

A stylized, low-poly mountain range in shades of blue and grey, set against a light yellow sky. A large, solid red rectangle is positioned in the foreground, partially obscuring the mountains.

chi-x

**Introducing the Chi-X VWAP
Closing Price Mechanism**



Contents

Part I: Introduction	2
Part II: Background	5
Part III: Closing Price Mechanisms Around the World	6
Part IV: Selecting a Suitable Chi-X Closing Price Mechanism.....	7
Part V: Refining the Parameters of the VWAP Closing Price.....	13
Part VI: VWAP Simulation	16
Part VII: Closing Price: Risks and Mitigants	17
Appendix.....	23

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Part I: Introduction

1.1 Overview

- 1.1.1** Chi-X Australia ("Chi-X") is an established securities and derivatives exchange providing competitive markets for trading and investing in Australia's leading securities. As an innovative modern exchange, Chi-X has introduced versatile new order types, lowered costs and supported the market with more efficient ways to trade. Participants of Chi-X are diverse and consist of investment banks, specialist market makers, mid-tier brokers, as well as full service and online retail brokers.
- 1.1.2** Chi-X seeks to generate an independent proprietary closing price (hereafter "closing price") for inclusion in Chi-X indices.

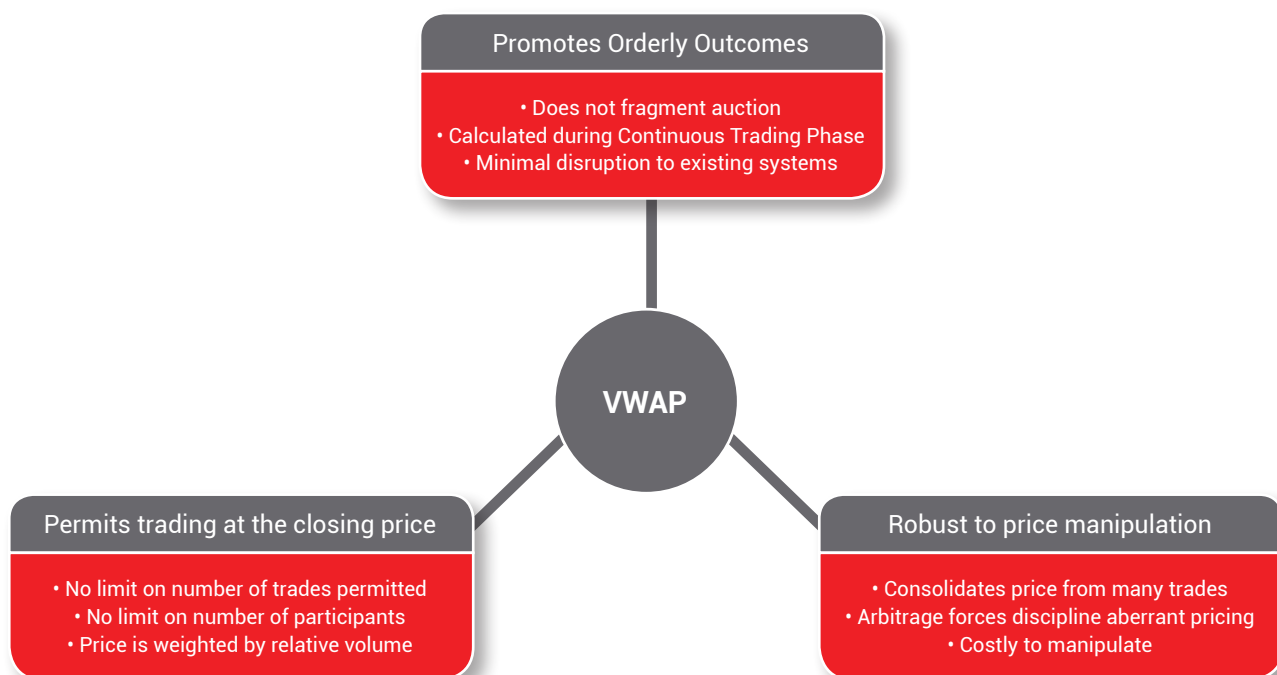
1.1.3 This paper reviews the common closing price mechanisms used globally and evaluates their suitability for Chi-X against key criteria. Chi-X is of the view that a VWAP (Volume-Weighted Average Price) based closing price is the most suitable methodology for Chi-X. This paper outlines the reasons for this.

1.1.4 Feedback from participants on any of the analysis and conclusions in this paper is very much welcomed.

1.2. Executive Summary

1.2.1 Internal research indicates that the VWAP (Volume-Weighted Average Price) based closing price mechanism is the most suitable for the Chi-X market. Exhibit 1 presents the key benefits of the VWAP over other types of closing price mechanisms. Analysis of historical data shows that trading between 15:45:00 to 15:59:50, is sufficient to produce a reliable closing price for securities that trade on the Chi-X market.

Exhibit 1: Key benefits of the VWAP Closing Price Mechanism



1.3 VWAP Closing Price Mechanism

A. If the security has traded during that day then

- a.** If the security has traded during the VWAP formation period then the closing price is the volume-weighted average price of on-market trades; otherwise
- b.** If the security has a valid Chi-X quote at the end of the VWAP formation period then the closing price is determined by reference to the last sale price that day and the prevailing best bid-ask quote at the end of the VWAP formation period;
 - i.** If the closing bid quote is greater than or equal to the last sale price then the closing bid quote; otherwise
 - ii.** If the closing ask quote is lesser than or equal to the last sale price then the closing ask quote; otherwise
- c.** A(a), A(b)(i), and A(b)(ii) do not apply then the last sale price

