 2011).

The China, Hong Kong, and Taiwan markets have experienced different

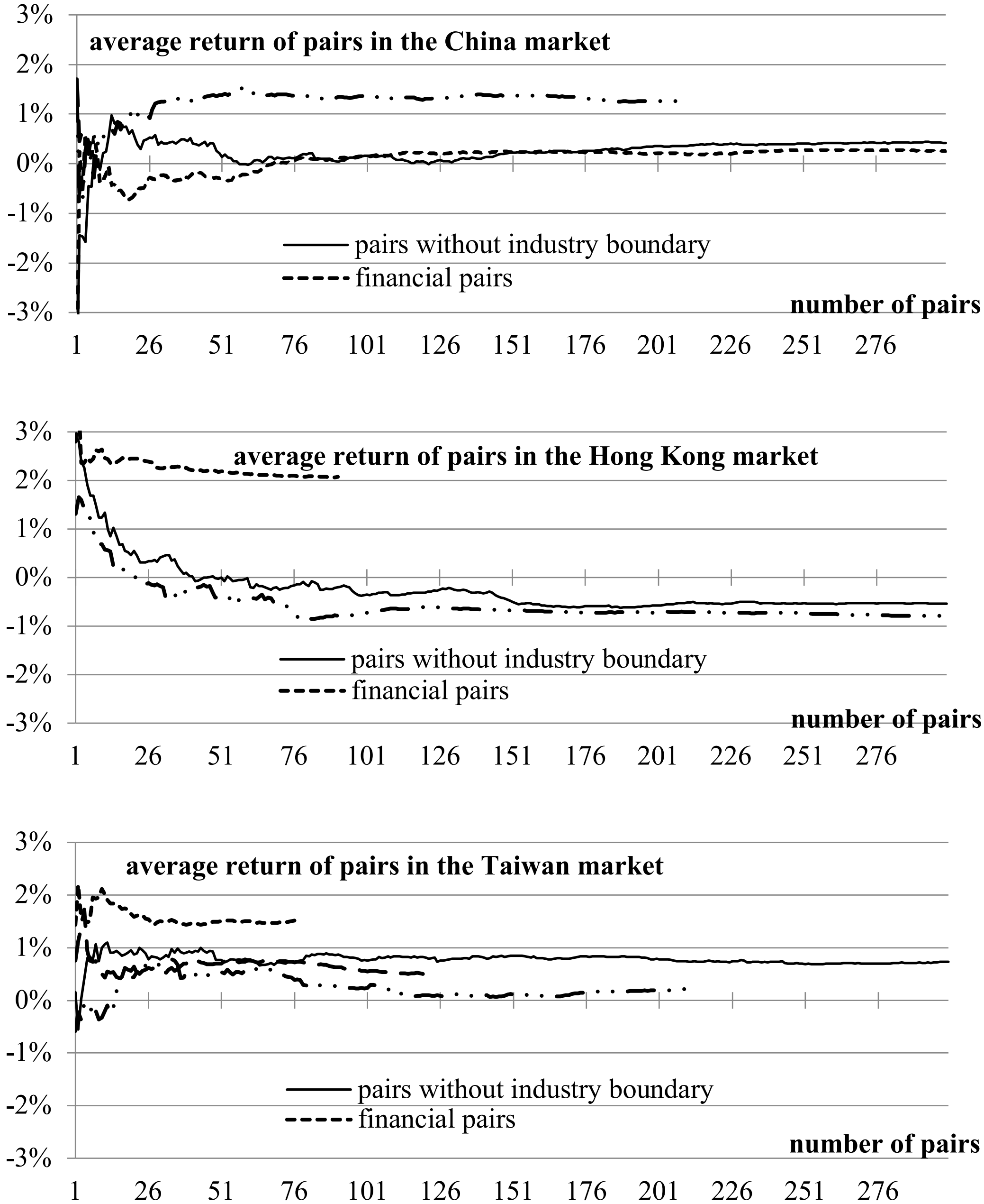


Figure 7

The average return of trade pairs and the number of trade pairs within different industry groups during 1990/01~2017/06

