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Comparison of the Stock Price Clustering of stocks which are traded in the US and Germany — Is XETRA more efficient than the NYSE?

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Comparison of the Stock Price Clustering of stocks which are traded in the US and Germany—Is XETRA more efficient than the NYSE?

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Abstract

We analyze intraday trades of German stocks (Daimler Chrysler and SAP) that are traded simultaneously at the German stock market XETRA and the New York Stock Exchange (NYSE). At first glance, the stock price clustering seems to be less pronounced at the NYSE. But after converting Euro-prices into Dollar-prices, we obtain the result that the clustering is stronger at the NYSE indicating that XETRA is more efficient with respect to this measure. This difference in the clustering at the different stock markets should not be observable if the no-arbitrage condition would hold. We also discuss several explanations, like ease of negotiation, convenience and rounding, attraction, odd pricing, and aspiration level for stock price clustering. As a result we see that no model is able to capture all of our empirical observations.

Keywords: behavioral finance; market microstructure; stock price clustering

JEL Classification: C50; D40; G12

1. Introduction

The phenomenon of price clustering—the tendency of prices to deviate from a uniform distribution, tending instead to cluster at certain prices and avoiding others—contradicts any strict definition of the efficient market hypothesis and therefore the random walk hypothesis as well.

Osborne (1962) and Niederhoffer (1965, 1966) began research into price clustering in the '60s. These early studies on the American stock market before the tick size was reduced, showed the effect of stock price clustering as 8/8 being more frequent than 4/8, 4/8 more frequent than 2/8 and 6/8, and 2/8 and 6/8 more frequent than 1/8, 3/8, 5/8, and 7/8. This is also denoted as follows: the even eighths (2/8, 4/8, 6/8, and 8/8) are more frequent than the odd eighths (1/8, 3/8, 5/8, and 7/8).

More recent studies discuss different aspects of price clustering. Harris (1991) showed that the effect occurs within different periods of time, for different market structures, and for different stocks. An intense discussion about price clustering started in 1994 when Christie et al. (1994) interpreted the fact that even eighths are more frequent than odd eighths at the NASDAQ (National Association of Securities Dealers Automated Quotation System). They stated that this was based on a tacit collusion between traders to raise profits.

Grossman et al. (1997) examined price clustering on the London Stock Exchange, using all inside quotes posted during October 1994 on the Stock Exchange Quotation System (SEAQ) for liquid stocks. Hameed and Terry (1998) examined the impact of tick size on price clustering and trading volume on the Stock Exchange of Singapore (SES). One of the main findings is that price clustering is found to increase when the tick size decreases. Vogt et al. (2001) studied the stock price clustering phenomenon in the context of numerical perception and response. Huang and Stoll (2001) analyzed transactions data of stocks traded on the London Stock Exchange (a dealer market) and also traded as American Depository Receipts (ADRs) on the New York Stock Exchange (an auction market). They concluded that market characteristics (e.g. clustering, tick size) are endogenous to the market structure. But the effect of price clustering is not limited to special stock exchanges. For example, Aitken et al. (1996) found price clustering at the Australian Stock Exchange while Aşçıoğlu et al. (2007) examined price clustering on the Tokyo Stock Exchange and Sonnemans (2006) studied stock price clustering using data from the Dutch stock market. Following the insights of these studies, one can conclude that stock price clustering is not an effect specific to a special market environment and thus not specific to the market rules. Rather it seems as if it is an underlying effect caused by human decision processes.

Besides the comprehensive empirical evidence of the occurrence of price clustering, numerous hypotheses have been proposed in the literature to explain the pervasive pattern of price clustering. For example, the analyses of Aitken et al. (1996) and Aşçıoğlu et al. (2007) are consistent with the attraction hypothesis, stating the preference of individuals for round numbers. The price resolution

hypothesis indicates that, if valuation is uncertain, traders may coordinate to restrict the price set to reduce search and cognitive costs (Harris, 1991). Another hypothesis is described by convenience and rounding. Rounding to convenient numbers seems to be a human habit, as for example when reading scales (Mitchell, 2001). According to Sonnemans (2006), the most plausible explanations for stock price clustering are the aspiration level hypothesis and the odd pricing hypothesis. The aspiration level hypothesis states that investors, when buying an asset, already have a target price in mind for which they are willing to sell in the future. These prices are typically round numbers. Odd pricing is the tendency of consumers to consider an odd price like 19.95 as significantly lower than the round price of 20.00. The results of that study, however, support the odd pricing hypothesis.

