A substitution effect between price clustering and size clustering in credit default swaps

Abstract:

In a perfectly liquid market, investors' optimal allocation decisions refer to maximising all three dimensions of liquidity, namely immediacy, width and depth. To the extent that investors fail to accommodate size (depth) along with price (width) in their optimal allocation decisions, their overall costs may increase. This paper focuses on the substitution of width and depth by investigating the simultaneous determination of price clustering and size clustering in the credit default swap (CDS) market. We report strong evidence that when traders round prices they tend to quote more refined sizes, and vice versa. The findings highlight a clear trade-off between price clustering and notional amount in the CDS market, and contribute to the emerging literature on size clustering.

Keywords: credit default swap, price clustering, size clustering, notional amount.

JEL codes: G10, G12.

1. Introduction

If a market is perfectly liquid, market participants can trade a desired quantity immediately without moving the market price. However, if a market is not perfectly liquid, market participants must compromise on one or more of the three dimensions of liquidity, i.e. immediacy, width and depth (see Hodrick and Moulton, 2009). Immediacy refers to the speed at which trades of a given size can be executed at a given cost; width refers to the cost of completing a trade of a given size; depth refers to the size of a trade that can be arranged at a given cost (see Harris, 2003, p. 398). For example, market participants may have to choose from a discrete set of prices or frequently quoted sizes for a financial asset in order to speed up order execution. Price clustering refers to the observation of a concentration of quotes or trades at certain integers, or significantly greater than 50% of quotes or trades occurring at even price fractions. There have been several proposed theories of the causes of price clustering, e.g. attraction of numbers (e.g. Goodhart and Curcio, 1991), price resolution (Ball et al., 1985), negotiation costs (Harris, 1991), and cultural factors (Brown et al., 2002) as well as empirical findings in support of different theories (e.g. Grossman et al, 1997). The presence of price clustering can have a significant impact not only on liquidity (as bid-ask spreads can only take discrete values given discrete bid and ask prices (see Christie and Schultz, 1994)), but on asset pricing in general since it implies non-randomness of the price process.

Analysis of size clustering is a recently emerging theme in the literature, which focuses on the quantity dimension of liquidity. There is currently no consensus definition; here, size clustering is defined as the concentration of the size of quotes or trades at certain amounts.

There have also been theories of the causes of size clustering (e.g. Hodrick and Moulton, 2009), though not as well-developed as those relating to price clustering. There has been investigation of the presence and determinants of trade size clustering in the equity, foreign exchange and index futures markets (see Alexander and Peterson, 2007; Moulton, 2005; and ap Gwilym and Meng, 2010; respectively), but not in other markets so far. There are some prior indications that size clustering (in notional amounts) exists in credit default swaps (CDS) (e.g. Houweling and Vorst (2005)), which suggests that the CDS market could be a fruitful location to investigate the possibility of substitution between price clustering and size clustering.

Credit derivatives are one of the most important financial innovations of the last 25 years, offering users the ability to manage credit risk. The credit derivatives market has attracted particular attention during the US sub-prime crisis and the European sovereign debt crisis, but relatively little empirical evidence exists relating to the market's microstructure. Heightened attention to CDS contracts is highlighted by the designation of a "credit event" by the International Swaps and Derivatives Association (ISDA) for the Greek debt restructuring in March 2012. The notional outstanding amount of CDS, the most important credit derivative product, grew from US$0.92 trillion in 2001 to US$62.17 trillion in 2007, a 6766% increase. However, due to the effects of the recent financial crisis, this fell back to 2006 levels and was estimated at US$26.26 trillion in 2010 (see Figure 1). Whereas the above prior literature has considered clustering in trade sizes, this paper focuses on size clustering in terms of notional amounts in CDS contracts. We adopt this approach because the notional amount forms the basis for calculating the payoff of a CDS contract, and this feature also adds to the uniqueness of this study.

*** Insert Figure 1 here***

This paper investigates the presence of price clustering and size clustering in the CDS market, and whether the two forms of clustering in this market are substitutes. To the best of our knowledge, this is the first empirical study that draws links between price clustering and size clustering in a formal model based on simultaneous determination. Additionally, although price clustering has been widely studied in financial markets, there are no such studies of the CDS market. This is important, given the growth of this market, and the attention it has received in recent years. Size clustering is an emerging theme in the literature, and has only been previously documented in the equity, foreign exchange and index futures markets.

The remainder of the paper is structured as follows. Section 2 reviews the previous theories and empirical findings regarding price clustering and size clustering, Section 3 discusses the data and Section 4 presents the evidence on price clustering and size clustering in CDS contracts. Section 5 studies the hypothesis that there is a substitution effect between price clustering and size clustering, and Section 6 concludes.

2. Literature review

2.1. Price clustering

Goodhart and Curcio's (1991) attraction theory suggests that discrete prices are obtained by rounding continuously distributed underlying values to the nearest available final unit. However, the rounding does not depend solely on linear distance, but also on the basic attraction of each integer. Ball et al (1985) suggest that price clustering results from the achievement of the optimal degree of price resolution, i.e. the desired level of price accuracy. The optimal degree of price resolution may depend on the amount of information in the market, i.e. the less information, the lower price resolution, and may be proportional to the price level. Harris' (1991) negotiation hypothesis argues that the price resolution hypothesis (achieving desired level of price resolution) can be motivated by negotiation costs.[1] Traders use a smaller discrete set of prices to limit the number of bids and asks that can be quoted, and thereby reduce the time involved in striking a deal.