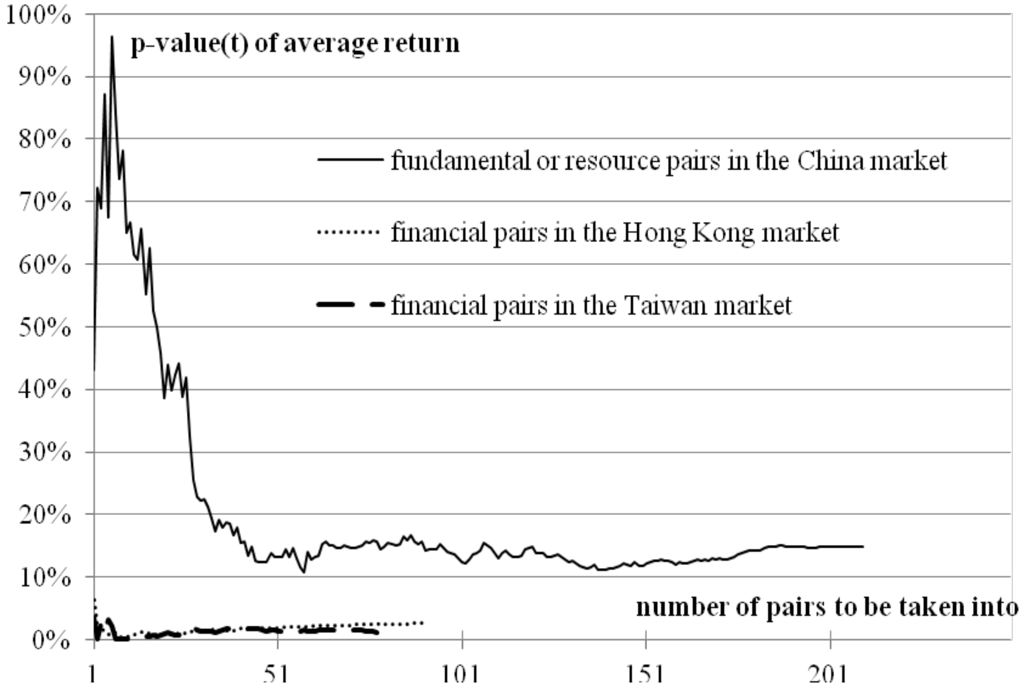


Figure 8
The p-value of t-statistics for the average return of trade pairs from different industry groups during 1990/01~2017/06

deregulation processes of short-selling policies, which can be a robustness factor of pair-trading profitability. Specifically, short-selling was first launched in the mainboard of the Taiwan market in the 1980s. On May 16, 2005, positions in the FTSE TWSE Taiwan 50 Index were allowed to be executed below the last trading-day closing price (Taiwan Stock Exchange Corporation, TWSE, 2017). Thus, both institutional and individual investors are able to implement pair-trading strategies in a friendly environment since then.

The Stock Exchange of Hong Kong (HKEx) introduced a short-selling scheme in January 1994 with a limited number of eligible positions. Several temporary suspensions or alterations followed later on. At present, only stocks specified by the HKEx can be sold short. Moreover, there is a restricted setting such as the additional requirement that the executable short-selling price cannot be lower than the latest best selling price, which must be higher than the last trading-day closing price (Stock Exchange of Hong Kong, 2017).

The China Securities Regulatory Commission (CSRC) formally launched its short-selling policy on March 31, 2010 to the constituent stocks of Shanghai 50 and Shenzhen 40 index, but the short-selling price cannot be executed below the last trading-day closing price (Shanghai Stock Exchange, 2017). Therefore, this study applies 2010/3, 1994/1, and 2005/6 as the cutoff dates of different sampling periods of these short-selling policies in the China, the Hong Kong, and the Taiwan markets. It helps to investigate the effects resulting from the deregulation of short-selling policies on pair-trading profitability.

As shown in Table 5, the average returns of all pairs and portfolio *GGR* in the China and the Hong Kong markets are very insignificant no matter after or before deregulation according to their p-values. This implies that the short-selling restriction plays a minor role in the determinants of pair-trading profitability in the two markets. However, this is not the case in the Taiwan market.

The average returns of all pairs and portfolio *GGR* in the Taiwan market are positive and significant within the 10% level before the deregulation that a short sale could be executed below the last trading-day closing price. Nevertheless, the average returns become insignificant to a large extent after the deregulation. Specifically, the average returns are 1.22% and 1.78% with p-values of 6.60% and 0.27% before the deregulation for the two enumerated portfolios. Their average returns turn into -0.06% and 0.25% with p-values of 90.30% and 63.68% after the deregulation.