In order to extend the insights of Sonnemans (2006), this paper focuses on the stock price clustering phenomenon when comparing stocks that are traded simultaneously at different stock markets (and denoted in different currencies). Sonnemans (2006) studied differences in stock price clustering after the change in trading currency from Guilders to Euros, using data from the Dutch stock market of the period 1990-2001. One of the main analyses compares Euro-prices and Guilder-prices that are obtained by converting the Euro-prices. Our study considers German stocks that are traded simultaneously at the German stock market XETRA (a continuous auction market) and the New York Stock Exchange (NYSE—a market maker market) in 1999. This enables us to analyze the Euro-prices of these stocks (observed at XETRA), the Dollar-prices that are obtained by converting the Euro-prices and, in addition, the Dollar-prices for which these stocks are actually traded at the NYSE.

While most analysts tend to consider the NYSE as a more efficient trading platform since a lower extent of stock price clustering is observed compared to other stock exchanges (Huang and Stoll, 2001), our data and analysis provide empirical evidence that contradicts this statement. Furthermore, this paper discusses the no-arbitrage condition of financial markets in the context of price clustering of stocks that are traded at different stock markets. Additionally, the results are discussed with respect to the different explanations for stock price clustering mentioned above.

In addition, our study examines prices of stocks traded at the NYSE in 1999 and 2004. There has been a change of the smallest trading unit between these years and we can observe whether people need time to adopt that change or not. This examination and the detailed analysis of German stocks that are traded simultaneously at both XETRA and the NYSE, provide empirical evidence that is inconsistent with the results of Sonnemans (2006) and might therefore lead to other possible explanations for stock price clustering.

The remainder of this article is organized as follows: Section 2 offers a short overview about the theoretical explanations of the price clustering phenomenon and Section 3 states three hypotheses derived from theory. The data is described in Section 4, the results are presented in Section 5, and the conclusions are stated in Section 6.

2. Theoretical Explanations of Price Clustering

There are several explanations for stock price clustering proposed in the literature, most of which focus on the last digits of prices. We discuss the following, but not necessarily competing theories.

1. Ease of negotiation/coordination on limited price set/price resolution hypothesis

Ball et al. (1985) stated that price clustering varies inversely with the degree to which the underlying value of an asset is known. The trader will use a fine set of prices if the value is well known. Otherwise, if the value is uncertain, investors may coordinate to restrict the price set to reduce search and cognitive costs. Thus, price clustering will occur if traders use discrete price sets to simplify their negotiations (Harris, 1991). That means, if there were no or only a small tick size, clustering would occur as a matter of trading convenience. Moreover, Harris (1991) found stock price clustering to increase with stock price and volatility and to decrease with capitalization and trading frequency.

2. Convenience and rounding

Round numbers are more convenient and calculations with such numbers are relatively easy to perform. Rounding to convenient numbers seems to be a human habit, as for example, when reading scales (Mitchell, 2001).

3. Preferences for round numbers/attraction hypothesis

An intuitive explanation is that individuals have a preference for round numbers and therefore like to trade at round number prices. That means, clustering is the result of a psychological preference for some 'attractive' price points. Aşçıoğlu et al. (2007) found that the observed price clustering on the Tokyo Stock Exchange is consistent with the attraction hypothesis and Aitken et al. (1996) argue that investors seem to have a basic 'attraction' to certain integers like zero or five.

4. Odd pricing hypothesis

Odd pricing is very common in the marketing of consumer goods, but also in real estate prices (Palmon et al., 2004). It means that the price is just below some round number (for example 9.99€ instead of 10.00€). Consumers (at least some of them) have the tendency to consider the odd price as significantly lower than the round numbered price. The same argument holds for financial markets. A stock price of 30 would be considered to be (much) higher than a price of 29.9. A seller will be quite happy to sell at 30 (more limit orders will be placed at 30) while a buyer will be reluctant to pay a price that is in the 30s and not in the 20s. Sonnemans (2006) concluded that the odd pricing hypothesis predicts that round number effects in Guilders would immediately cease to exist in January 1999 and round number effects in Euros would immediately appear. The results show an abrupt change in clustering effects on round numbers for stock prices converted from Euros to

Guilders after January 1st, 1999, thus, supporting the odd price hypothesis. Stated differently, people have no absolute measure of value for currencies. When converting currencies, there is direct adaptation of new currencies.