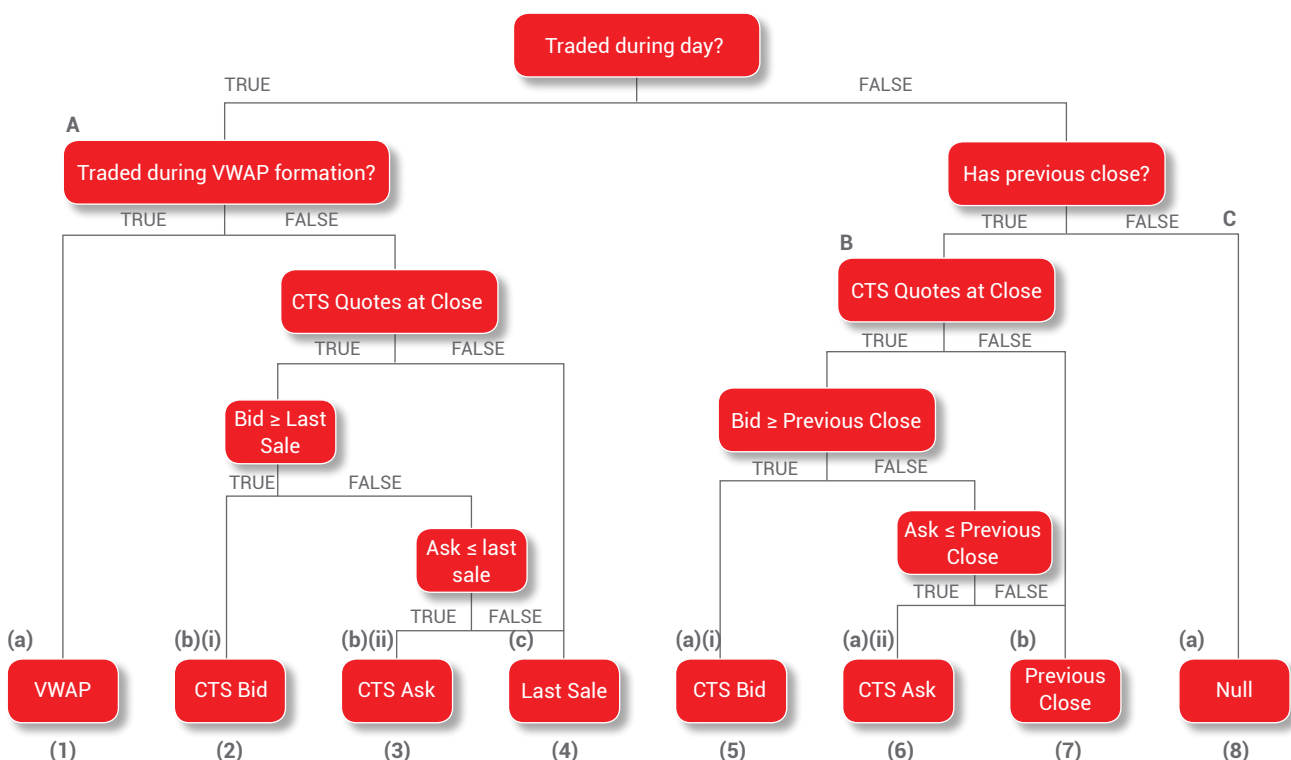
B. If the security has not traded during that day, but has previously traded on Chi-X then

- a.** If the security has a valid Chi-X quote at the end of the VWAP period, then the closing price is determined by reference to the previous day's closing price and the closing bid ask quote prevailing at the end of the VWAP formation period;
 - i.** If the closing bid quote is greater than or equal to the previous day's closing price, then the closing bid quote; otherwise
 - ii.** If the closing ask quote is lesser than or equal to the previous day's closing price then the closing ask quote; otherwise
- b.** If B(a)(i) and B(a)(ii) do not apply, then the previous day's closing price otherwise

C. If the security does not have a previous closing price, or has not previously traded on Chi-X then

- a.** The price shall remain Null until an on-market trade occurs on the Chi-X venue

Exhibit 2: Proposed VWAP Closing Price Mechanism algorithm



Definitions

Closing bid quote: The highest prevailing visible bid quote on the Chi-X order book at the end of the VWAP formation period

Closing ask quote: The lowest prevailing visible ask quote on the Chi-X order book at the end of the VWAP formation period

Last sale price: The last recorded on-market traded price prior to the commencement of the VWAP formation period

On-market trades: A trade that has occurred on the Chi-X venue, including both hidden and visible trades, but excluding: off-market, booking purpose trades, and market-on-close trades

Valid CXA quote: Any visible quote displayed on the Chi-X Order Book (including where only one side exists e.g. if a bid quote exists and an ask quote does not exist and vice-versa)

VWAP formation period: Unless otherwise notified, the VWAP Formation Period shall commence at 15:45:00.0000 and end at 15:59:50.0000.

Volume Weighted Average Price (VWAP): The volume-weighted average price computed over the VWAP formation period. It is defined as the ratio between the on-market value traded and the on-market quantity of shares traded for each symbol, on the Chi-X venue. Assuming N trades occur for stock i then the VWAP is:

$$VWAP_i = \frac{\sum_{j=1}^N P_j V_j}{\sum_{j=1}^N V_j} = \frac{\text{Value Traded}_i}{\text{Quantity Traded}_i}$$

Part II: Background

2.1 Key Requirements of a Chi-X Closing Price Mechanism

2.1.1 Chi-X seeks to provide a competitive, easy to use, and difficult to manipulate closing price mechanism to generate reference prices for securities which trade on Chi-X platforms. It is important that this mechanism does not disrupt the market and adheres to best practices. To assist in achieving this, we have compared the most common closing price mechanisms used by exchanges around the world and benchmarked them against the following five criteria:

- i. Preserves price discovery:** The Chi-X closing price must not impair the price-discovery functions of the existing system.
- ii. Orderly outcome:** The closing price should not deliver disorderly outcomes, for example by delivering unexplained or significantly different outcomes to existing benchmarks such as ASX's Closing Single Price Auction (CSPA).
- iii. Robust:** Prices must be robust and able to withstand price manipulation.
- iv. Tradeable:** The closing price mechanism must permit large volumes to be traded at, or very close to the closing price.
- v. Representative:** The closing price should be based on observable prices generated in bona fide transactions dictated by the competitive forces of supply and demand.

Part III: Closing Price Mechanisms Around the World

3.1 Closing Price Mechanisms

3.1.1 In addition to the traditional closing call auction, there are three types of non-auction closing price mechanisms used around the world¹: the VWAP, the TBMP (Time-Based Median Price) and the LSP (Last-Sale Price).² This section provides a brief description of each.

3.2 Closing Call Auction

3.2.1 In developed markets, the most common method used to generate a closing price is the single price call auction. This mechanism operates in two distinct phases. In the first phase orders are consolidated in the limit order book and ranked according to order-precedence rules (usually price-time priority). In the second phase, an order matching algorithm generated a unique closing price that maximises the executable volume of all orders consolidated during the first phase. Should this mechanism be unable to generate a unique crossing price, then secondary trading rules are implemented to determine a unique closing price.

3.2.2 A significant impediment to Chi-X offering this option at present is the potential for disorderly outcomes given the existing auction process used in ASX benchmarks. This is discussed further in section 3.6 below.

3.3 Volume Weighted Average Price

3.3.1 The VWAP algorithm calculates a closing price in a specified period, often towards the end of the continuous trading phase. The VWAP can be defined as the total dollar value of trades occurring within this time segment divided by the total number of shares traded in the same segment. The VWAP captures the expectation that large volume orders may trade at inferior prices and is generally considered a fair measure of the price that the average uninformed trader can achieve.

3.4 Time Based Median Price

3.4.1 The TBMP was a unique closing price mechanism deployed on the Hong Kong Exchange (HKEX) until mid-2016 when it was replaced by a closing call

auction. Under this previous system the closing price is calculated by reference to the median of 5 snapshots of the “nominal”³ price of a stock. Each snapshot is taken at 15 seconds intervals starting from 3:59:00PM and concluding at 4:00:00PM. The effect of TBMP algorithm is that it randomises the closing price amongst five previously executed prices over the final minute of trading.