Christie and Schultz (1994) argue that the lack of odd eighths quotes at Nasdaq was due to dealers' implicit collusion to maintain wide spreads. Barclay (1997) found a greater average narrowing of spreads for stocks quoted on even eighths than on mixed eighths, which supported the evidence for the collusion hypothesis. Grossman et al (1997) argue that Christie and Schultz's (1994) collusion hypothesis ignored the fact that the number of actual competitors on Nasdaq is too large to enable collusion, and noted the ability of dealers to compete in other areas such as commission. They also found that after the news

[1] Costs of negotiation consist of fluctuation in inventory values while the negotiation takes place and the total fees earned per unit of time by executing customer orders.

reports about Christie and Schultz's (1994) finding and the subsequent legal actions against the brokerage firms which allegedly brought down the even-eighth system, there is no significant change in price clustering of the 100 companies in Christie and Schultz's (1994) original sample.

Mitchell (2001) argues from a psychological point of view that price clustering is caused by the slower mental response to odd numbers than to even numbers, and the increased mental processing time where there is inconsistent number format (such as changing decimal places). Also, Brown et al. (2002) show that cultural habits and superstition are a significant factor in explaining price clustering e.g. the avoidance of the "unlucky" number 4 by traders in mainland China.

Researchers have documented price clustering in various markets. Christie and Schultz (1994), Aitken et al (1996), Grossman et al (1997), Hameed and Terry (1998), Kandel et al. (2001), Chung et al (2004), Ahn et al (2005) and Ohta (2006) find evidence of price clustering in equity markets around the world. Price clustering is also reported in the foreign exchange market by Bessembinder (1994), Sopranzetti and Datar (2002) and Osler (2003). In derivatives markets, ap Gwilym et al (1998a) find that there are few half index point quotes in the FTSE100 index futures and options markets. Schwartz et al (2004) document price clustering at ".00" and ".50" for S&P 500 futures contracts. ap Gwilym et al (1998b) document price clustering for the German Bund, UK Long Gilt, the Italian BTP and the Japanese JGB in the bond futures market.

The literature on the price clustering determinants indicates that price clustering has a positive relation with the level of prices and price volatility, and it has an inverse relation with transaction frequency and order size (see Harris, 1991; Aitken et al, 1996; ap Gwilym et al, 1998a; Hameed and Terry, 1998; Sopranzetti and Datar, 2002; Schwartz et al, 2004; Ahn et al, 2005). Recently, Liu and Witte (2012) show that high expected rates of return may lead to faster trade execution and hence to greater price clustering. Further, the authors report an inverse relationship between contract liquidity and price clustering.

2.2. Size clustering

Most of the relevant previous theoretical frameworks (Copeland and Galai, 1983, Kyle, 1985; O'Hara 1995) assume that there are liquidity providers (e.g. a market maker) and liquidity demanders. In their models, liquidity demanders can always trade the quantities they desire, i.e. quantity demand and quantity supply are always in equilibrium. In Hodrick and Moulton's (2009) model, the uninformed traders' desire for trade quantity satisfaction is influenced by factors such as seasonal pressures and access to substitute products. Therefore quantity demand and supply are not always in equilibrium. They suggest that under some seasonal pressures, such as a heightened desire to hedge portfolios at times when external and internal scrutiny may be greater, they may have a greater desire to satisfy specific quantity demands.

Empirical studies on the choice of trade size and its impact on financial markets can be divided into two themes. The first theme is concerned with the evidence and determinants of size clustering. The second theme in the literature focuses on block trades and their impact on market price.[2] Focusing on size clustering, Alexander and Peterson (2007) report increased clustering around multiples of 500, 1000 and 5000 shares at the NYSE between 1990 and 2001. They find that trade size clustering is positively related to the volatility of stock prices and the number of trades, and is inversely related to price levels. Moulton (2005) investigates trade size clustering in the foreign exchange market. She finds that trade size is less clustered at fiscal quarter ends. In addition, she finds that the degree of trade size clustering has a positive relation to trading activity and the volatility of foreign exchange rates.

A small group of papers have attempted to link size clustering and price clustering. Alexander and Peterson (2007) examine trade-size clustering in NYSE and Nasdaq and find trade-size and price rounding tend to occur simultaneously when trading is abnormally heavy. They suggest that the use of rounded size and price simplifies the negotiation process. Blau et al. (2012) investigate short sellers' trade-size and price choices at the NYSE and Nasdaq. In contrast to Alexander and Peterson (2007), they find that short sellers are indifferent to round sizes at rounded prices at the NYSE, and size clustering and price clustering are inversely related at Nasdaq. They suggest that short sellers' motivation of size-price choices is different from non-short traders. Finally, for index futures, ap Gwilym and Meng (2010) find that less clustered prices have more clustered sizes, which is suggestive that price resolution and size resolution may be substitutes in that market setting.

[2] In the interests of brevity, we do not expand on this second theme here.

3. Data

The CDS data used in this paper are a sample of American market quoted prices (hereafter referred to as "quotes") and traded prices (hereafter referred to as "trades") from the Market Prices database of CreditTrade.[3] CreditTrade divides Market Prices into America, Europe, Asia and Japan. American market prices are defined as prices on reference entities from North America and Latin America. The sample period is from January 2, 2000 to March 3, 2005. There are in total 739 reference entities quoted during this period, among which 39 are banks, 671 are corporates and 29 are sovereigns.