We note that the China and Hong Kong markets do not allow a short sale to be executed below the last closing price as the Taiwan market does. Therefore, it is consistent with the argument that pair-trading sentiment rises with lower costs in a friendly market such as in the Taiwan market, and more pair-trading activities thereby diminish profitability in a more obvious pattern as in the Taiwan market. It also could result from the fact that the pairs themselves are not profitable enough in the first place, which makes the short-selling restriction neutral to

Table 5

Statistics of pair-trading returns for different sampling periods — before and after short-selling deregulations

	China market		Hong Kong market		Taiwan market	
	all trade pairs	*GGR*	all trade pairs	*GGR*	all trade pairs	*GGR*
Panel A: before the date of short-selling deregulation						
Average return	1.23%	0.22%	-1.37%	-0.43%	1.22%	1.78%
t-statistic	1.26	0.19	-0.82	-0.22	1.90	3.22
p-value	23.10%	84.92%	41.99%	82.71%	6.60%	0.27%
Standard error	3.67%	4.16%	10.08%	11.67%	3.90%	3.36%
Panel B: after the date of short-selling deregulation						
Average return	0.20%	0.26%	-0.32%	0.60%	-0.06%	0.25%
t-statistic	0.16	0.17	-0.53	1.07	-0.12	0.48
p-value	87.16%	86.89%	59.85%	29.22%	90.30%	63.68%
Standard error	6.84%	8.68%	4.23%	3.96%	2.31%	2.51%

Notes: Following the information in a previous formation period (a 250-trading-day period), this study conducts pair trading in the subsequent trading period (a 125-trading-day period) on a daily basis during 1990/01~2017/06. All available pairs without an industry boundary are applied. The reinvestment mechanism in the same trading period allocates the accumulated total cash flow equally between the long and short positions in the next open operation. 2010/3, 1994/1, and 2005/6 are the cutoff dates before and after the short-selling policies in the China, Hong Kong, and Taiwan markets appear. *GGR* denotes the portfolio specified by Gatev *et al.* (2006) that consists of only one matching partner for each stock by finding the security that minimizes *SSD*.

pair-trading profitability. By investigating how the return statistics change before and after deregulation for those profitable pairs only, the deregulation effect can be further discerned.

As shown in Table 6, the average returns of all financial pairs and the portfolio GGR formulated by financial stocks are 4.05%, 5.80%, 2.40%, and 2.87% with p-values of 4.21%, 2.46%, 0.93%, and 0.21% before their deregulation dates in the Hong Kong and the Taiwan markets. All of them are positive within the 5% significance level. It is anticipated that these figures unanimously become very insignificant after deregulation. Specifically, the average returns of all financial pairs in the two markets drop from 4.05% and 2.40% to 0.65% and 0.61% before and after their deregulation dates. Their p-values diminish

Table 6
Return statistics of financial trade pairs before and after short-selling deregulation appears in the Hong Kong and Taiwan markets

	Hong Kong market		Taiwan market	
	all financial trade pairs	*GGR* by financial stocks	all financial trade pairs	*GGR* by financial stocks
Panel A: before the date of short-selling deregulation				
Average return	4.05%	5.80%	2.40%	2.87%
t-statistic	2.11	2.35	2.76	3.33
p-value	4.21%	2.46%	0.93%	0.21%
Standard error	11.35%	14.58%	5.14%	5.03%
Panel B: after the date of short-selling deregulation				
Average return	0.65%	0.27%	0.21%	0.32%
t-statistic	0.92	0.32	0.35	0.57
p-value	36.30%	75.26%	73.08%	57.68%
Standard error	4.97%	5.95%	2.87%	2.71%

Notes: Following the information in a previous formation period (a 250-trading-day period), this study conducts pair trading in the subsequent trading period (a 125-trading-day period) on a daily basis during 1990/01~2017/06. The reinvestment mechanism in the same trading period allocates the accumulated total cash flow equally between the long and short positions in the next open operation. 1994/1 and 2005/6 are the cutoff dates before and after the short-selling policies in the Hong Kong and Taiwan markets appear. *GGR* by financial stocks denotes the portfolio that consists of only one matching partner for each stock by finding the security that minimizes *SSD* within the financial industry group.

from significant 4.21% and 0.93% to insignificant 36.30% and 73.08%.

The above findings match the argument that short-selling deregulation encourages pair-trading activities and thereby diminishes profitability. Even though the industry effect contributes to the pair-trading profitability in the Hong Kong and the Taiwan markets during the entire sampling period, it can be diluted by the impact resulting from the short-selling deregulation.