3.5 Last Sale Price

3.5.1 Prior to the shift to closing call auctions, many markets around the world used the last sale price during the continuous trading phase as the official closing price. Today, some emerging markets still use this method to generate official closing prices.

3.6 Competing closing call auctions

3.6.1 Although closing call auctions are the most common method of generating a closing price, a competing call auction over the same underlying securities remains an unproven concept in the current competitive landscape.

3.6.2 The auction mechanism poses particular issues for a market operators competing with the existing closing. In particular, there are risks that can arise from the uncertainty in attracting liquidity to a competing auction. Auctions rely on consolidating orders to generate equilibrium prices, however insufficient liquidity may lead to a failure to generate an equilibrium price. Secondly, insufficient liquidity can increase volatility, and increase the risk of price manipulation.

3.6.3 In theory a competing call auction would divide order flow, creating a fragmented auction market, which would then lead to inferior market outcomes. Section 4.2 and 4.3 below outlines that the risk of creating a disorderly market, for products that are the subject of two competing closing price mechanisms, is increased if there are significant differences between the closing prices generated by the competing mechanisms. Together these risks are a significant factor in Chi-X declining to pursue a competing closing call auction at this stage of the development of its market.

¹ Refer to Appendix, Table 1 for a survey of the top 20 largest equity exchanges around the world

² On 25 July 2016 HKEX changed from the Time-Based Median Price to a Closing Auction Session

³ The nominal price is usually defined as the last traded price prior to the snapshot, however under certain situations can also take a bid quote, ask quote, or previous close price

Part IV: Selecting a suitable Chi-X Closing Price Mechanism

4.1 Methodology

4.1.1 To determine the most suitable closing price mechanism, Chi-X evaluates the three available closing price mechanisms against the five criteria selected in Part II above. To account for the relative importance of each criterion, Chi-X has developed a weighting scheme that attempts to balance the anticipated functionality demanded by users of the closing price, and the requirements of Chi-X own commercial and regulatory expectations.

4.2 Price discovery (HIGH)

4.2.1 The existence of an effective price discovery mechanism at the close is an integral part of well-functioning capital markets.⁴ An alternative closing price mechanism should not impair the price-discovery functions of the existing system.

4.2.2 Price discovery at the close can be adversely affected by a fragmented auction market. This is because the auction relies on consolidating order flow to determine the equilibrium price. Diverting orders away from the auction can operate to impair this function. Therefore, minimising order flow fragmentation in the existing auction is a desirable feature of closing price. The two statistically derived methods (VWAP and TBMP) are expected to have minimal impact because they are derived only from trades that occur during the continuous trading phase (i.e. prior to the start of the pre-CSPA). The LSP outperforms under this criterion because it presents extremely minimal disruption to the existing regime.

Criterion 1: Preserves price discovery

IMPORTANCE: HIGH	COMMENTS	ASSESSMENT
Volume-Weighted Average Price (VWAP)	<ul style="list-style-type: none">Derived from trades occurring during continuous tradingTrades which target the close do not compete with auction	Neutral
Time-Based Median Price (TBMP)	<ul style="list-style-type: none">Derived from trades occurring during continuous tradingTrades which target the close do not compete with auction	Neutral
Last Sale Price (LSP)	<ul style="list-style-type: none">Derived from trades occurring during continuous tradingTrades that target the close may divert additional order flow into closing auction	Strong Outperform

⁴ For example, asset managers and brokerage clients may use the closing price to benchmark fund performance and evaluate transaction quality. Market makers of structured products may need to trade at the closing price in order to create or redeem units. Index arbitrageurs use the closing price to manage risk. The wider market uses closing prices as barometers of economic performance

4.3 Orderly outcomes (HIGH)

4.3.1 In the context of the competing closing prices in the Australian market, an orderly outcome is also one where the Chi-X closing price is aligned with contemporaneous prices generated at other venues. The Chi-X closing price needs to be generated at the end of the trading day, and hence, needs to be numerically similar to other end-of-day price benchmarks. A significant difference with an existing benchmark can impact on the efficacy of existing hedging instruments for products which will reference the closing prices. Abnormally large divergences between an existing benchmark and the Chi-X closing price may also indicate flaws in the closing price methodology. Further, a closing price that is significantly different from an existing benchmark will mean users are not able to easily compare between the values of referenced financial products.

4.3.2 Three key factors may cause the price generated by an alternative closing price mechanism to naturally diverge from the benchmark. They are:

- i. Methodology** – The price formation process generated by a call auction is different to the price formation process generated during a continuous auction. This can influence investor behaviour whereby identical latent demand may generate differential prices across different closing price regimes.

ii. Timing – The CSPA closes at a random time between 16:10 – 16:12, therefore it is not possible for a Chi-X closing price to conclude contemporaneously with the ASX. In so far as timing differs, information impounded on price will also differ.

iii. Market Frictions – Even if (i) and (ii) above did not apply, market frictions in the form of transaction costs, search costs, and latency can limit the ability of arbitrage forces to influence a convergence in prices thereby producing pricing errors that may be thought of as noise.

4.3.3 As all three factors are in operation in the market, divergences in closing price are an inevitable outcome under any regime. Given the constraints of the other four criteria, the objective is to select a closing price mechanism which minimises divergences. Assuming there are non-overlapping time periods (consistent with criterion 1); Both VWAP and TBMP have the capacity of consolidating trades to produce a singular price. The VWAP performs well as it minimises noise caused by market frictions by averaging across a large number of trades. The TBMP is conceptually similar but incorporates fewer trades in its calculation. The LSP performs relatively poorly as it is generated by a single trade which increases the risk of an aberrant trade forming the closing price.