Insert Table 1A here

Table 1A shows that although the entire sample contains 739 reference entities the frequency of trading among these reference entities is very unevenly distributed, with the top 30 reference entities accounting for about half of the activity. However, the most frequently quoted reference entities are not necessarily aligned with most frequently traded reference entities (see Table 1B).

[3] CreditTrade, incorporated in the UK, is a broker in global credit markets, specialised in CDS and secondary loans. CreditTrade provides CDS transaction services through an Internet-based online trading platform or through telephone. For the period from June 1997 to March 2005, CreditTrade's database contains 1500 reference entities. GFI and Creditex are the main competitors, and their databases have 1700 and 1400 reference entities respectively. This indicates that CreditTrade's database represents a substantial proportion of trading activity in the CDS market during the sample period. CreditTrade and Creditex later merged.

Insert Table 1B here

89.6% of the reference entities in the sample are rated by Moody's Investors Service. Table 2, Panel A, shows the distribution of ratings from 2000 to 2005. Except for the lowest band 'Caa1-C', the distribution changes substantially across the sample period. Reference entities with A1 or above ratings account for a declining proportion. The Baa rating band has consistently been the most heavily represented since 2000. There is a large proportion of Ba- and B-rated entities at the beginning and the end of the sample period. Table 2, Panel B, shows that as the market matures, less focus is placed on the highest-rated entities (Aaa-A3) and there is greater focus on speculative grade entities (Ba1-C). Also, in 2008, the high proportion of low rating categories reflects the height of the dotcom bubble.

Insert Table 2 here

CreditTrade confirmed that the majority of the quotes in the dataset are tradable, i.e. they were submitted electronically and could be matched automatically. Analysis of these quotes allows us to investigate the bidding and asking process prior to when the order is filled. Notional amount, used in both CDS quotes and trades, works in the same way as for interest rate swaps, i.e. it is the amount on which payments under CDS are calculated.

Table 3 contains the descriptive statistics for notional amount, maturity, and bid/ask/trade prices of the sample. We observe that the notional amount and maturity are very concentrated around the mean. The mean trade price is closer to the mean ask price than to the mean bid price.

4. Evidence of Price Clustering and Size Clustering

Table 4 presents the distributions of the final digits of quoted and traded prices. We use the standardized range (SR) as a measure of the degree of price clustering for comparison across different markets (see Grossman et al., 1997).[4] The most striking feature is the predominant use of "0" (35% of quoted prices, and 30% of traded prices) and "5" (27% of quoted prices and 24% of traded prices) as the last digits of prices. In general, the extent of price clustering in the CDS market is greater than in other markets, e.g. the equity market (Ahn et al, 2005), the London equity index derivatives markets (ap Gwilym et al, 1998a), and bond futures markets (ap Gwilym et al 1998b). This greater degree of price clustering is also reflected in the standardised range of 3.19 (in quotes) and 2.58 (in trades) in comparison to standardised ranges of 0.24 on NYSE/AMEX, 1.36 on Nasdaq, and 0.70 on LSE (see Grossman et al 1997).

Insert Table 4 here

[4] The SR measure is preferred over the more commonly used measure of χ^2 because the latter only addresses the existence of price clustering, not its extent. The formula for SR is: SR = (Max(ω_i) - Min(ω_i)) / x_i, where ω_i refers to the percentage of observations at final digit i, and Min( ), Max( ) refer to the minimum and maximum value of the set, respectively. x_i refers to the percentage at each final digit i if no price clustering is present. The absence of price clustering would lead to a SR value of zero. For ten possible final digits of price, 100% concentration at one particular digit would give a SR value of ten.

To examine the causes of price clustering, we also calculate the CDS mean notional amounts for quotes and trades at each final digit of price. If the negotiation hypothesis (Harris, 1991) is valid, rarely used final digits should have larger mean notional amounts than the others, while the most frequently occurring digits should have the smallest mean notional amounts.

Insert Table 5 here

Table 5 presents the mean notional amounts for trades and quotes at each final digit of price. Prices ending with ".5" have much larger mean notional amounts than prices ending with any other digit, while prices ending with "0" have the smallest notional amounts followed by prices ending with "5". Overall, the deviation of the mean notional amount for each digit from the total mean notional amount is negative and significant for prices ending in "0" and "5" and strongly positive and significant for prices ending in ".5". The significance of these final digits is also observed for quotes. These findings are very supportive of the negotiation hypothesis (Harris, 1991), i.e. when the size of the CDS contract is large, traders tend to prefer greater price resolution because the benefits of negotiating prices are greater.

Table 6 shows the distribution of the most frequently used notional amounts for trades and quotes. While US$5 million is the most frequently used notional amount for both trades (62.8%) and quotes (89.6%), the use of US$10 million is much more frequently observed in trades (13.1%) than in quotes (0.8%). This is also consistent with Table 5 where the mean trade sizes are generally larger than the mean quote sizes. In addition, US$2 million and US$3 million are also among the most frequently used notional amounts for both trades and quotes. In summary, there is apparently a phenomenon of size clustering in the CDS market, in particular the use of US$5 million as the most popular notional amount.

Insert Table 6 here

ap Gwilym and Verousis (2013) show that price clustering is inversely related to maturity in equity options. That is, prices tend to be more clustered for the shorter-to-mature contracts as traders' urgency to trade increases as the expiry date approaches. Panel A of Table 7 indicates the extent of price and size clustering in quotes for different CDS maturity dates.