3.5 Investor discipline and pair-trading profitability

Gatev *et al.* (2006) specify the length settings of 12-month/6-month for the formation/trading periods in their pair-trading study. However, the behavior issue may make investors lose their investment discipline in reality. Shefrin and Statman (1985) define the reluctance to realize losses for retail investors as the disposition effect. Odean (1998) empirically tests this hypothesis by analyzing real trading accounts. He finds a tendency of investors to hold positions at a loss for too long and sell winning ones too soon. The disposition effect also has been found in institutional trading such as for professional futures traders (Locke and Mann, 2005) and mutual fund managers (Frazzini, 2006).

At the end of a trading period, pairs still in an open status imply that they are either not profitable enough or losing money at that time. Are investors determined enough to mark these pairs to market to maintain the discipline as they had planned at the beginning of the trading period? They may overlook these pairs still in the open status to lessen any discomfort or regret at the end of the trading period. They may even formulate their limited perception of the pair-trading profitability by those pairs with complete open-close loops in the same trading period only.

The extent of investor discipline is not directly observable. However, a comparison of return statistics between the two scenarios, with and without the marking-to-market discipline at the end of trading periods, can be conducted. As shown in Figure 9, the average returns for all portfolios consisting of different numbers of pairs with investor discipline are unanimously inferior to those ones without investor discipline in the three markets. This result is not surprising. However, if investors formulate their expectation by the scenario without the discipline only, then a misleading lucrative comprehension of pair-trading profitability thus arises.

Although the setting without investor discipline is inappropriate in the academic sense, the resulting average returns are much larger than those in the scenario with investor discipline according to Figure 9. This might imply that pairs still in an open status at the end of the trading period could provide potential profitability in the future. A comparison between different lengths of trading period given the setting with investor discipline helps to explore this