Criterion 2: Provides orderly outcomes

IMPORTANCE: HIGH	COMMENTS	ASSESSMENT
Volume-Weighted Average Price (VWAP)	<ul style="list-style-type: none">Averaging across many trades may reduce the ability for aberrant trades to significantly affect priceLonger formation time increases divergence due to new information	Outperform
Time-Based Median Price (TBMP)	<ul style="list-style-type: none">Closing price is based on a singular price chosen from 5 snapshot prices and hence is susceptible to aberrant tradesShorter formation time decreases divergence due to new information	Outperform
Last Sale Price (LSP)	<ul style="list-style-type: none">Single capture point and hence is susceptible to aberrant trades	Underperform

4.4 Robust to closing price manipulation (MEDIUM)

4.4.1 Due to its importance, there may be strong incentives to manipulate the closing price. The robustness of the VWAP depends on the liquidity in the underlying security, for highly liquid securities the VWAP would be costly to manipulate.⁵ However, for thinly traded securities the risk of closing price manipulation is magnified (although the probability of detection also increases). The TBMP aims to produce a randomised closing price, however as it relies on taking snapshots of trades at predictable intervals, it is theoretically possible for a manipulator to opportunistically target these snapshots. The LSP has been found to have several anomalies (e.g. end of day price dislocation, overnight reversals, increasing volatility and spread) associated with it and is considered most susceptible to manipulation.⁶

Criterion 3: Robust to closing price manipulation

IMPORTANCE: MEDIUM	COMMENTS	ASSESSMENT
Volume-Weighted Average Price (VWAP)	<ul style="list-style-type: none">• VWAP is naturally weighted towards volume, therefore costly to manipulate for most symbols	Outperform
Time-Based Median Price (TBMP)	<ul style="list-style-type: none">• TBMP is a semi-randomised price however snapshots can be targeted opportunistically	Neutral
Last Sale Price (LSP)	<ul style="list-style-type: none">• Can be targeted cheaply and opportunistically• Documented anomalies (End of day price dislocation, overnight reversals, increasing volatility and spread)	Strong Underperform

⁵ Goetzmann, William, Jonathan Ingersoll, Matthew Spiegel, and Ivo Welch. "Portfolio performance manipulation and manipulation-proof performance measures." *Review of Financial Studies* 20, no. 5 (2007): 1503-1546

⁶ Harris, Lawrence. "A day-end transaction price anomaly." *Journal of Financial and Quantitative analysis* 24, no. 01 (1989): 29-45

4.5 Permits Trading at the Closing Price (MEDIUM)

4.5.1 The ability to trade at the closing price is highly useful to a variety of participants. Asset managers, brokers, market-makers, arbitrageurs, and other investors find it desirable to execute trades at the closing price. A tradeable closing price should support large volumes, maximise certainty of execution, and minimise implicit and explicit trading costs. Conversely, a closing price which is not tradeable implies the existence of tracking errors for users of the closing price.

4.4.2 The VWAP cannot be guaranteed without an explicit cost.⁷ To achieve VWAP, traders must participate proportionately to the price-volume curve during the VWAP formation period. Under the TBMP, traders bear the risk that they may mistime a trade snapshot. Even if trades successfully target a snapshot, traders cannot know which of the snapshots will form the eventual median price. For these reasons the TBMP is effectively a randomised price that occurs within the final minute of trading. The LSP is the most restrictive as it permits only a single trade to form the closing price.

Criterion 4: Permits trading at the closing price

IMPORTANCE: MEDIUM	COMMENTS	ASSESSMENT
Volume-Weighted Average Price (VWAP)	<ul style="list-style-type: none">• VWAP has a natural bias towards large volume transactions• Many algorithms exist in the market that aim to target the VWAP• Continuous opportunity to participate in VWAP formation	Outperform
Time-Based Median Price (TBMP)	<ul style="list-style-type: none">• Multiple discrete opportunities to participate in median price formation• Difficult to target the snapshot price and median price	Neutral
Last Sale Price (LSP)	<ul style="list-style-type: none">• Provides only a single opportunity to capture the last traded price	Strong Underperform

⁷ Brokers may offer guaranteed VWAP however the cost depends on a range of factors including: size, basket, and difficulty of execution

4.6 Representative of Bona-Fide, Arm's Length Transactions (LOW)

4.6.1 The International Organisation of Securities Commission (IOSCO) has established a set of overarching principles which together form a framework to safeguard the integrity of financial benchmarks. Creating a closing price which incorporates the principles set out in the, *Principles for financial benchmarks: Final report (July, 2013)* is a key objective for Chi-X. Principle 7 informs that the data used to construct a benchmark should be sufficient to accurately and reliably represent the Interest measured by the Benchmark and should be:

"...based on prices that have been formed by the competitive forces of supply and demand... And be anchored by observable transactions entered into at arm's length between buyers⁸ ...Principle 7 does not preclude Benchmark Administrators from using executable bids or offers as a means to construct Benchmarks where anchored in an observable market consisting of Bona Fide, Arms-Length transactions."⁹

4.6.2 This criterion is substantially fulfilled under each of the proposed closing price mechanisms. However, the LSP fulfils a more literal interpretation of Principle 7 compared to the statistically derived closing prices generated by the VWAP and TBMP.

Criterion 5: Representative of bona fide, arms-length transactions

IMPORTANCE: LOW	COMMENTS	ASSESSMENT
Volume-Weighted Average Price (VWAP)	• Continuous trading does not guarantee execution during VWAP formation, therefore may resort to bid-ask quotes where trades do not occur	Neutral
Time-Based Median Price (TBMP)	• All "snapshot" values are based on comparison between transacted prices and bid-ask quote	Neutral
Last Sale Price (LSP)	• By definition based on transacted prices	Outperform

⁸ IOSCO, Principles for financial benchmarks: Final report (July, 2013), pg 20

⁹ IOSCO, Principles for financial benchmarks: Final report (July, 2013), pg 21

4.7 Summary

4.7.1 Exhibit 3 presents a summary of the preceding analysis. The VWAP is adequate across all aspects, whereas the TBMP's main shortcoming is the risk of aberrant trades producing disorderly outcomes. Despite the relative strength the LSP has in some criteria, it also has some severe shortcomings in that it can be prone to manipulation, is difficult to trade, and susceptible to producing disorderly outcomes.

4.7.2 On the balance of factors outlined above, Chi-X believes the VWAP closing-price mechanism is the most suitable for generating end-of-day reference pricing on the Chi-X market. The VWAP does not adversely affect the existing price discovery process, has the advantage of being familiar to existing market participants and on average generates a closing price that is aligned with the existing benchmark, and remains relatively robust to price manipulation.

Exhibit 3: Summary scorecard

CRITERIA	PRICE DISCOVERY	ORDERLY OUTCOMES	ROBUSTNESS	TRADABILITY	REPRESENTATIVE	RANK
Volume-Weighted Average Price (VWAP)						1
Time-Based Median Price (TBMP)						2
Last Sale Price (LSP)						3
IMPORTANCE	HIGH	MEDIUM	MEDIUM	MEDIUM	LOW	

Worse      Better

Part V: Refining the Parameters of the VWAP Closing Price

5.1 VWAP Parameters

- 5.1.1** The following three parameters must be considered when deciding how to implement a VWAP based closing price mechanism:
- i. What types of trades are included in the calculation of the VWAP?
 - ii. What is the optimal duration and timing of the VWAP formation period?
 - iii. How should the closing price be determined when VWAP is unavailable?

