The Effect of the Asian Financial Crisis on Inter-Market Arbitrage Efficiency between Individual Stock Futures and Underlying Stocks

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Abstract

Before the Asian financial crisis and after discretionary government intervention in the stock and index futures markets, the prices of individual stock futures were all within the no-arbitrage bounds when realistic estimates of trading costs were accounted for. Potential arbitrage opportunities emerged during the crisis, but despite the high degree of market volatility both the number of instances and magnitude of mispricing were quite limited. There were only 35 occurrences of mispricing for members and 26 for non-members in the 15 months surrounding the crisis. We attribute this individual futures/stock price alignment to onscreen trading in both markets.

JEL classifications: G13/G19
Keywords: financial crisis; stock futures; arbitrage efficiency; price alignment.

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1. Introduction

Price and quantity uncertainty are major hurdles to arbitrage (Kumar and Seppi 1994), and more so under stressful market conditions because arbitrageurs face the risk of low liquidity and adverse selection. During the October 1987 stock market crash, the reporting time lag, execution risk, and order congestion that are inherent in floor-trading systems were purportedly the main reasons for the large negative basis between index futures and the stocks traded on the New York Stock Exchange (e.g., Kleidon 1992, Kleidon and Whaley 1992, Harris 1989, Stoll and Whaley 1990). However, Fung and Draper (2003) show that during the Asian financial crisis that hit Hong Kong in 1997, despite extreme volatility in the stock and index futures markets, the alignment between futures and the underlying cash index remained largely unaffected. They attribute this index futures/stock price integration to the onscreen trading system for stocks that provides instantaneous execution and continuous updates of market information. Nonetheless, Draper and Fung (2003) find that the arbitrage efficiency between the index futures and the cash index was impeded during the government's discretionary intervention in the stock and index futures markets in 1998.

Previous research into arbitrage efficiency has used market indices. Miller, Muthuswamy, and Whaley (1994) demonstrate that mean reversion in the index basis change is a statistical illusion, due to infrequent trading of individual stocks within the index portfolio. Harris (1989) finds that the large futures index basis that was observed during the week of the 1987 stock market crash can be explained by non-synchronous trading. Fung and Draper (2000) and Draper and Fung (2003) use index futures and stock indices in their study of arbitrage efficiency during the Asian financial crisis and the subsequent government intervention. However, arbitrage is direct and convenient for individual stock futures, and the cost-of-carry model is appropriate by implementing

individual stocks and stock futures. In this paper, we examine the inter-market pricing efficiency using individual stock futures contracts and the underlying stocks during the Asian financial crisis and the subsequent government's direct interventions in Hong Kong's financial markets. The stocks that we include in the analysis are the constituent blue chips of the market index. To minimize the effect of non-synchronous prices, we match the prices of individual stock futures and the underlying cash stocks within narrow one-minute intervals because the underlying cash asset is a single stock instead of a basket of stocks.

Draper and Fung (2003) describe a situation in which the stock index was screen-traded but the index futures were traded in the pit via open outcry. In our study, both the futures on individual stocks and the underlying stocks were electronically traded. Electronic trading enhances the price discovery process (Domowitz 1990) because price and liquidity information are continuously updated. Cheng, Fung, and Tse (2004), Blennerhasset and Bowman (1998), and Frino, McInish and Toner (1998) conclude that switching from open-outcry to screen-based trading improves market efficiency. Beelders and Massey (2002) find that the index futures market became more informative after the introduction of electronic trading. Cheng, Fung, and Tse (2004) also find that the switching from open-outcry to electronic trading greatly shortens the time for correcting mispricings. Electronic trading minimizes the market friction that arises from manual quote-revisions and execution delays under an open-outcry system, and provides up to the moment price and liquidity information. We postulate that onscreen trading systems for both the individual stock futures and the underlying stock help to maintain the individual stock futures/stock price alignments even under stressful market conditions.

We find that potential arbitrage opportunities emerged during the Asian financial crisis. However, despite high market volatility, both the number and magnitude of

mispricing were quite limited in the 15 months surrounding the financial crisis. Almost all of the potential arbitrage opportunities disappeared after factoring in the transaction costs that were faced by members and non-members. Computerized onscreen trading helped to maintain the price alignment between stock futures and the underlying stocks even during the stressful Asian financial crisis.