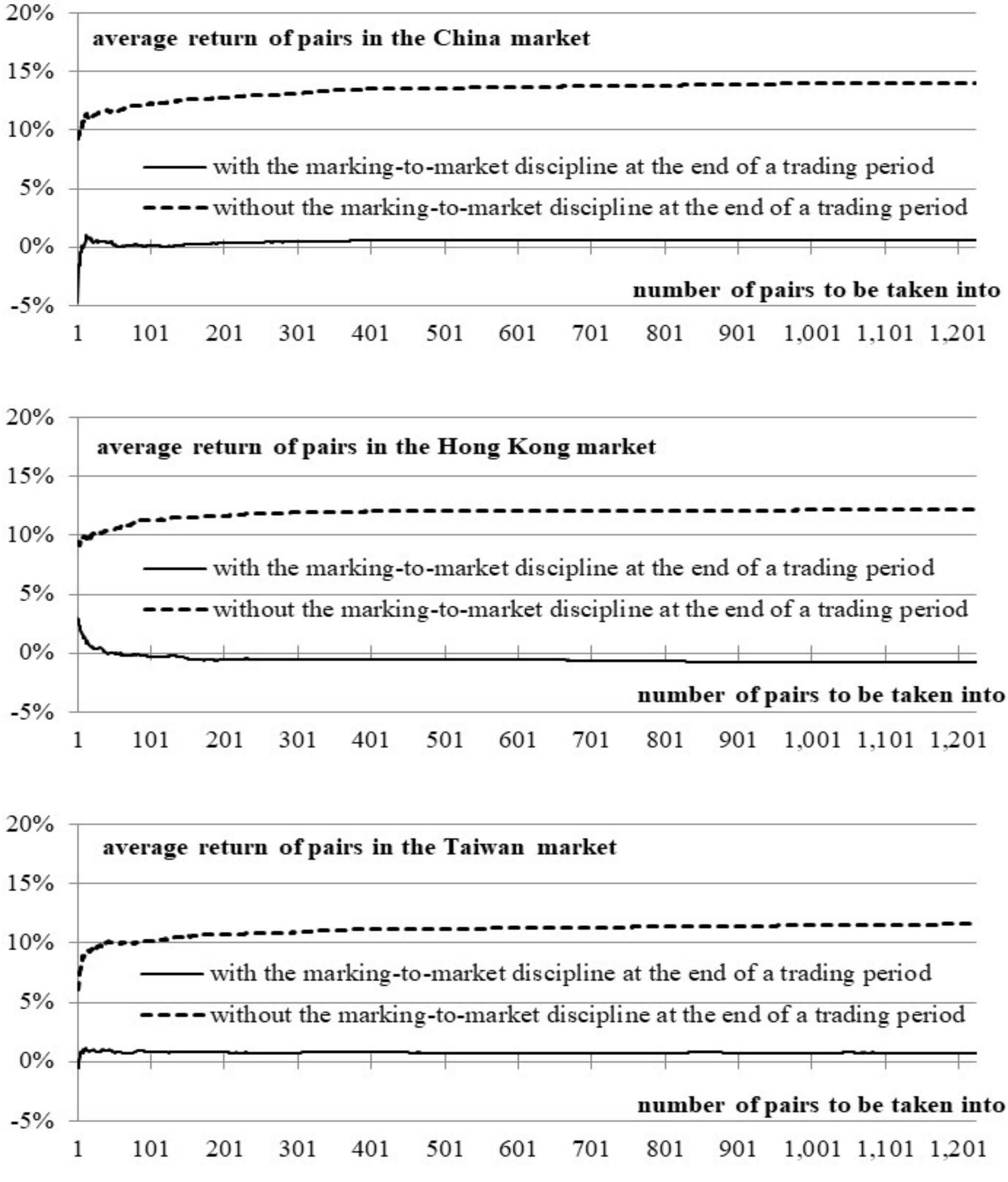


Figure 9

The average return of trade pairs and the number of trade pairs with and without the marking-to-market discipline at the end of a trading period during 1990/01~2017/06

problem in a further step.

As shown in Figure 10, the 250-trading-day setting does not provide higher average returns in the three markets. Specifically, when more than 4, 23, and 21 pairs are taken into consideration, the average returns given the 125-trading-day setting are unanimously higher than those given the 250-trading-day setting in the three markets. This means that pairs still in an open status at the end of the trading periods cannot provide stable and extra profitability by extending the length of the trading period. This should be kept in mind for investors when formulating their expectation on any pair-trading profitability.

3.6 Short-selling deregulation effect under considerations of bankruptcy risk, filter type, industry effect, and investor discipline

The deregulation effect may play a minor role on profitable pair-trading portfolios, because of the interfering effects resulting from those considerations mentioned in the context. Therefore, this subsection further investigates how return statistics change before and after short-selling deregulation arises given these considerations.

Based on the unequal reinvestment mechanism, Table 7 demonstrates that only the average returns of all pairs and portfolio *GGR* in the Taiwan market are positive and significant within the 10% level before short-selling deregulation. Other enumerated portfolios in the China and the Hong Kong markets are very insignificant no matter after or before short-selling deregulation according to their p-values. This denotes that a discussion of the deregulation effect is trivial in these two markets. Specifically, the average returns are 1.20% and 1.64% with p-values of 6.95% and 0.35% before deregulation for the enumerated portfolios in the Taiwan market. Their average returns turn into -0.06% and 0.25% with p-values of 90.30% and 63.68% after deregulation, thus demonstrating a quite similar empirical result as illustrated in Table 5. Therefore, the short-selling deregulation effect holds given the consideration of bankruptcy risk in the Taiwan market.