Insert Table 7 here

The results show that price clustering is greatest for the shortest maturity contracts (consistent with ap Gwilym and Verousis, 2013). Size clustering consistently increases for longer maturities, up to the point where all CDS contracts with 20 years of more maturity have US$5m notional amounts.[5] The results indicate that the negotiation hypothesis is better able to explain the short-term maturity effect for price clustering whereas for the very long-maturity contracts, the price resolution hypothesis prevails.

[5] Quote observations are not uniformly distributed across maturity dates (see also Meng and ap Gwilym, 2007).

5. A Substitution Effect between Price Clustering and Size Clustering

We now turn our attention to the hypothesis that price clustering and size clustering are determined simultaneously. Panel B of Table 7 reports price clustering and size clustering at value quartiles. The results show a clear trade-off in price clustering and size clustering as value increases (based on multiple of price and notional amount). That is, the distribution of notional amounts is coarser for larger values, whereas the distribution of prices diminishes. For high value contracts, prices are more clustered (as in prior literature) while more notional amounts are available. A further indication of the relationship between price and size clustering is offered in Figure 2. This shows the time series percentage distribution of clustered quoted sizes and the weighted average proportion of clustered asks plus clustered bids per day during the sample period. The correlation coefficient between size clustering and price clustering is -0.48. A second element evident in Figure 2 is that there is a trend towards increased size clustering and lesser price clustering during the sample period. The CDS market has tended toward more standardization of notional amounts (greater size clustering) as it has matured.

Insert Figure 2 here

The following simultaneous equations are used to formally examine the hypothesis of a substitution effect between price clustering and size clustering in the CDS market. This system of equations is estimated by three-stage least squares (3SLS).

$$PC_t = \alpha + \beta_1 SC_t + \beta_2 NM_t + \beta_3 PL_t + \beta_4 AR_t + \beta_5 IQ_t + \beta_6 EOQ + e_{1t}$$

(1)

$$SC_t = \alpha + \beta_7 PC_t + \beta_8 Q_t + \beta_9 EOQ + \beta_{10} i_t + \beta_{11} IMB_t + \beta_{12} NM_t + \beta_{13} AR_t + \beta_{14} MR_t + e_{2t}$$

(2)

Where: t indexes the days in the sample; PC is the degree of price clustering measured by the daily proportion of quoted prices which have final digits of "0" or "5", i.e. the number of quotes ending in "0" or "5" divided by the total number of quotes.[6] SC is the degree of size clustering measured by the daily proportion of quoted prices which have a notional amount of US$5 million.[7] The expected signs for SC in equation (1) and for PC in equation (2) are both negative if there is a substitution effect. NM is the daily mean notional amount of quotes. According to the negotiation hypothesis, participants with large trades should have more incentive to negotiate or search for more refined prices, therefore the expected coefficient sign is negative for equation (1). The larger the order size, the more likely that traders will break the order into a multiple of US$5 millions, so the expected sign for

[6] Various measures of price clustering appear in the literature. Ball et al (1985) investigated the phenomenon of clustering at 20, 25, 50 and 100 cents in the gold market. For US stocks, Harris (1991) used the difference between the number of even and odd eighth prices and the frequency of integer prices. Due to the extreme clustering of CDS prices around 0 and 5, we use the proportion of prices ending in 0 and 5.

[7] Moulton (2005) used the number of distinct trade sizes as the measure of size clustering in the foreign exchange market, and Alexander and Peterson (2007) measured size clustering in the US stock market as the multiples of 500, 1000 and 5000. This paper refers to 'size' as the notional amount since this forms the basis for calculating the payoff of a CDS contract, and the choice of US$5 million is based on the results in Section 4.

equation (2) is positive. PL is the daily mean quoted CDS price. Since Ahn et al (2005) and others find that in general higher-priced assets demonstrate more clustering, the expected sign is positive. AR is the daily mean absolute return. According to the price resolution hypothesis, clustering is expected to increase during periods of high volatility, thus the coefficient on AR is expected to be positive in both equations. IQ is the inverse square root of the number of quotes on the day. Harris (1991) finds that clustering decreases with transaction frequency, showing that price uncertainty is proportional to the inverse square root of the number of transactions, therefore the expected sign is positive.

Q is the total number of quotes. The coefficient is expected to be negative, i.e. the more quotes, the more distinct sizes are available. *EOQ* is a binary dummy variable that takes the value of 1 when a contract trades at a calendar quarter end. Moulton (2005) shows that size clustering decreases at quarter-end periods which reflects the internal monitoring of trading firms. Liu and Witte (2012) find that price clustering increases during quarter ends, so the expected sign is positive in equation (1). i is the change in the risk-free interest rate, estimated using the average of 1-year Treasury bill and 2-year to 30-year government bond yields (all the maturities in between).[8] Increases in risk-free rates often signal the arrival of tighter credit conditions relative to the previous period, and the cost of servicing the outstanding debt can also increase. This may in turn lead to an increase in the probability that an issuer will default on its debt. As a result, there may be more investors who wish to hedge their bond holding and the number of distinct notional amounts is expected to rise. Therefore, the sign is expected to be negative. IMB refers to order imbalance and is

[8] CDS maturities have a similar range.

calculated as the absolute value of one minus the bid/ask frequency ratio. The coefficient for IMB is expected to be negative which will reflect that large order imbalances imply a shift in the demand and/or the supply curve, hence CDS contracts are expected to be more accurately priced. MR is the daily percentage of CDS contracts with a modified restructuring clause. Since MR is the most commonly used restructuring form we suggest that traders combine US$5 million notional amount with MR to speed up order flow. Hence the expected sign is positive.