The remainder of this paper is organized as follows. Section 2 reviews previous studies of the effects of the Asian financial crisis on the cash and derivatives markets. Section 3 describes the data, and Section 4 describes our methodology. Section 5 reports the empirical findings, and Section 6 concludes the paper.

2. Literature Review

2.1. Arbitrage Efficiency and the Asian Financial Crisis

The Asian financial crisis hit Hong Kong in the latter half of 1997, and the Hong Kong government took the unprecedented step of fending off speculative attacks on the local securities and foreign exchange markets. In August and September 1998, and on August 28, 1998, in particular, the government bought over HK$100 billion (US$1 = HK$7.8) or 10% of the cash market out of public coffers.

Fung and Draper (2000) and Draper and Fung (2003) show that despite extreme volatility in both the stock and the index futures markets during the Asian financial crisis, the alignment between the prices of the HSI futures and the cash index was largely unaffected. They attribute this to the use of an onscreen trading system for stocks, whereas the index futures were still traded by open outcry. However, Draper and Fung (2003) find that when the government intervened in the stock and index futures markets as the crisis worsened in 1998, the arbitrage efficiency between the index futures and the cash index was impeded. Cheng, Fung, and Chan (2000) show that the integrity between the HSI

index futures and options prices were largely maintained. Other studies of the arbitrage efficiency of the derivatives markets also primarily use market indices. For Hong Kong, Fung and Mok (forthcoming), Fung and Mok (2001), Fung, Cheng, and Chan (1997), and Fung and Fung (1997) study the arbitrage efficiency between the Hang Seng Index futures and options. Fung and Draper (1999) examine the pricing relationship between the Hang Seng index futures and the underlying cash index.

Hong Kong is among a handful of markets in the world where individual stock futures are traded. Brailsford and Cusack (1997) have examined the pricing efficiency of individual stock futures traded on the Sydney Futures Exchange. In this paper, we investigate individual stock futures and their underlying stocks traded in Hong Kong.

2.2. Hong Kong's Stock and Stock Futures Markets

Individual stock futures contracts have been traded in Hong Kong since March 1995. Individual stock futures are traded on the Hong Kong Futures Automated Trading System (HKATS), for which computer terminals are located at the premises of Exchange Participants, and the underlying stocks are traded on the Automatic Order Matching and Execution System (AMS) of the Exchange. The morning session for stock futures commences at 10 a.m. and breaks for lunch at 12:30 p.m. Trading resumes at 2:30 p.m. and closes at 4:00 p.m.[1]

Under the automated HKATS system, participants can view real-time price information, click on a bid or ask price, and execute the order. Orders of stock futures are electronically matched based on price and time priorities. With this onscreen trading,

[1] Expiry day is the business day immediately before the last business day of the contract month. To avoid price manipulations, the final settlement price of a stock futures is set to be the average of the midpoints of the best bid and offer prices for the underlying stock quoted on the Hong Kong Exchange (HKEx), taken at five-minute intervals throughout the last trading day.

brokers can confirm the execution of orders to clients immediately. Bid, offer, and transaction prices are instantly transmitted throughout the market. Electronic trading minimizes the market friction due to manual quote-revisions and execution delays under an open-outcry system.

Although market volatility was high during the Asian financial crisis, stocks and index futures were quite liquid. However, the individual futures of constituent stocks were quite illiquid.[2] Faced with the immense uncertainty during the stressful 1997-98 Asian financial crisis, arbitrageurs reduced the trading of individual futures to avoid adverse selection costs. However, with a high degree of price and market transparency, and the immediate execution of orders under the onscreen trading systems, we postulate that despite thin trading the arbitrage efficiency of individual stock futures and the underlying cash stocks were not impeded.

3. Data

Our data set contains complete records of 24 months (between January 1997 and December 1998) of time-stamped transaction data of all 17 stock futures that were available in the study period.[3] The underlying stocks are the major constituent blue chips of the widely quoted HSI market index. The study period is divided into seven sub-periods:

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[2] Kleidon (1992) also find non-trading in constituent stocks on the NYSE during the October 1987 crash.