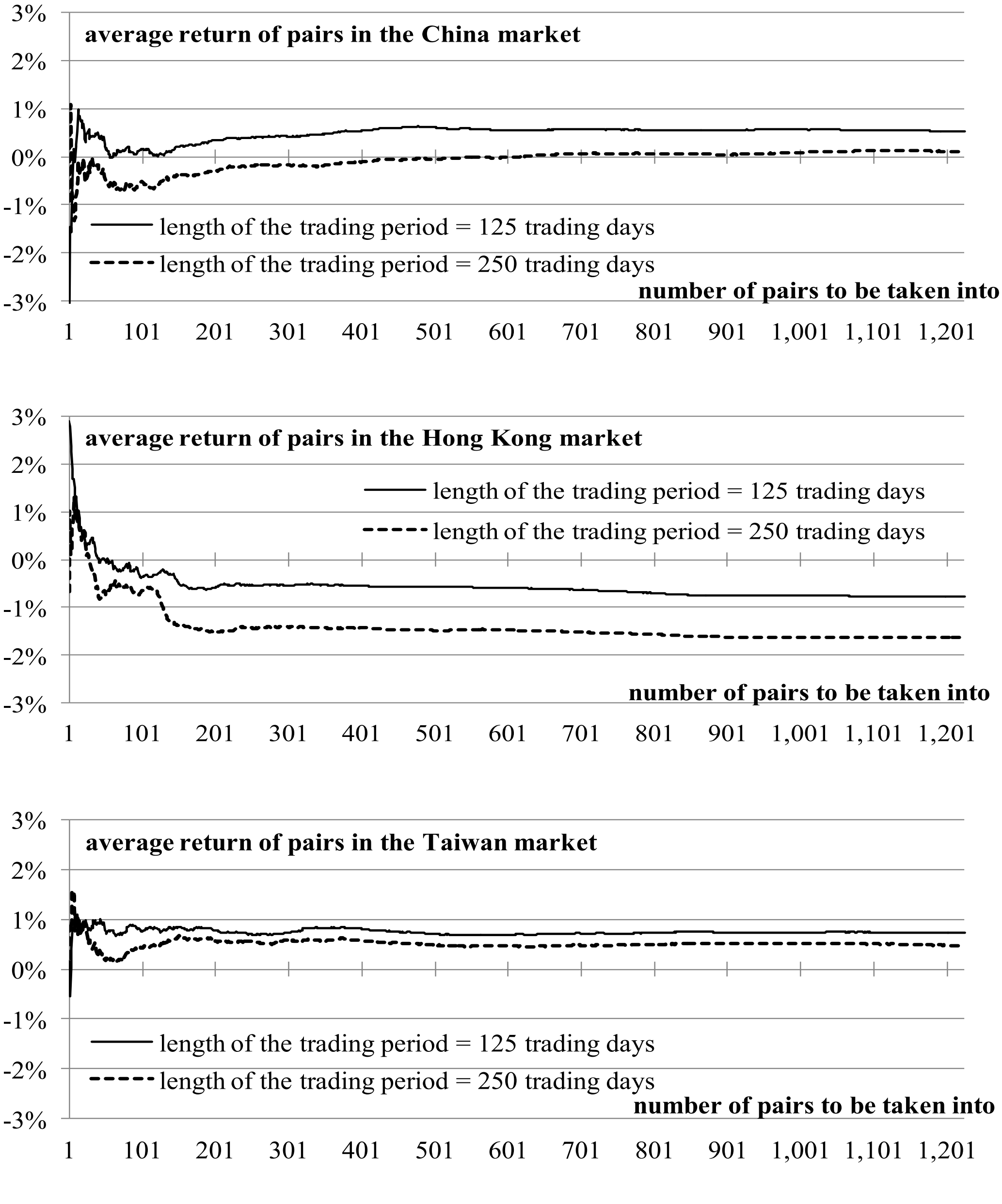


Figure 10

The average return of trade pairs with investor discipline and the number of trade pairs given different lengths of trading period during 1990/01~2017/06

Table 7

Statistics of pair-trading returns before and after short-selling deregulation appears with unequal reinvestment mechanism by separately allocating the cash flows accumulated from the last long and short positions to the next open occasion

	China market		Hong Kong market		Taiwan market	
	all trade pairs	*GGR*	all trade pairs	*GGR*	all trade pairs	*GGR*
Panel A: before the date of short-selling deregulation						
Average return	0.73%	0.60%	-1.22%	-0.42%	1.20%	1.64%
t-statistic	0.68	0.47	-0.76	-0.22	1.87	3.13
p-value	50.10%	64.32%	45.11%	82.81%	6.95%	0.35%
Standard error	5.84%	7.00%	9.60%	11.54%	3.90%	3.18%
Panel B: after the date of short-selling deregulation						
Average return	0.20%	0.26%	-0.32%	0.60%	-0.06%	0.25%
t-statistic	0.16	0.17	-0.53	1.07	-0.12	0.48
p-value	87.16%	86.89%	59.85%	29.22%	90.30%	63.68%
Standard error	6.84%	8.68%	4.23%	3.96%	2.31%	2.51%

Notes: Following the information in a previous formation period (a 250-trading-day period), this study conducts pair trading in the subsequent trading period (a 125-trading-day period) on a daily basis during 1990/01~2017/06. All available pair trades without an industry boundary are applied. Here, 2010/3, 1994/1, and 2005/6 are the cutoff dates before and after the short-selling policies in the China, Hong Kong, and Taiwan markets. *GGR* denotes the portfolio specified by Gatev *et al.* (2006) that consists of only one matching partner for each stock by finding the security that minimizes *SSD*.

Table 8 demonstrates the return statistics of portfolio *SSD*(50), which is formulated by the distance filter, portfolio *ZC*(50), which is formulated by the frequency filter, and portfolio *SZ*(50), which is formulated by the distance and frequency filters simultaneously. All of the three portfolios consist of the top fifty pairs according to their formulation rules. Only *SSD*(50) in the Taiwan market exhibits a significantly positive average return before deregulation, or 1.61% with a p-value of 1.02%. It turns into an insignificant negative average return after deregulation, or -0.59% with a p-value of 35.30%. This is also consistent with the argument that pair-trading sentiment rises with lower costs in a friendly market such as in the Taiwan market, and more pair-trading activities thereby diminish the profitability in a more obvious pattern. For those portfolios formulated by the frequency filter and simultaneously formulated by the distance and frequency filters, their average return statistics are very insignificant no matter after or before short-selling deregulation according to their p-values, meaning that the deregulation effect is trivial for further discussion in the additional consideration of the frequency filter.