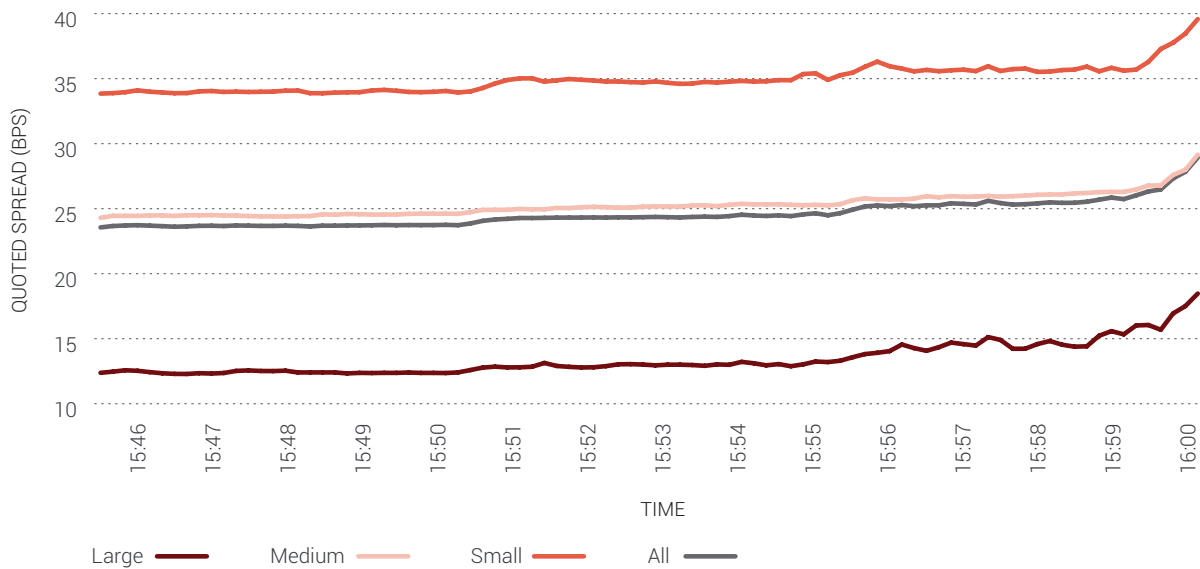
5.2 What types of trades are included in the calculation of the VWAP?

- 5.2.1** All on-market trades are included in Chi-X's VWAP calculation. This includes both hidden and visible trades. Chi-X's integrated order book permits orders to interact with hidden liquidity pegged between the visible spread. Compared to the unintegrated order book, this permits an incoming aggressive order to achieve price-improvement and preserves anonymity of the passive order.
- 5.2.2** Permitting hidden order types in the VWAP calculation can offer several advantages for participants. First, hidden orders will increase the tradability of the Chi-X closing price by permitting more trades to be included during the closing price formation period. Secondly, pegged orders can offer price-improvement opportunities for investors seeking to use market orders to achieve VWAP, therefore reducing the costs of using market orders to target VWAP. Finally, including mid-point trades preserves the consistency of Chi-X trading rules during the VWAP formation period.

5.3 What is optimal duration and timing of the VWAP formation period?

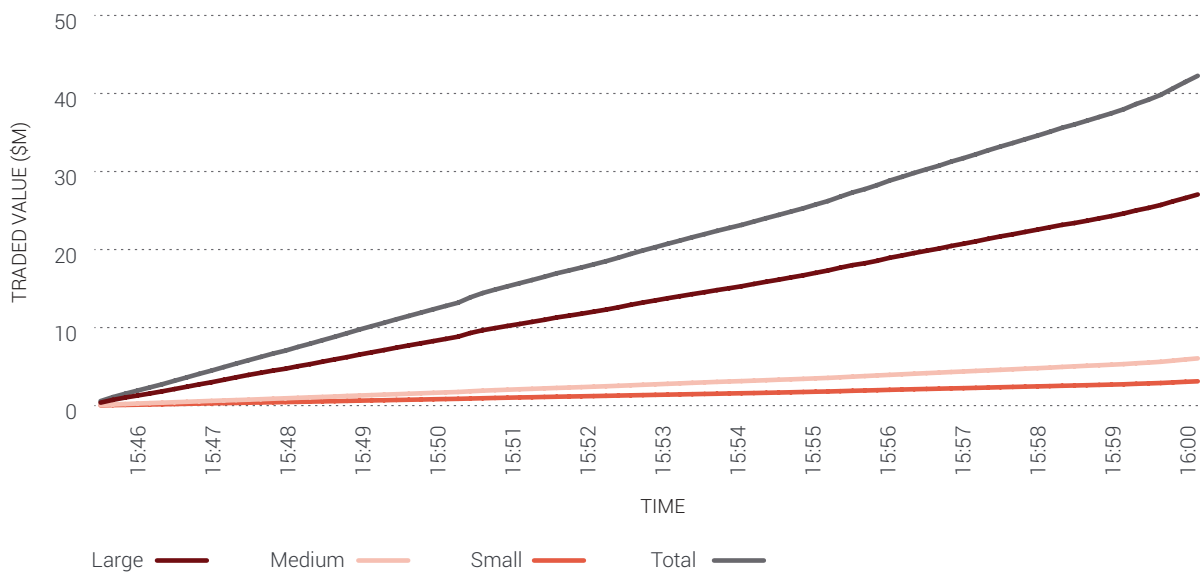
- 5.3.1** The duration of the VWAP formation period can affect the tradability and representativeness of the VWAP to contemporary prices. If the time-period is too short, the price impact of large orders will be higher, which leads to deviations from the fair price. At the same time, a time period that is too long may incorporate stale prices and therefore risk disorderly outcomes.
- 5.3.2** Chi-X proposes a VWAP formation period starting at 15:45:00 and ending at 15:59:50. Current trading behaviour on Chi-X indicates that very few executions occur after 16:00:00. In addition to this, overlapping the VWAP formation period with the CSPA call period may lead to auction fragmentation and disorderly outcomes.
- 5.3.3** In the lead-up to 16:00:00, orders are cancelled on Chi-X as participants vie for priority in the closing auction. As a result, the final sale price can often occur in times of thin liquidity.
- 5.3.4** Exhibit 4 on the next page shows that the quoted spread across all stocks increases markedly after 15:59:00, increasing by up to 60% at the final moments of trading. This behaviour may indicate that the final moments of trading on Chi-X are not reflective of normal market conditions. Nevertheless, the increase in urgency during the final minute of trading can contribute to significant increases in overall liquidity. It is therefore preferable to conclude the VWAP formation period prior to the increase in quotes. A 10 second time buffer between the end of the Chi-X VWAP formation period and the start of the ASX's pre-CSPA will reduce the risk that aberrant quotes are used in closing price calculations.

Exhibit 4: Average quoted spread at close, segmented by marketcap



5.3.5 Exhibit 5 below shows that trading volumes are linearly related to the duration of formation periods. For the top 200 symbols, on average every 5 minutes of trading permits an additional \$10M to be traded at the close. Extending VWAP can directly improve the tradability criterion; however the trade-off is a greater divergence from the ASX CSPA price.