[3] (1) Cheung Kong (Holdings) Limited Futures Contract; (2) CLP Holdings Limited Futures Contract; (4) The Wharf (Holdings) Limited Futures Contract; (5) HSBC Holdings Plc. Futures Contract; (6) Hong Kong Electric Holdings Limited Futures Contract; (8) Hong Kong Telecommunication Limited Futures Contract; (11) Hang Seng Bank Limited Futures Contract; (12) Henderson Land Development Company Limited Futures Contract; (13) Hutchison Whampoa Limited Futures Contract; (16) Sun Hung Kai Properties Limited Futures Contract; (17) New World Development Company Limited Futures Contract; (19) Swire Pacific Limited 'A' Futures Contract; (54) Hopewell Holdings Limited Futures Contract; (267) CITIC Pacific Limited Futures Contract; (291) China Resources Enterprise, Limited Futures Contract; (363) Shanghai Industrial Holdings Limited Futures Contract; and (941) China Mobile (Hong Kong) Limited Futures Contract. (*Stock codes in parentheses*.)

P1: Pre-Crisis Period (January 1 to May 13, 1997)

P2: Crisis Period (May 14, 1997 to August 13, 1998)

P3: Preliminary Intervention Period (August 14-27, 1998)

P4: August 28, 1998 (an all-out government intervention)

P5: Post-Intervention Period – Before the up-tick rule (August 31 to September 6, 1998)

P6: Post-Intervention Period - After the up-tick rule (September 7 - 30, 1998)

P7: Post-Intervention Period (October 1 to December 31, 1998)

The Asian financial crisis began around May 14-15, 1997 when the Thai baht came under speculative attack. Hence, the pre-crisis period (P1) of January 1, 1997 to May 13, 1997 is used as the control period. The 15 months between May 14, 1997 and August 13, 1998 is defined as the crisis period (P2).

As the Asian financial crisis worsened, the Hong Kong government launched a counter-attack by buying over HK$100 billion of the index constituent stocks on August 28, 1998, during (P4). The period between August 14 and September 30, 1998 is separated into two post-government intervention periods (P5 and P6). The market stabilized afterwards, and the period from October 1, 1998 to December 31, 1998 represents the aftermath of government interventions or the post-crisis period (P7).

The transaction data of the stock futures and their underlying stocks are matched within one-minute time intervals.[4] Time-stamp transaction records for individual stock futures, their corresponding cash stocks, and dividend information were obtained from the Hong Kong Futures Exchange (HKFE) and the Stock Exchange of Hong Kong (SEHK),

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[4] Note that as we match the transaction data according to one-minute interval, the frequency of stock-futures arbitrage pairs could have been underestimated.

respectively. Four Hong Kong Inter-Bank middle quotes are used to interpolate the riskless rate for appropriate maturity for the entire period.

4. Methodology

4.1. Parity Condition between Individual Stock and Stock Futures

The Modest and Sundaresan (1983) cost-of-carry model that allows for dividend payments is adopted to test the arbitrage relationship between stock futures and the underlying stock. The "fair" value of a stock futures F^* at a particular point in time of day t is determined by the following formula:

$$F_t^* = \left[S_t - PV_t(D)\right]e^{rT}, \qquad (1)$$

where $PV(D)$ is the present value of the dividend that is accrued to the cash stock (S) during the holding period of the futures contract (T), D is the known dividend of the stock, and r is the risk-free rate of interest for the holding period.

The upper and lower no-arbitrage bound (F^+ and F^-) are determined by the following formulae:

$$F^+ = F^* + C, \qquad (2)$$

$$F^- = F^* - C, \qquad (3)$$

where F^* is the "fair" value of a stock futures and C represents the total transaction costs. For members of the exchange we include the total transaction costs for stocks (brokerage fee, stamp duty, and transaction levy, etc.), and for non-members we include the total transaction costs for stock futures trading (exchange fee, SFC levy, compensation fee levy, etc.). For comparison, we use a benchmark group of zero-transaction-cost arbitrageurs.

Overpricing occurs when the actual stock futures is priced above the upper no-arbitrage bound, $F > F^+$, and underpricing occurs when the actual stock futures price is below the lower no-arbitrage bound, $F < F^-$.