5. Aspiration level hypothesis

Some investors, when buying a stock, already have a target price in mind for which they are willing to sell the stock in the future. For example, an investor who buys a stock for 22€ may expect the price of this stock to rise to 40€ in the future. These target prices may be considered to be an aspiration level and they typically seem to be round numbers.

According to Sonnemans (2006), the aspiration level hypothesis predicts that a round number effect in Guilders will only slowly disappear after the transition of the Euro, because stocks bought before but held after January 1st, 1999, will have target prices that are still round numbered in Guilders, but not so in Euros. That means people have a certain measure of value when converting currencies. After the translation, they still think in the currency they are accustomed to, at least for a certain time.

The results of Sonnemans (2006) do not support this hypothesis.

3. Hypotheses

A comparison of the Euro-prices and the Dollar-prices of German stocks that are traded simultaneously at the stock markets XETRA and the NYSE reveals interesting possibilities to discuss the theoretical explanations of the price clustering effect stated in Section 2. Furthermore, it enables us to discuss this effect in the context of the efficiency of financial markets.

The ease of negotiation hypothesis would explain a stock price clustering effect to the same extent on both exchanges XETRA and the NYSE. Despite differing currencies, traders simplify their negotiations by using a discrete set of prices, which means the exchange rate only has a minor effect. The ease of negotiation hypothesis could not explain vanishing stock price clustering effects or stock price clustering effects to different extents when comparing both exchanges XETRA and the NYSE.

The convenience and rounding hypothesis could be an explanation for price clustering if Dollar-prices were obtained by converting and rounding the (convenient) Euro-prices to the next possible Dollar-price.

The attraction hypothesis would also explain the stock price clustering phenomenon on both exchanges to the same extent, but it cannot account for vanishing stock price clustering effects. The same arguments apply to the aspiration level hypothesis.

The odd price hypothesis implies that people do not have an absolute measure of value for currencies. When converting currencies, there is direct adaptation to new currencies and therefore

stock price clustering should only be observable when looking at Euro-prices at XETRA and the Dollar-prices at the NYSE should be obtained by converting and rounding the Euro-prices to the next possible Dollar-price.

The no-arbitrage condition of financial markets implies that the Dollar-prices of German stocks that are traded simultaneously at the stock exchanges XETRA and the NYSE should be obtained by converting and rounding the Euro-prices into the next possible Dollar-prices. Transaction costs might lead to deviations from this rule. But since these costs apply to all possible prices, the clustering, which is an aggregate effect, should be the same. That means transaction costs only have an effect on single prices and should not disturb the clustering.

We did some simulations with realistic costs and the relation between the theoretically predicted stock price clustering at the NYSE and the clustering at XETRA seems to be robust concerning these factors. We took the German clustering, converted the Euro-prices into Dollar-prices, added fees, and obtained the US clustering. The results reveal the same extent of price clustering as without adding transaction costs. We therefore neglect the effects of such costs in our argument.

Comparing the Dollar-prices that are obtained by converting the Euro-prices with the prices for which the above mentioned stocks are actually traded at the NYSE (as it is done in Section 5) leads to the following hypothesis.

Hypothesis 1:

The Dollar-prices of German stocks that are traded simultaneously at both stock markets XETRA and the NYSE are not obtained by converting and rounding the Euro-prices to the next possible Dollar-price.

The discussion about the theoretical explanations of price clustering stated above and an analysis of different studies concerning this phenomenon lead to another hypothesis, which is not necessarily competing to Hypothesis 1. To be more specific: the following Hypothesis 2 is our important hypothesis since it concerns aggregate behavior. Hypothesis 1 is used to clarify our arguments.

Hypothesis 2:

The stock price clustering effect is observable with a higher degree at the NYSE compared to XETRA. Therefore, XETRA is a more efficient stock market compared to the NYSE.

The appropriate analyses and results are presented in Section 5.

4. Data

The data used in this study consists of all intraday trades of the two German stocks Daimler Chrysler and SAP that are traded at the German stock market XETRA and the New York Stock Exchange (NYSE) in 1999 and 2004. Moreover we used the daily Euro-Dollar exchange rates of the year 1999.

At the beginning of 1999, stock prices at XETRA were listed in Euros with a tick size (smallest trading unit or minimum price variation) of 1 Euro-cent while at the NYSE prices were listed in Dollar with a tick size of 1/16 of a Dollar (6.25 Dollar-cents)[1]. In 2004, the tick size at the NYSE was 1 Dollar-cent[2].