Before estimating the above 3-stage least square regression, we use the Durbin-Wu-Hausman test to confirm the endogeneity of price clustering and size clustering. The residuals of endogenous variables generated from the first stage are used in the second stage for testing endogeneity.[9]

In the Durbin-Wu-Hausman test, the F-statistics of the residuals of endogenous variables (price clustering and size clustering) are 73.28 and 94.74 (both significant at the 1% level). This provides strong evidence that the price clustering and size clustering variables are endogenous. Therefore, OLS estimation of the model would be biased and inconsistent, hence we use 3SLS. Results for Equation (2) are presented in Panel A of Table 8. There is a strong and significant inverse relation between price clustering and size clustering, i.e. a reduced degree of size clustering (measured by the reduced use of US$5 million as the notional amount) is associated with an increased degree of price clustering (measured by increased use of “0” and “5” as the last digit of quoted prices). The daily mean notional

[9] As trades are dispersed and irregularly spaced, we employ the 3SLS model on quotes only.

amount has a positive impact on price clustering. This is not consistent with the hypothesis that larger sizes would lead to negotiating more refined prices, however the size of the coefficient is negligible. The extent of price clustering on a given day is positively and significantly related to the daily mean CDS premium. This is as expected, i.e. the higher the price level, the more likely that more rounded prices will be quoted. The mean absolute return has a positive relation with price clustering, and this is consistent with the hypothesis that price clustering increases during periods of high volatility. The inverse square root of number of quotes has a negative relation with price clustering. This is in conflict with Harris' (1991) hypothesis that higher transaction frequency signals more information arrival and less uncertainty, and therefore leads to less price clustering. However, our finding is consistent with ap Gwilym et al (1998a) who suggest that during busy times the use of refined prices is cumbersome. Finally, the end-of-quarter dummy has an inverse relation to price clustering, but this finding is not statistically significant.

Insert Table 8 here

Results for Equation (2) are presented in Panel B of Table 8. As expected, price clustering is inversely and significantly related to size clustering, i.e. the use of more refined prices is more common for contracts with the popular notional amount of US$5 million. The coefficient on the number of quotes is significant and negative as hypothesized, hence the greater the number of quotes, the smaller the overall proportion of clustered trade sizes that are available. There is also evidence that higher interest rates are associated with more size clustering, which is contrary to expectations. The coefficient for IBM is negative which reflects greater size accuracy for shifts in the demand and supply curves of CDS contracts. As hypothesized, the larger the order size, the more traders break their orders into multiples of US$5 millions, hence the realized sign for NM is positive. Size clustering increases in periods of high volatility, a finding which supports the price resolution hypothesis. Finally, the results for the MR variable show that traders cluster order sizes to speed up order flow.

Linking Panels A and B, we note that the coefficient of size clustering is much larger than that of price clustering. This implies that if traders desire a more refined (unusual) notional amount, they will have to accept a rounded price. In short, it is more difficult to trade in an unpopular notional amount than to negotiate a more refined price for a popular notional amount.

6. Conclusion

This paper initially examines the extent of price clustering in the CDS market. There is strong price clustering whereby 30% of traded prices end with "0" and 24% end with "5". The proportions for quoted prices are even higher, at 35% and 27% respectively. The mean notional amounts of traded and quoted prices ending with "0" and "5" are smaller than for the other final digits, and prices ending with the rarely used ".5" have a much larger mean notional amount. This supports the negotiation hypothesis, i.e. when the contract size is large, it is worthwhile to negotiate more refined prices. However, when controlling for the contract maturity effects, we show that while the negotiation hypothesis is more able to explain price clustering for the shorter-to-mature contracts, the price resolution hypothesis prevails for the longer-to-mature contracts. We also document extreme size clustering in the CDS market, whereby US$5 million is by far the most frequently used notional amount and is used in 63% of trades and 90% of quotes.

The simultaneous determination of price and size clustering is subsequently investigated. There is a strong inverse relationship between price clustering and size clustering, i.e. a reduced degree of size clustering is associated with an increased degree of price clustering and vice versa. Both the daily mean CDS premium and the mean absolute return have the expected positive relations with price clustering. These are consistent with the hypotheses that prices are more rounded at higher price levels and at more volatile times. The daily mean notional amount and the inverse square root of number of quotes do not have the expected relations with price clustering. However, the positive impact of the former is very marginal, and the negative impact of the latter may be due to traders' propensity to quote rounded prices during busy times. Price clustering itself is the most important determinant in the size clustering equation, and higher interest rates have a positive association with more size clustering. Due to the limited choice of notional amounts in the CDS market, it is more difficult to trade in an unusual notional amount than to negotiate a more refined price.

This paper addresses a void in the literature on CDS market microstructure, and presents a novel investigation of price clustering and size clustering in a model of simultaneous determination. It appears that the CDS market has tended toward more standardization of notional amounts as it has matured. Overall, the findings suggest that both price and quantity dimensions should be taken into consideration simultaneously when evaluating the liquidity of the CDS market, i.e. market participants need to be aware of the implications of discrete sets of prices and notional amounts on order execution.

References

Ahn, H., Cai, J., Cheung, Y. L. 2005. Price clustering on the limit-order book: Evidence from the Stock Exchange of Hong Kong. Journal of Financial Markets, 8**,** 421-451.