A positive error ($e^+ = F - F^+$) indicates the magnitude of positive mispricing. A profitable arbitrage strategy is to short the stock futures and hedge the short futures exposure by buying the underlying stocks. A negative error ($e^- = F - F^-$) indicates the magnitude of negative mispricing. The strategy in this case to exploit the mispricing is to sell short the underlying stock and hedge it with a long position in stock futures. The ability of the arbitrageur to borrow and short the underlying stock is essential to take advantage of the mispricing and to correct it. Hence, the magnitude and frequency of the negative mispricing (or underpricing) reflects the cost and difficulty against arbitrageur in selling short the stocks because the cost of adverse selection is high. Thus, we do not expect the active arbitrage trading of stock futures and cash stocks. The absolute value of the error |*e*| ignores the direction of the bound violations and reveals the absolute magnitude of the mispricing.

5. Empirical Results and Discussions

We observe 5,746 trades of individual stock futures over the entire study period (Table 1). There was an increase of individual stock futures trades (4,133) in the 15-month crisis period (P2), but it dwindled to only two trades on the day of the all-out government intervention (P4). The trade volume of individual stock futures returned to the pre-crisis level after the government's intervention (P7).[5] This shows the illiquidity of individual stock futures during the financial crisis. As the crisis worsened, arbitrageurs drastically

reduced the arbitrage trading of individual stock futures to limit the cost of adverse selection.

5.1. The Quantity of Mispricing

Out of the 5,746 observed trades of individual stock futures (Table 1), 2,343 individual stock futures/stock pairs are obtained by the one-minute matching criterion (Table 2). Among them, 1,731 matched pairs cluster in the 15-month crisis period (P2). However, when accounting for the minimum transaction costs, we find only 35 cases (2.02% of 1,731) of mispricing for members and 26 cases (1.50% of 1,731) for non-members in the 15-month crisis period (P2) (Table 2). All of the riskless arbitrage opportunities disappeared in other sub-periods as we filtered in transaction costs for members and non-members.

5.2. The Magnitude of Mispricing

Table 3 provides further details of the magnitude of mispricing in the different phases of the crisis and intervention. The pricing errors (e) are expressed in percentages relative to the corresponding bounds. The distribution of e shows how the errors are distributed around the no-arbitrage band. For example, if the mean of e is negative, then the futures are underpriced.

For members, the average magnitude of the pricing errors for the 35 cases of riskless arbitrage opportunities that we observed in P2 was –0.2155%, and that for the 6 cases that we observed in P5 was –0.8083%. For non-members, the average magnitude of the pricing errors for the 26 cases of riskless arbitrage opportunities that we observed in

[5] Evidence (not reported) shows that the stock futures contracts had low liquidity, as evidenced by low frequencies of trading of all the stock futures, with the exception of Cheung Kong (Holdings) Limited (Code

P2 was –0.4419%, and that for the 5 cases that we observed in P5 was –0.6400%. Arbitrage opportunities are rare and short-lived. The predominance of underpricing reflects the high cost for arbitrageurs in selling short the stocks. When the Hong Kong government intervened in the market in 1998, all apparent riskless arbitrage opportunities disappeared after accounting for the transaction costs for members and non-members.

The crisis period (P2) and the intervention period (P5) were characterized by high market volatility (Draper and Fung 2003), thin trading, and limited mispricing. This extremely low quantity of mispricing suggests that the price alignment between the individual stock futures and the underlying stocks was actually unaffected during the crisis and intervention period.

6. Conclusions

Using complete time-stamped transaction data, we examine the pricing efficiency between individual stock futures and the underlying stocks during the Asian financial crisis that hit Hong Kong in 1997, and during the unprecedented market intervention by the Hong Kong government in the latter part of 1998. We divide the sample into seven sub-periods and match the prices of individual stock futures and the underlying cash stocks within narrow one-minute intervals to minimize non-synchronous prices.

Potential arbitrage opportunities emerged in the crisis period. However, despite large market volatility, both the quantity and magnitude of mispricing were quite limited – there were only 35 instances for members and 26 for non-members – in the 15 months surrounding the financial crisis. Underpricing predominates, which seems to suggest a high cost for arbitrageurs in selling short the stocks during stressful market conditions. There was no mispricing on the day of the all-out government intervention in August

1) and HSBC Holdings Limited (Code 5).