We focused our analyses on the trading days and the time period for which both stock markets XETRA and the NYSE are open simultaneously in January and February 1999 and in November and December 1999. That means, for January and February 1999, we considered 38 trading days and a time period of 3:30 pm to 5 pm for XETRA and 9:30 am to 11 am for the NYSE. For November and December 1999, we analyzed 41 trading days and a time period of 3:30 pm to 5:30 pm for XETRA and 9:30 am to 11:30 am for the NYSE. There had been a change in the closing time for XETRA and this enabled us to extend the analyzed time period. The results in Section 5 are presented for Daimler Chrysler for January and February 1999. SAP reveals the same effects and shows similar patterns (Appendix A). Furthermore, analyzing the data of November and December 1999 leads to the same conclusions (Appendix B). The number of trades and the mean stock prices of Daimler Chrysler are presented in Table 1.

Table 1

Number of trades and mean stock prices of Daimler Chrysler in 1999

	Daimler Chrysler	
	XETRA	NYSE
Number of trades in January and February 1999	13946	6506
Mean stock price in January and February 1999	88.48€	101.17$
Number of trades in November and December 1999	16823	5650
Mean stock price in November and December 1999	70.19€	71.47$

[1] In 1999, the minimum price variation at the NYSE was 1/16 of a Dollar for stocks traded at or above 50 Dollar-cents per share and 1/32 of a Dollar for stocks traded below 50 Dollar-cents. In this study we focused on stocks traded above 50 Dollar-cents.

[2] In 2004, the minimum price variation at the NYSE was 1 Dollar-cent for stocks traded below 100,000 Dollar and 10 Dollar-cents otherwise. The stocks considered in this paper for 2004 have a minimum price variation of 1 Dollar-cent.

To compare the Dollar-prices observed at the NYSE with the Dollar-prices that are obtained by converting and rounding the Euro-prices (observed at XETRA) to the next possible Dollar-price, we used the daily exchange rates. The mean exchange rates for the analyzed time periods in 1999 are presented in Table 2.

Table 2

Mean exchange rates in 1999

	January and February 1999	November and December 1999
Mean exchange rate in $/€	1.1411	1.0243

Furthermore we examined the intraday stock prices of stock Y (Alleghany Corporation) observed in November and December 1999 and November and December 2004 at the NYSE. There had been a change in the smallest trading unit from 1/16 of a Dollar (6.25 Dollar-cents) to 1 Dollar-cent in 2001. Table 3 provides the number of trading days, the number of trades, and the mean stock prices for stock Y in November and December 1999 and 2004.

Table 3

Number of trading days, number of trades, and mean stock prices of Y in 1999 and 2004

	November and December 1999	November and December 2004
Number of trading days	43	43
Number of trades	392	1788
Mean stock price	191.48$	282.66$

5. Results

5.1 Stock Price Clustering at XETRA

First, we studied the intraday trades of SAP and Daimler Chrysler at XETRA in January and February 1999 (38 trading days, time period 3:30 pm to 5 pm). Analyzing the last digits of these stock prices (0 to 9 Euro-cents), we observe the following frequency distributions.

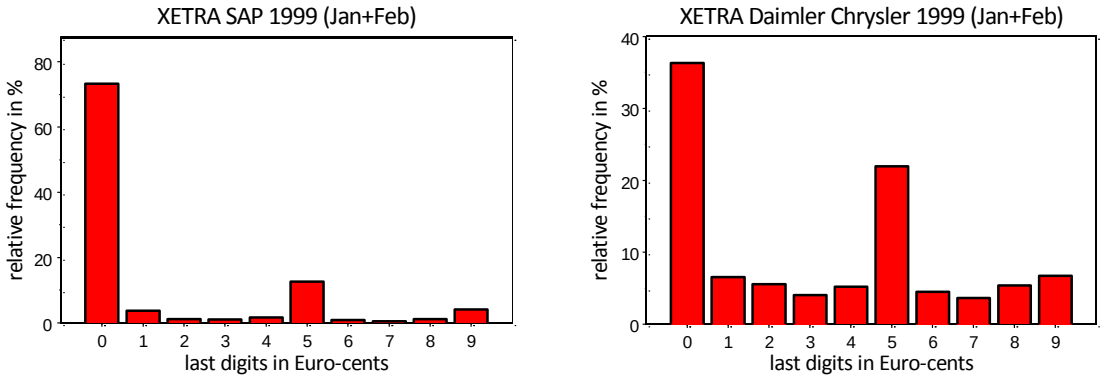

Figure 1: Frequency distributions of the last digits of the stock prices of SAP and Daimler Chrysler at XETRA in January and February 1999 (38 trading days, time period 3:30 pm to 5 pm).