Aitken, M., Brown, P., Buckland, C., Izan, H. Y., Walter, T. 1996. Price clustering on the Australian Stock Exchange. Pacific-Basin Finance Journal, 4**,** 297-314.

Alexander, G., Peterson, M. 2007. An analysis of trade size clustering and its relationship to stealth trading. Journal of Financial Economics, 84**,** 435-471.

ap Gwilym, O., Clare, A., Thomas, S. H. 1998a. Extreme price clustering in the London equity index futures and options markets. Journal of Banking and Finance, 22**,** 193-206.

ap Gwilym, O., Clare, A., Thomas, S. H. 1998b. Price clustering and bid-ask spreads in international bond futures. Journal of International Financial Markets, Institutions and Money, 8**,** 377-391.

ap Gwilym, O., Meng, L. 2010. Size clustering in the FTSE100 index futures market. Journal of Futures Markets, 30, 432-443.

ap Gwilym, O., Verousis, T. 2013. Price clustering in individual equity options: Moneyness, maturity and price level. Journal of Futures Markets. 33, 55-76.

Ball, C. A., Torous, W. A., Tschoegl, A. E. 1985. The degree of price resolution: The case of the gold market. Journal of Futures Markets, 5**,** 29-45.

Barclay, M. 1997. Bid-ask spreads and the avoidance of odd-eighth quotes on Nasdaq: An examination of exchange listings. Journal of Financial Economics, 45**,** 35-60.

Bessembinder, H. 1994. Bid-ask spreads in the interbank foreign exchange markets. Journal of Financial Economics, 35**,** 317-348.

Blau, B. M., van Ness, B. F., van Ness, R. A. 2012. Trade-size and price clustering: The case of short sales and the suspension of price tests. Journal of Financial Research. 35, 159-182.

Brown, P., Chua, A., Mitchell, J. 2002. The influence of cultural factors on price clustering: Evidence from Asia-Pacific stock markets. Pacific-Basin Finance Journal, 10, 307-332.

Christie, W. G., Schultz, P. H. 1994. Why do Nasdaq market makers avoid odd-eighth quotes? Journal of Finance, 49**,** 1813-1840.

Chung, K. H., van Ness, B. F., van Ness, R. A. 2004. Trading costs and quote clustering on NYSE and NASDAQ after decimalization. Journal of Financial Research, 27**,** 309-328.

Copeland, T., Galai, D. 1983. Informational effects on the bid ask spread. Journal of Finance, 38**,** 1457-1469.

Goodhart, C., Curcio, R. 1991. The clustering of bid-ask prices and the spread in the foreign exchange market. FMG Paper 110. London School of Economics.

Grossman, S. J., Miller, M. H., Fischel, D. R., Cone, K. R. 1997. Clustering and competition in asset markets. Journal of Law and Economics, 40**,** 23-60.

Hameed, A., Terry, E. 1998. The effect of tick size on price clustering and trading volume. Journal of Business Finance and Accounting, 25**,** 849-867.

Harris, L. 1991. Stock price clustering and discreteness. Review of Financial Studies, 4**,** 389-415.

Harris, L. 2003. Trading and exchanges, Oxford, Oxford University Press.

Hodrick, L. S., Moulton, P. 2009. Liquidity: Considerations of a portfolio manager. Financial Management, 38, 59-74.

Houweling, P., Vorst, T. 2005. Pricing default swaps: Empirical evidence. Journal of International Money and Finance, 24**,** 1200-1225.

Kandel, S., Sarig, O., Wohl, A. 2001. Do investors prefer round stock prices? Evidence from Israeli IPO auctions. Journal of Banking and Finance, 25**,** 1543-1551.

Kyle, A. 1985. Continuous auctions and insider trading. Econometrica, 53**,** 1315-1335.

Liu, H., Witte, M. 2012. Price clustering in the US dollar/Taiwan dollar swap market. The Financial Review. Forthcoming.

Meng, L., ap Gwilym, O. 2007. The characteristics and evolution of credit default swap trading. Journal of Derivatives and Hedge Funds, 13, 186–198.

Mitchell, J. 2001. Clustering and psychological barriers: The importance of numbers. Journal of Futures Markets, 21**,** 395-428.

Moulton, P. 2005. You can't always get what you want: Trade-size clustering and quantity choice in liquidity. Journal of Financial Economics, 78**,** 89-119.

O'Hara, M. 1995. Market microstructure theory, Cambridge, MA, Blackwell Publishers.

Ohta, W. 2006. An analysis of intraday patterns in price clustering on the Tokyo Stock Exchange. Journal of Banking and Finance, 30**,** 1023-1039.

Osler, C. 2003. Currency orders and exchange rate dynamics: An explanation for the predictive success of technical analysis. Journal of Finance, 58**,** 1791-1819.

Schwartz, A., van Ness, B., van Ness, R. 2004. Clustering in the futures market: Evidence from S&P 500 futures contracts. Journal of Futures Markets, 24**,** 413-428.

Sopranzetti, B. J., Datar, V. 2002. Price clustering in foreign exchange spot markets. Journal of Financial Markets, 5**,** 411-417.