As shown in Table 6, the average returns of financial trade pairs in the Hong Kong and Taiwan markets are significant and positive within the 5% level before deregulation. They then turn into insignificance after the deregulation date. Such a transformation is consistent with the argument that pair-trading sentiment rises and more pair-trading activities thereby diminish the profitability in an obvious

Table 8

Statistics of pair-trading returns before and after short-selling deregulation appears based on different filters

	China market			Hong Kong market			Taiwan market		
	SSD(50)	*ZC*(50)	*SZ*(50)	*SSD*(50)	*ZC*(50)	*SZ*(50)	*SSD*(50)	*ZC*(50)	*SZ*(50)
Panel A: before the date of short-selling deregulation									
Average return	0.13%	0.24%	0.39%	-0.51%	-1.32%	-0.23%	1.61%	0.83%	0.72%
t-statistic	0.10	0.14	0.24	-0.41	-0.98	-0.21	2.71	1.08	0.85
p-value	92.12%	89.02%	81.20%	68.41%	33.59%	83.86%	1.02%	28.82%	40.29%
Standard error	7.36%	9.48%	8.99%	7.45%	8.13%	6.62%	3.62%	4.69%	5.20%
Panel B: after the date of short-selling deregulation									
Average return	0.38%	0.58%	0.60%	0.33%	-0.36%	-0.07%	-0.59%	0.12%	-0.55%
t-statistic	0.30	0.44	0.47	0.56	-0.48	-0.10	-0.95	0.32	-0.77
p-value	77.02%	66.53%	64.91%	57.83%	63.39%	92.04%	35.30%	75.46%	44.91%
Standard error	4.73%	4.94%	4.83%	4.10%	5.28%	4.93%	2.97%	1.83%	3.42%

Notes: Following the information in a previous formation period (a 250-trading-day period), this study conducts pair trading in the subsequent trading period (a 125-trading-day period) on a daily basis during 1990/01~2017/06. All available pair trades without an industry boundary are applied. Here, 2010/3, 1994/1, and 2005/6 are the cutoff dates before and after the short-selling policies in the China, Hong Kong, and Taiwan markets. *SSD*(50) and *ZC*(50) denote the portfolios that choose pair trades with the 50 lowest *SSD* values and the 50 largest *ZC* values, respectively. *SZ*(50) denotes the portfolio consisting of the first 50 pairs with the smallest *SSD* values and with the largest *ZC* values simultaneously.

pattern. Table 9 demonstrates the return statistics of pair-trading portfolios that are formulated within different industry groups in the three markets.

It can be found that except for the financial pair trades in the Hong Kong and Taiwan markets, other numerated portfolios within different industry groups and markets are all very insignificant to a noticeable extent before and after deregulation. Therefore, the deregulation effect is trivial in the consideration of different industry groups or markets except for the financial industry group of the Hong Kong and Taiwan markets.

As discussed in subsection 4.5, investors may lose their investment discipline in reality and may be reluctant to offset unprofitable pair trades still in an open status to lessen discomfort or regret at the predetermined end of the trading period ex post. However, a discussion of the deregulation effect needs a definite setting of investment horizon ex ante to calculate return statistics. Therefore, the deregulation effect contradicts the behavior without any investment discipline in the first place, and their relationship will not be further discussed in this study.

4. Conclusions

The domestic market capitalization of the main stock exchanges in Taiwan, Hong Kong, and China is US$11,349 billion at the end of 2016 (Statista, 2017), making them targets for investors to implement various trading strategies. This study explores the pair-trading strategy in the three markets under unified empirical specifications of sampling period, parameters, and filters to prevent voiding any comparison results. Moreover, this study looks to explain the profitability difference among the three stock markets in terms of short-sale deregulation types and other robust factors. Similar studies with simultaneous considerations of a unified setting of the three markets, deregulation types, and other robust factors are less available in the literature.