Exhibit 5: Average cumulative traded value at close, segmented by marketcap



5.3.6 Due to the competing tension between similarity and tradability, Chi-X proposes a 14-minute and 50 seconds VWAP starting at 15:45:00 and ending at 15:59:50 to balance the need for a closing price that delivers orderly outcomes and enhances the tradability criterion. A 10 second buffer between the end of the formation period and the pre-CSPA provides an opportunity for traders to withdraw in an orderly manner from the venue prior the commencement of the pre-CSPA.

5.4 How should the closing price be determined when VWAP is unavailable?

5.4.1 As discussed in section 4.6, IOSCO Principles provide guidance on the hierarchy of data sources in the absence of trades for a particular security. A choice exists between using the previous day's closing price, using the last trade, and/or incorporating quotes.¹⁰ For thinly traded securities, incorporating quotes may provide a more contemporary capture of asset prices.

5.4.2 In cases where no trades occur during the VWAP formation period, contingency price rules will rely on a comparison between the last recorded sale price and the bid-ask quote prevailing at 15:59:50. In general:

- i. If the last recorded sale price is greater or equal to the best-bid quote, or lesser or equal to the best ask-quote then the last recorded sale price will be used as the closing price.
- ii. If the last recorded price is lower than the best bid-quote then the bid-quote will be the closing price, whereas if the last recorded price is greater than the best-ask quote then the ask-quote shall be the closing price.
- iii. In all other non-VWAP cases the closing price will be determined by either the last recorded price (if available) or the previous day's closing price.¹¹

5.4.3 The effect of this rule is that a bid or ask quote that offers price improvement on the last recorded sale price will be the quote that forms the closing price.

¹⁰ IOSCO Principle 7 does not preclude the Benchmark Administrator from using executable bids or offers as a means to construct Benchmarks where anchored in an observable market consisting of Bona Fide, Arms-length transactions – Principles for financial benchmarks: Final report (July, 2013)

¹¹ Refer to Exhibit 2 for a diagram on contingency price rules

Part VI: VWAP Simulation

6.1 Scope of simulation

6.1.1 In order to assess the efficacy of the VWAP closing price mechanism, a simulation of the VWAP Closing Price Mechanism was conducted on the historical Chi-X order book and transaction data for the period 1 July 2015 to 30 June 2016. The simulation was restricted to the top 200 most liquid symbols in the market. In total, 253 trading days across 200 symbols generated 50,800 closing prices over this period.

6.2 Simulation results

6.2.1 Table 1 below presents descriptive statistics on the VWAP simulation. Column 3 shows the frequency of each contingency scenario occurring as a percentage of the total number of stock days. In 97.3% of cases the closing price can be formed on a VWAP, in 0.3% of cases prices are based on a bid or ask quote at the end of the VWAP formation period, in 1.6% of cases the last sale price is used and in 0.1% of cases no trades and no quotes exist, therefore necessitating the use of a previous day's closing price.

6.2.3 The difference between the Chi-X closing price and that of an existing benchmark can be used as a proxy for evaluating a disorderly outcome. Column 4 shows the mean difference between the Chi-X closing price and the ASX closing price. Here the differences are expressed as a percentage of the ASX CSPA price. On average, the Chi-X closing price was 0.5 basis points (bps) lower than the CSPA Close, with a standard deviation of 44.7 bps over this time period. Taking absolute values, provides a sense of the magnitude of the average deviation, and here the mean absolute difference was 27.4 bps. This figure implies that for stocks priced below \$4, the average difference was within a one-tick deviation of the benchmark close price. These results indicate the VWAP methodology is not systematically biased despite the existence of timing and market frictions.

Table 1: Simulation of VWAP on historical data

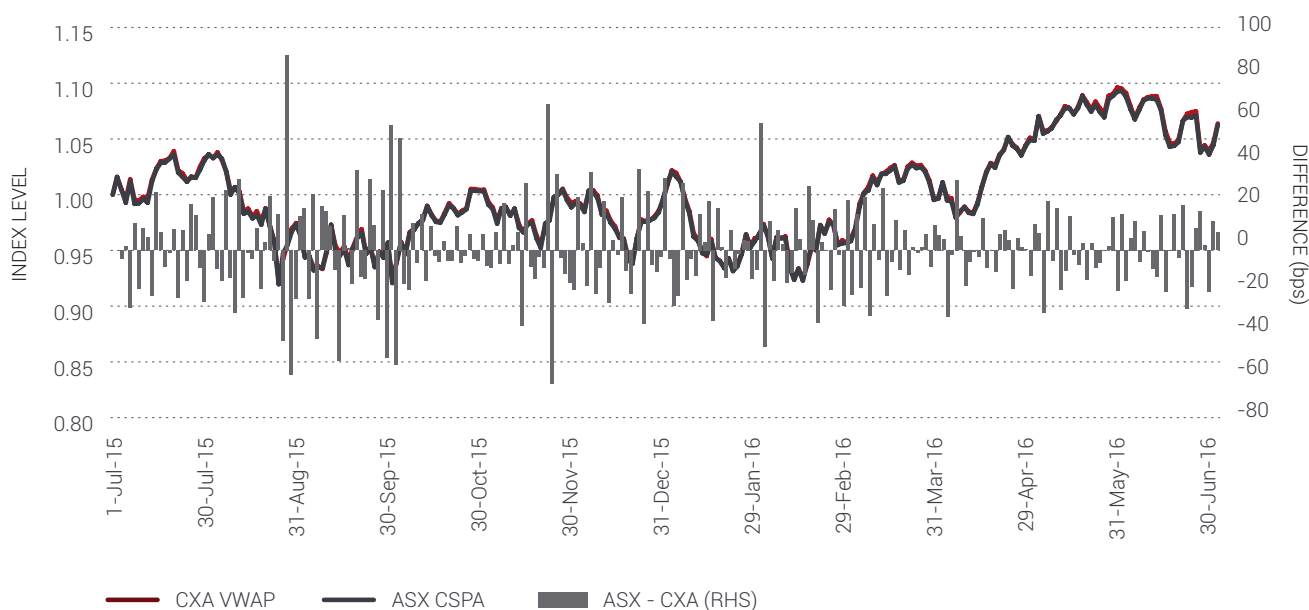
CONTINGENCY	OBSERVATIONS	PROPORTION	MEAN DIFF	MEAN ABS DIFF	STD DIFF
1. VWAP	49426	97.3%	-0.5bps	26.7bps	42.4bps
VWAP Close Price	49426	97.3%	-0.5bps	26.7bps	42.4bps
2. Bid Quote	156	0.3%	-40.4bps	57.4bps	101.9bps
3. Ask Quote	27	0.1%	28.9bps	38.9bps	51.6bps
4. Last Trade	810	1.6%	3.8bps	52.8bps	90.5bps
Non VWAP Close Price	993	2.0%	-2.5bps	53.2bps	93.0bps
7. Previous Close	72	0.1%	19.1bps	167.3bps	220.7bps
Previous Closing Price	72	0.1%	-225.9bps	167.3bps	220.7bps
8. Halt/Suspended	309	0.6%	-		-
No Closing Price	309	0.6%	-		-
Total Stock Days	50800		-0.5bps	27.4bps	44.7bps