Table 1A: Top 30 reference entities by frequency of being quoted

Reference entity	Count	% of total
Federative Republic Of Brazil	14807	4.17%
AT&T Corp	10006	2.82%
United Mexican States	8571	2.41%
Time Warner Inc	7902	2.23%
Ford Motor Credit Co	7173	2.02%
Verizon Global Funding Corp	6188	1.74%
General Motors Acceptance Corp	6123	1.72%
Altria Group Inc	6019	1.69%
Electronic Data Systems Corp	5833	1.64%
Republic Of Colombia	5785	1.63%
Republic Of Venezuela	5538	1.56%
Sprint Corp	5341	1.50%
Liberty Media Corp	5284	1.49%
Eastman Kodak Co	5154	1.45%
Cendant Corp	4663	1.31%
Sears Roebuck Acceptance	4610	1.30%
Walt Disney Co	4428	1.25%
Tenet Healthcare Corp	4333	1.22%
Toys R Us Inc	3764	1.06%
HCA Inc	3721	1.05%
Cardinal Health Inc	3660	1.03%
Omnicom Group	3618	1.02%
Interpublic Group Cos. Inc	3588	1.01%
Cox Communications Inc	3509	0.99%
AT&T Wireless Services Inc	3387	0.95%
Carnival Corp	3174	0.89%
SBC Communications Inc	3108	0.88%
RJ Reynolds Tobacco Holdings	3035	0.85%
Wyeth	2989	0.84%
Household Finance Corp	2946	0.83%
Others	196879	55.44%

Table 1B: Top 30 reference entities by frequency of being traded

Reference entity	Count	% of total
Federative Republic Of Brazil	714	6.49%
United Mexican States	443	4.03%
AT&T Corp	372	3.38%
Cardinal Health Inc	250	2.27%
Ford Motor Credit Co	246	2.24%
Electronic Data Systems Corp	234	2.13%
Altria Group Inc	233	2.12%
Eastman Kodak Co	231	2.10%
Time Warner Inc	222	2.02%
General Motors Acceptance Corp	220	2.00%
Republic Of Colombia	205	1.86%
HCA Inc	197	1.79%
Liberty Media Corp	197	1.79%
Republic Of Venezuela	197	1.79%
Sprint Corp	177	1.61%
Verizon Global Funding Corp	168	1.53%
AT&T Wireless Services Inc	165	1.50%
Tenet Healthcare Corp	143	1.30%
Toys R Us Inc	124	1.13%
Merck & Co Inc	121	1.10%
Sears Roebuck Acceptance	120	1.09%
Cendant Corp	119	1.08%
Walt Disney Co	110	1.00%
Household Finance Corp	108	0.98%
Cox Communications Inc	107	0.97%
Wyeth	106	0.96%
SBC Communications Inc	101	0.92%
Bristol-Myers Squibb Co	95	0.86%
Carnival Corp	95	0.86%
RJ Reynolds Tobacco Holdings	90	0.82%
Others	5090	46.27%

Table 2: Credit rating distribution of reference entities

	2000	2001	2002	2003	2004	2005
Panel A: Broad categories						
Aaa-Aa3	9.73	10.09	10.92	4.54	4.55	6.90
A1-A3	33.14	36.43	35.04	23.11	18.55	9.97
Baa1-Baa3	34.56	38.83	42.60	61.22	46.39	37.80
Ba1-Ba3	2.12	4.07	7.59	6.16	15.17	20.70
B1-B3	20.45	10.17	3.83	4.54	15.29	24.54
Caa1-C	0	0.41	0.02	0.43	0.06	0.08
Panel B: Top ratings versus speculative grade						
Aaa-A3	42.87	46.52	45.96	27.65	23.1	16.87
Ba1-C	22.57	14.65	11.44	11.13	30.52	45.32

The ratings above are based on Moody's Investors' Service. In Panel A, percentages in each category (columns sum to 100%).

Table 3: Descriptive statistics

	Amount (US$m)	Maturity (Months)	Trade (bps)	Bid (bps)	Ask (bps)
Mean	4.78	60.68	192.3	179. 4	198.1
Median	5.00	62	130	117	128
Std. Dev.	1.11	14.61	203.96	189.97	215.01
Min	1.00	1	0.75	1	1
Max	50.00	636	2150	5530	4500
Observation	355135	355135	6888	121082	120096

*Amount is the notional amount of CDS; trade is traded price, bid, ask are bid and ask prices.

Table 4: Trade and quote price clustering

	Trades	Quotes
Final digit*	%	%
0	29.98	34.87
1	4.65	3.10
2	6.72	6.49
3	5.73	5.45
4	5.52	4.12
5	23.64	26.75
6	4.76	3.98
7	6.71	5.62
8	7.20	6.50
9	4.15	3.01
Standardised Range	2.58	3.19
Count	6888	240953

*There are 65 (0.94%) traded prices, and 223 (0.09%) quoted prices which end with ".5".

Table 5: Mean notional amount (size) for trades and quotes at each final digit of price

Last digit	Mean trade notional amount ($million)	Difference	Mean quote notional amount ($million)	Difference
0	5.435	-0.286***	4.583	-0.199***
1	6.407	0.686***	5.068	0.286***
2	6.025	0.304**	5.087	0.305***
3	5.740	0.019	4.995	0.213***
4	5.750	0.029	5.168	0.386***
5	5.588	-0.133*	4.694	-0.088***
6	5.907	0.186	5.042	0.260***
7	5.804	0.083	4.985	0.203***
8	5.890	0.169	5.089	0.307***
9	6.157	0.436*	5.049	0.267***
.5	7.768	2.047***	7.598	2.816*
Overall	5.721	.	4.782	.
Count	6888	.	240953	.