1998. These results suggest that arbitrageurs responded rationally by limiting the cost of adverse selection during extreme market volatility. During and at the end of the all-out governmental effort to rescue the slumping market, all arbitrage opportunities disappeared when transaction costs are filtered in. Thus, a virtual absence of pricing errors suggests that the transparent electronic trading system, *inter alia*, maintained the price alignment of individual stock futures and the cash stock even in the prolonged Asian financial crisis.

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Table 1

Summary Statistics of the Stock Futures Volume for Different Phases of the Crisis and Government Intervention

[a] N is the number of trading days for the particular stock futures during the period.

[b] Mean is the average trading volume for the particular stock futures during the available trading days, i.e., the total trading volume for the particular stock futures divided by the number of trading days for that futures.

[c] Min, Median, and Max are the minimum, median, and maximum trading volumes during the available trading days.

[d] For the "overall" statistics, N is the total number of trading days for the 17 stock futures during the period.

Overall: January 1, 1997 to December 31, 1998
P1: Pre-Crisis Period (January 1 to May 13, 1997)
P2: Crisis Period (May 14, 1997 to August 13, 1998)
P3: Preliminary Intervention Period (August 14-27, 1998)
P4: August 28, 1998
P5: Post-Intervention Period – Before the Up-Tick Rule (August 31 to September 6, 1998)
P6: Post-Intervention Period – After the Up-Tick Rule (September 7-30, 1998)
P7: Post-Intervention Period (October 1 to December 31, 1998).

Period	N [a]	Std	Mean [b]	Volume	Min [c]	Median [c]	Max [c]
P1	90	14.5575	9.1111	820	0	0	115
P2	308	13.1083	13.4188	4,133	0	0	71
P3	9	8.5163	12.5556	113	0	0	21
P4	1	-	2	2	0	0	2
P5	5	6.0663	7.6000	38	0	0	6
P6	18	3.3122	2.5000	45	0	0	10
P7	61	10.4557	9.7541	595	0	0	41
Overall [d]	492	12.9654	11.6789	5,746	0	0	115

Table 2

Relative Frequency of Mispricing during Different Phases of the Crisis and Government Intervention
Overall: January 1, 1997 to December 31, 1998
P1: Pre-Crisis Period (January 1 to May 13, 1997)
P2: Crisis Period (May 14, 1997 to August 13, 1998)
P3: Preliminary Intervention Period (August 14-27, 1998)
P4: August 28, 1998
P5: Post-Intervention Period – Before the Up-Tick Rule (August 31 to September 6, 1998)
P6: Post-Intervention Period – After the Up-Tick Rule (September 7-30, 1998)
P7: Post-Intervention Period (October 1 to December 31, 1998)
P+ and P- denote the relative frequency of over-pricing and under-pricing. P is the total (%) of over and under-pricing. P+ (P-) is the number of over-pricing (under-pricing) opportunities divided by the number of valid comparisons for the period (i.e., N). A valid comparison is a comparison of the futures and the upper and/or lower bound, which allows for the determination of whether the future is above, below, or within the bounds. Two cases are not counted as valid comparisons: when the future is above the lower bound in the absence of a comparable upper bound, and when the futures is below the upper bound in the absence of a comparable lower bound.

Overpricing occurs when the actual futures price is above the upper no-arbitrage bound, $F > F^{+}$; and underpricing is where the actual futures price is below the lower no-arbitrage bound, $F < F^{-}$; where $F^{*} = \left[S - PV(D)\right]e^{rT}$; $F^{+} = F^{*} + C$ and $F^{-} = F^{*} - C$

		Overall	P1	P2	P3	P4	P5	P6	P7
Zero Cost	N	2343	269	1731	51	1	19	27	245
	P	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	P+	50.32%	52.04%	51.82%	49.02%	0.00%	5.26%	11.11%	46.12%
	P-	49.68%	47.96%	48.18%	50.98%	100.00%	94.74%	88.89%	53.88%
Member	N	2343	269	1731	51	1	19	27	245
	P	1.79%	-	2.02%	-	-	31.58%	-	0.41%
	P+	1.20%	-	1.56%	-	-	-	-	0.41%
	P-	0.60%	-	0.46%	-	-	31.58%	-	-
Non-Member	N	2343	269	1731	51	1	19	27	245
	P	1.32%	-	1.50%	-	-	26.32%	-	-
	P+	0.81%	-	1.10%	-	-	-	-	-
	P-	0.51%	-	0.40%	-	-	26.32%	-	-