6.3 Index backtest: VWAP Index vs. CSPA Index

6.3.1 Another proxy for a disorderly outcome would be if the Chi-X closing price delivered significantly different outcomes to CSPA closing prices when used for a benchmark process, such as the calculation of an index. Exhibit 6 below presents the results of a back-tested hypothetical market capitalisation index using Chi-X VWAP closing prices compared to ASX CSPA prices, for the period 1 July 15 to 30 June 16. The constituents are the top 200 ranked by market capitalisation, rebalanced quarterly. The left hand side axis

represents the price level and the right hand side represents the difference in daily returns between the CSPA and VWAP indices (expressed in bps of the ASX). The results show that although the overall index returns possess negligible differences in the long-run, short-term daily variability due to differences in closing price methodology may cause daily index returns to vary by up to 100bps. These differences are elevated on index rebalance dates, but also appear to be mean-reverting, large positive differences are followed by large negative differences (and vice-versa).

Exhibit 6: Daily index levels and returns comparison (VWAP v CSPA)



6.3.2 Table 2 below presents the statistical characteristics of the daily index returns series and a comparison between the CSPA index and the VWAP index. Column 3 shows the difference between the daily return series (equivalent to the LHS chart series in Exhibit 6 above). In order to assess the impact that outliers have on the distributional properties of the two indices, the outliers in the stock-date record

have been removed.¹² It can be observed that after the removal of outliers the moments of the distribution remain largely unchanged, measures of location such as the median and interquartile range are marginally improved. This indicates that the returns of Chi-X VWAP index remains stable despite the presence of extreme differences in individual stock closing prices.

Table 2: Index back testing – simulation results

	CSPA INDEX RETURN	VWAP INDEX RETURN	DIFFERENCE	DIFFERENCE EX. OUTLIER
Mean	3.1bps	3.0bps	0.0bps	-0.1bps
Std. Deviation	114.9bps	109.0bps	20.6bps	20.5bps
Skewness	-0.3	-0.3		
Kurtosis	0.4	0.2		
Min	-401.8bps	-359.6bps	-62.5bps	-61.8bps
P25	-63.5bps	-64.4bps	-12.6bps	-12.4bps
Median	9.4bps	7.7bps	-1.1bps	-1.3bps
P75	75.9bps	73.8bps	12.2bps	11.3bps
Max	300.3bps	248.3bps	91.1bps	90.6bps

¹² Outliers are defined as those stocks where the absolute daily difference in returns between the CSPA and VWAP is greater than 1%

Part VII: Closing Price: Risks & Mitigants

7.1 What factors contribute to greater divergence in closing prices?

- 7.1.1** As identified in section 4.5, a variety of factors can contribute to the divergence in closing prices between the Chi-X VWAP and the ASX's CSPA. This is relevant in ensuring orderly outcomes.
- 7.1.2** The difference in closing prices is a 12-minute rate of return between the VWAP and the price generated by the ASX's CSPA. A number of factors can be expected to influence the size of these deviations. Financial theory informs us that the evolution of intraday prices reflects changes in response to new information about the company, discount rates, and order flow. In the relatively short time frame under consideration, it is unlikely that changes in fundamental information is driving significant changes in price, rather aggregate market movements and price discovery from information impounded in order flow is expected to have a greater impact on prices. Idiosyncratic factors may also drive higher intraday volatility on individual stocks. Finally, in the context of closing prices, institutional features, such as index rebalance dates and contract expiration dates can also drive abnormal price and volume changes.

7.1.3 Exhibit 7 below plots the 12-minute midpoint return from 16:00 – 16:12 of the SPI Future contract (which trades continuously during the auction call period) versus the CSPA to VWAP return for the same period. The return on the SPI future proxies for price discovery arising from the published closing auction imbalance. As expected a positive linear relationship is observed between the difference in closing prices and the return on the SPI. The R-square of 0.63 (and associated correlation of 0.79) suggests that the majority of CSPA-VWAP divergences can be explained by price discovery in the auction.

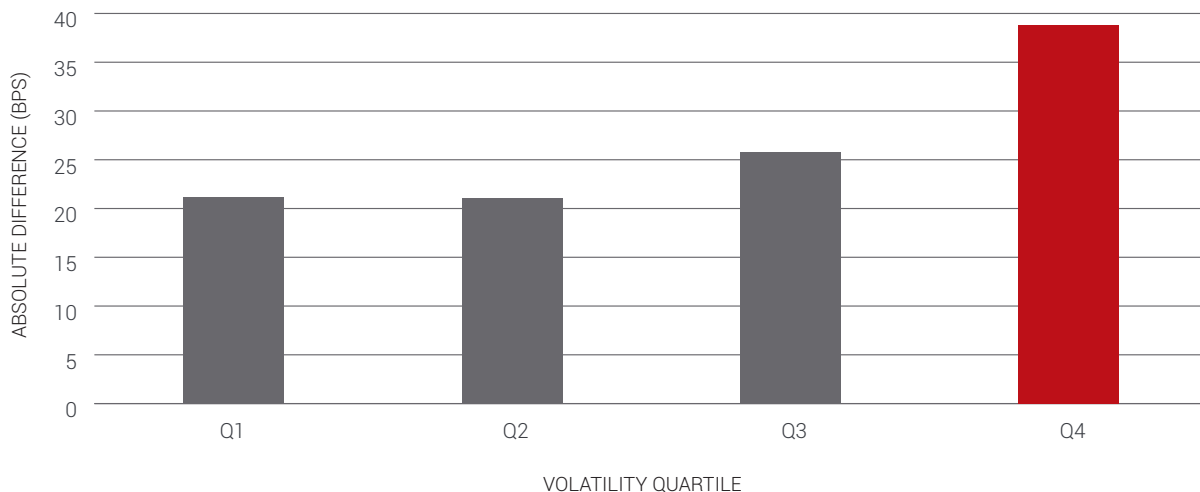
Exhibit 7: SPI returns vs VWAP index return



7.1.4 Exhibit 8 below shows the relationship between volatility and closing price deviation. Symbols are partitioned into quartiles based on the magnitude of its intraday volatility,¹³ the average absolute closing price deviation (expressed in bps) for each quartile is then calculated. Symbols in the bottom 50% of volatility, the average absolute difference is on the order of 20bps. For symbols in the top 50% of volatility, we see increasing

absolute differences, for symbols in the 3rd quartile the average absolute difference is 25% higher at approximately 25bps, while 4th quartile symbols possess an average absolute difference of approximately 40bps, corresponding to a 50% increase over quartile 3 stocks. As expected, high volatility symbols are associated with greater closing price deviation than low volatility symbols.