Difference refers to the deviation of the mean notional amount for each digit from the overall mean notional amount. *, ** and ***denote significance at the 10% level, 5% level and 1% level.

Table 6: Distribution of size (notional amount in US $)

Trade		Quote	
	%		%
5000000	62.8	5000000	89.6
10000000	13.1	2000000	8.1
2000000	12.5	3000000	1.1
3000000	5.0	10000000	0.8
15000000	1.3	1000000	0.2

Table 7: Maturity and Value effects

	Panel A: Clustering across Maturity (months)						Panel B: Mean (SD) of clustering at Value Quartiles			
	1--12	13-59	60-64	65-120	121-240	>240	0-25%	26-50%	51-75%	76-100%
PC	0.91	0.82	0.59	0.71	0.73	0.85	0.51 (0.08)	0.58 (0.09)	0.63 (0.10)	0.70 (0.11)
SC	0.88	0.90	0.89	0.96	0.99	1.00	0.94 (0.05)	0.92 (0.06)	0.90 (0.07)	0.87 (0.09)

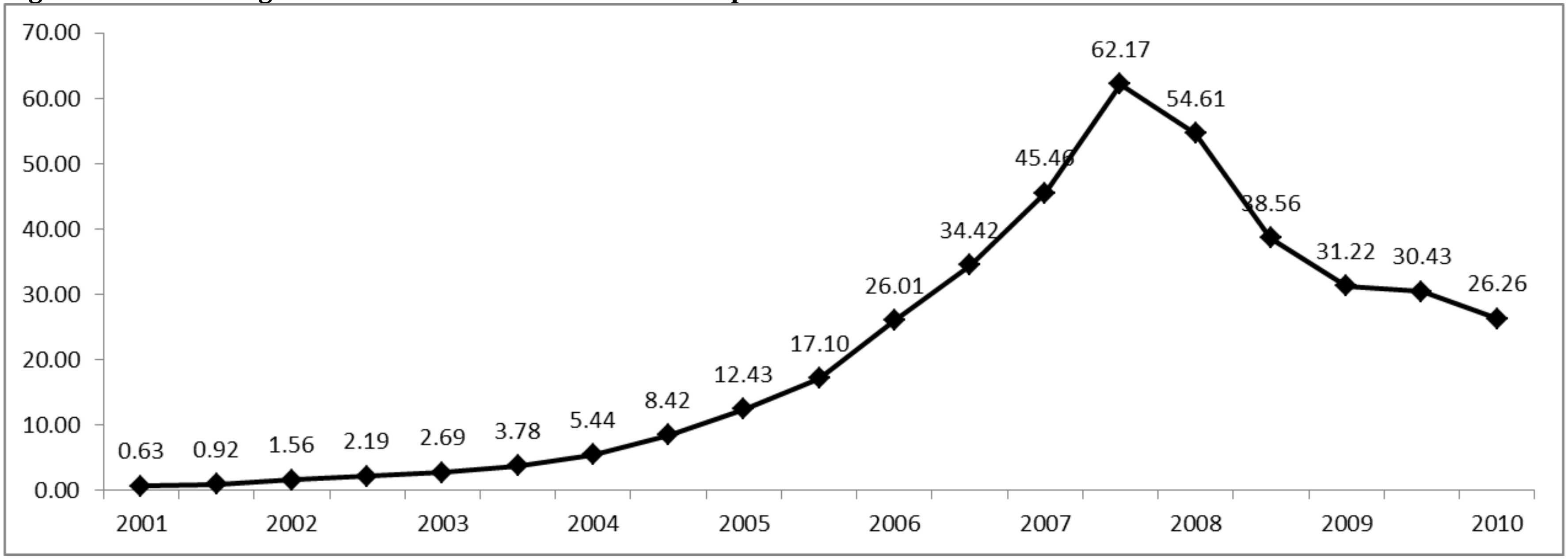
PC is the degree of price clustering measured by the daily proportion of quoted prices which have final digits of “0” or “5”. SC is the degree of size clustering measured by the daily proportion of quoted prices which have a notional amount of US$5 million.

Table 8: 3SLS estimation of price-size clustering model

	Coefficient	T-statistics
Panel A: Price clustering		
Constant	1.131***	8.56
SC	-1.316***	-3.94
NM	1.11e-07**	2.40
PL	0.001***	6.21
AR	2.743***	3.14
IQ	-0.245***	-3.63
EOQ	-0.007	-0.59
R^2	0.321	
Panel B: Size clustering		
Constant	0.482***	8.61
PC	-0.229***	-6.92
Q	-3.28e-05***	-2.96
EOQ	-0.004	-0.69
i	0.322**	2.37
IMB	-0.040**	-2.34
NM	1.10e-07***	13.72
AR	0.798*	1.77
MR	0.055***	2.71
R^2	0.515	

SC is size clustering (quotes only); NM is the daily mean notional amount of quotes; PL is the daily mean quoted CDS price; AR is the daily mean absolute return; IQ is the inverse square root of the number of quotes on the day; PC is price clustering (quotes only). Q is the total number of quotes; EOQ is a dummy variable denoting the end of quarter; i denotes change in 3-month Libor, IMB denotes the imbalance between bids and asks which is calculated as the absolute value of one minus bid/ask ratio. MR is the daily percentage of CDS contracts with modified restructuring clause.
***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

Figure 1: Outstanding notional amount of credit default swaps



Source: International Swaps and Derivatives Association market survey historical data (2001-2010)

Figure 2: Time series distribution of PC and SC (Quotes only)