Table 3

Summary Statistics of the Distribution of Mispricing during Different Phases of the Crisis and Government Intervention

Overall: January 1, 1997 to December 31, 1998
P1: Pre-Crisis Period (January 1 to May 13, 1997)
P2: Crisis Period (May 14, 1997 to August 13, 1998)
P3: Preliminary Intervention Period (August 14-27, 1998)
P4: August 28, 1998
P5: Post-Intervention Period – Before the Up-Tick Rule (August 31 to September 6, 1998)
P6: Post-Intervention Period – After the Up-Tick Rule (September 7-30, 1998)
P7: Post-Intervention Period (October 1 to December 31, 1998)

$$e^{+} = \frac{F - F^{+}}{F^{+}} \times 100 \text{; where } F > F^{+}; \qquad e^{-} = \frac{F^{-} - F}{F^{-}} \times 100 \text{; where } F < F^{-}; \qquad e^{+} = e^{+} \text{; when } F > F^{+}, \quad = -e^{-} \text{ when } F < F^{-}$$

e+ and e- represent over-pricing and under-pricing of the futures contract relative to the upper and lower no-arbitrage bounds. The absolute value of the error |e| ignores the sign of the error and reveals the absolute magnitude of the mispricing.

	Overall			P1			P2			P3			P4			P5			P6			P7		
	N	Mean	Median	N	Mean	Media	N	Mean	Median	N	Mean	Median	N	Mean	Median	N	Mean	Median	N	Mean	Median	N	Mean	Median
Zero Cost																								
e	2343	0.0199	0.0091	269	0.0983	0.0214	1731	0.0663	0.0323	51	-0.1793	-0.1282	1	-1.4075	-1.4075	19	-2.4933	-2.8996	27	-1.4727	-1.2831	245	0.0122	-0.0546
|e|	2343	0.5489	0.3624	269	0.3571	0.2809	1731	0.5465	0.3700	51	0.6909	0.4942	1	1.4075	1.4075	19	2.6042	2.8996	27	1.6738	1.2831	245	0.4596	0.3789
e+	1179	0.5651	0.3953	140	0.4375	0.3013	897	0.5913	0.3994	25	0.5219	0.4942	0	-	-	1	1.0535	1.0535	3	0.9048	0.8418	113	0.5114	0.4168
e-	1164	0.5325	0.3316	129	0.2699	0.2420	834	0.4984	0.3145	26	0.8534	0.4953	1	1.4075	1.4075	18	2.6904	2.9018	24	1.7699	1.3008	132	0.4152	0.3446
Member																								
e	42	-0.2922	0.2289	0	-	-	35	-0.2155	0.3858	0	-	-	0	-	-	6	-0.8083	-0.8916	0	-	-	1	0.1175	0.1175
|e|	42	1.3134	0.6693	0	-	-	35	1.4342	0.6389	0	-	-	0	-	-	6	0.8083	0.8916	0	-	-	1	0.1175	0.1175
e+	28	0.7659	0.6158	0	-	-	27	0.7899	0.6233	0	-	-	0	-	-	0	-	-	0	-	-	1	0.1175	0.1175
e-	14	2.4085	1.0418	0	-	-	8	3.6086	3.1994	0	-	-	0	-	-	6	0.8083	0.8916	0	-	-	0	-	-
Non-Member																								
e	31	-0.4738	0.2917	0	-	-	26	-0.4419	0.3611	0	-	-	0	-	-	5	-0.6400	-0.6473	0	-	-	0	-	-
|e|	31	1.4479	0.4728	0	-	-	26	1.6033	0.4698	0	-	-	0	-	-	5	0.6400	0.6473	0	-	-	0	-	-
e+	19	0.7947	0.4458	0	-	-	19	0.7947	0.4458	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-
e-	12	2.4823	0.9230	0	-	-	7	3.7982	2.9005	0	-	-	0	-	-	5	0.6400	0.6473	0	-	-	0	-	-