Exhibit 8: Average closing price deviation by volatility

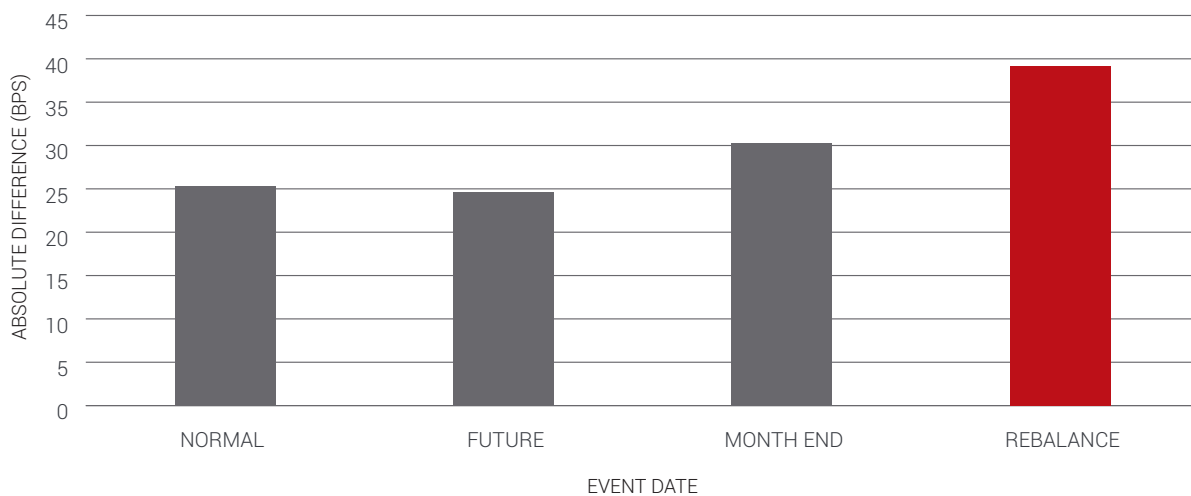


¹³ Measured in standard deviation of the log midpoint return

7.1.5 Exhibit 9 below compares the average absolute deviation between closing prices on event dates where an abnormal proportion of trading typically occurs during the closing auction. Column 1 shows that the average absolute price deviation on normal (non-event) trading dates is approximately 25bps. Column 2 shows the average absolute price deviation on Index Future expiry dates, these dates are associated with a lower than average auction proportion, here the average price deviation remains approximately 25bps. Month end dates, shown in column 3, are associated with greater than average auction

volume, and corresponding greater than average absolute price deviations. Finally, index rebalance dates (quarterly S&P rebalance and quarterly MSCI rebalance) which typically experience extremely high levels of auction activity are associated with the greatest average absolute difference with an average deviation that is approximately 55% higher than the average of all other days. These results suggest that there is a link between the relative volume between the closing auction and continuous trading and the degree of closing price deviation in securities.

Exhibit 9: Average closing price deviation by event date



7.1.6 Exploratory analysis on the drivers of closing price deviation offers Chi-X the ability to create a data-driven analytical model to monitor for aberrations during the VWAP price formation. Insofar as deviations represent market frictions, it is expected that the implementation of the VWAP will increase liquidity during the VWAP formation period, this increase in liquidity is expected to reduce known sources of market friction, Chi-X expects that this will improve market quality outcomes.¹⁴

¹⁴ For example; reduce end-of-day price dislocation that is observed between the end of continuous trading, and the end of the closing auction

7.2 Volatility control

- 7.2.1** Volatility control mechanisms, such as the Extreme Trading Range (ETR) that applies to products traded on Chi-X, act as a circuit-breaker when markets experience extreme turbulence. These mechanisms aim to curtail excess volatility by temporarily suspending trading and allowing market participants time to process new information and normalise trading behaviour.
- 7.2.2** Extreme price dislocations can be categorised into permanent or temporary price dislocation events. An example of a permanent price impact event would be an unexpected event such as a natural disaster. If such an event triggers a circuit breaker mechanism, then trading would cease and depending on the circumstances, one of the contingency methods described in section 5.4 would be deployed if the VWAP cannot be formed.
- 7.2.3** In cases where the price impact is temporary, for example during a cascading error scenario (aka “flash crash”), then the appropriate reference price under ASIC Market Integrity Rules may be the opening price as determined by a call auction on the ASX. In the case of an ETR event during the VWAP formation period, and in accordance with the given circumstances, Chi-X may exercise its discretion to determine an appropriate reference price, for example, Chi-X may select the first trade on Chi-X after the re-opening auction on the ASX.

7.3 Closing price manipulation

- 7.3.1** The Chi-X VWAP formation period occurs during a period of continuous trading on both Chi-X and the ASX. Under normal market operations arbitrage forces are sufficient during continuous trading to keep prices between the two markets aligned.
- 7.3.2** For actively traded stocks, closing price manipulation would be extremely costly as a manipulator would need to take liquidity from the order book faster than it can be replenished and this would need to occur throughout the 15-minute VWAP formation period. For thinly traded stocks, the potential for closing price manipulation is higher as capital commitment is smaller.
- 7.3.4** In order to safeguard against closing price manipulation, Chi-X will closely monitor for aberrant prices and volumes and quoting activity during the VWAP formation period. In addition to this, comparing the closing price to the CSPA price may assist in identifying cases of closing price manipulation.

Appendix

i. Table of Closing Price Mechanisms Deployed at Major Exchanges

COUNTRY	MECHANISM	ON-CLOSE FACILITY	VOLUME ON CLOSE	COUNTRY	MECHANISM	ON-CLOSE FACILITY	VOLUME ON CLOSE
Australia	Auction		9.3%	Japan	Auction		5.0%
Austria	Auction		17.0%	Netherlands	Auction	Yes	10.5%
Belgium	Auction	Yes	5.0%	New Zealand	Auction		10.0%
Canada	Auction	Yes	5.0%	Norway	Auction		11.7%
Finland	Auction	Yes	10.2%	Portugal	Auction	Yes	10.4%
France	Auction	Yes	13.0%	Singapore	Auction		9.3%
Germany	Auction		12.2%	South Korea	Auction		0.6%
Greece	Auction		6.8%	Spain	Auction		25.5%
Hong Kong	Median Price			Sweden	Auction	Yes	10.2%
Ireland	Auction		16.0%	Switzerland	Auction		13.1%
Israel	Auction		7.5%	United Kingdom	Auction		12.6%
Italy	Auction		7.5%	United States	Auction	Yes	4.5%

Source: FTSE January 2016, ITG August 2014



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