According to the empirics and given different numbers of pairs to be taken into consideration, the Taiwan market performs better than the China and the Hong Kong markets in terms of the average returns during the entire sampling period, 1990/1/4~2017/6/30. The empirical results are robust to the bankruptcy

Table 9
Statistics of pair-trading returns before and after short-selling deregulation appears within different industry groups

Panel A: before the date of short-selling deregulation			
China	financial	fundamental or resource	other
Average return	-0.83%	1.35%	3.34%
t-statistic	-0.26	1.15	1.37
p-value	79.84%	26.20%	18.87%
Standard error	16.14%	6.02%	10.03%
Hong Kong	financial	fundamental or resource	Other**
Average return	4.05%	-2.22%	
t-statistic	2.11	-1.04	
p-value	4.21%	30.42%	
Standard error	11.35%	12.75%	
Taiwan	financial	electronics	other
Average return	2.40%	0.08%	0.99%
t-statistic	2.76	0.09	1.41
p-value	0.93%	92.54%	16.63%
Standard error	5.14%	4.94%	4.28%
Panel B: after the date of short-selling deregulation			
China	financial	fundamental or resource	other
Average return	0.21%	1.07%	-2.82%
t-statistic	2.49	0.95	-0.98
p-value	22.73%	35.71%	34.32%
Standard error	3.33%	4.21%	10.71%
Hong Kong	financial	fundamental or resource	other
Average return	0.65%	0.11%	-10.79%
t-statistic	0.92	0.20	-1.60
p-value	36.30%	84.51%	11.83%
Standard error	4.97%	3.98%	43.30%
Taiwan	financial	electronics	other
Average return	0.21%	0.41%	-0.28%
t-statistic	0.35	0.46	-0.51
p-value	73.08%	64.88%	61.32%
Standard error	2.87%	4.24%	2.60%

Notes: Following the information in a previous formation period (a 250-trading-day period), this study conducts pair trading in the subsequent trading period (a 125-trading-day period) on a daily basis during 1990/01~2017/06. The reinvestment mechanism in the same trading period allocates the accumulated total cash flow equally between the long and short positions in the next open operation. Here, 1994/1 and 2005/6 are the cutoff dates before and after the short-selling policies in the Hong Kong and Taiwan markets.
** Time series data before the deregulation date within this industry group are too short to calculate statistics.

risk addressed by Gatev *et al.* (2006) and different filters of pair trades addressed by Do and Faff (2010).

For investors interested in these emerging or developing markets, not only is the profitability of investment strategies explored, but the institutional factors underlying the trading deserve more attention. For instance, while no significant and positive industry effect occurs in the China market, financial pair trades prevail in the Hong Kong and the Taiwan markets. This is consistent with the argument that financial companies are more constricted by their government. Hence, share prices of financial positions are more likely to move together and their pair trades are more profitable.

In terms of short-selling regulation, all three markets allow margin trading, but the China and the Hong Kong markets do not allow any short sale to be executed below the last closing price like the Taiwan market does. The empirical results show that the profitability diminishes in a more obvious pattern after deregulation in the Taiwan market than it does in the China and Hong Kong markets. This is consistent with the argument that pair-trading sentiment rises with lower costs in a friendly market, and more pair-trading activities thereby diminish the profitability in a clear obvious pattern.

Except for those unprofitable pair trades, the deregulation effect on the profitable financial pair trades in the Hong Kong and the Taiwan markets provides further empirical evidence. Even though the industry effect contributes to pair-trading profitability in the two markets, it can be further diluted by the impact resulting from the short-selling deregulation.

Investors interested in pair trading in practice can choose to implement their strategies in markets with more short-sale regulations, particularly for those investors holding stocks already before they consider any pair-trading strategy. This is because they are immune to the short-sale regulation and are expected to outperform those investors who only have pair-trading sentiment, but who do not hold enough stocks beforehand to complete a long-short operation. Similarly, pair trades from a more regulated industry such as the financial industry can be more profitable. However, such an industry effect can be further diluted by the impact resulting from short-selling deregulation later on.

We also see that in order to lessen discomfort or regret, investors may not really mark pairs still in an open status to market at the end of trading period because these pairs are at a loss. This fails the investment discipline as planned from the beginning. Moreover, if market-wide perception is limited by those pairs with complete open-close loops in the same trading period only, ignoring those pairs without investment discipline, then a misleading lucrative comprehension of profitability thus arises.

This study directly applies the usual or conventional levels of 1%, 5%, or 10% as testing thresholds to avoid possible conflicts resulting from miscellaneous, ad hoc, or arbitrary settings during the procedure of pair-trading simulation or calculation. Nevertheless, this study does appreciate the referee's valuable comment on the determination of an appropriate level of significance and concur with the literature that key factors such as sample size, power of the test, and expected losses from Type I and II errors should be taken into account to produce more sensible testing results (Leamer, 1978; Kim and Ji, 2015). Therefore, this comment is covered here in the conclusions to inspire future improvement on this issue.

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