Both plots reveal evidence for stock price clustering in the last digit of Euro-prices. Considering Daimler Chrysler, 36% of all stock prices (13,946 trades) have 0 and 22% have 5 as the last digit. That means 58% of all observations show a 0 or a 5 as the last digit. For SAP, we observed 86% of all stock prices (7,209 trades) to end with 0 or 5. If the last digits were uniformly distributed, we would expect 10% of all stock prices to fall in each of the 10 categories 0 to 9 Euro-cents (that would imply no stock price clustering). The hypothesis of a uniform distribution can formally be rejected at any significance level (using a chi-squared test).

The following analyses and explanations are presented for Daimler Chrysler in January and February 1999. SAP reveals the same effects and shows similar patterns (as it can be seen in Appendix A). Furthermore, analysis of the data of November and December 1999 leads to the same conclusions. These findings are presented in Appendix B. The mean exchange rates (in $/€) are 1.1411 for January and February 1999 and 1.0243 for November and December 1999.

5.2 Stock Price Clustering at the NYSE

In the next step, we examined the last digits of the stock prices of Daimler Chrysler at the NYSE (for January and February 1999, 38 trading days, time period 9:30 am to 11 am). In 1999, stock prices at the NYSE were listed in Dollars with a tick size of 1/16 of a Dollar (6.25 Dollar-cents). The appropriate 16 last digits are 0/16 to 15/16 of a Dollar or 0.00 to 93.75 Dollar-cents, respectively. Figure 2 presents the frequency distribution of the last digits of the stock prices of Daimler Chrysler.

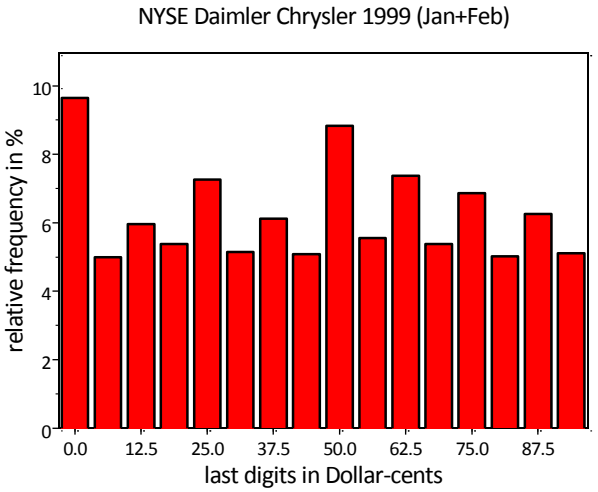

Figure 2: Frequency distributions of the last digits of the stock prices of Daimler Chrysler at the NYSE in January and February 1999 (38 trading days, time period 9:30 am to 11 am).

The relative frequency of prices ending in 0 or 50 Dollar-cents is 19.5%. A uniform distribution would imply that only 12.5% of all prices have 0 or 50 Dollar-cents as the last digit[3]. Initially, the stock price clustering of the Dollar-prices at the NYSE seems to be of a lesser extent than observed for the Euro-prices at XETRA. Similar results proclaiming the lesser extent of stock price clustering at the NYSE in comparison with other stock exchanges can, for example, be found in Huang and Stoll (2001). They observed the quote clustering to be higher at the London Stock Exchange than at the NYSE.

But the comparison of the stock price clustering phenomenon of Daimler Chrysler is based on the last digits, i.e. 0 to 9 Euro-cents (multiples of the tick size 1 Euro-cent) at XETRA and 0.00 to 93.75 Dollar-cents (multiples of the tick size 1/16 of a Dollar or 6.25 Dollar-cents, respectively) at the NYSE. That means we compare the relative frequency of the last digits of Euro-prices (with a smaller tick size which is 1/6.25 of the tick size at the NYSE) with the relative frequency of the last digits of Dollar prices. This means that several last digits of the Dollar-prices correspond to one last digit of the Euro-prices. To test the influence of this difference in the last digits for the extent of stock price clustering, we do the following analyses.

5.3 Comparison of Stock Price Clustering at XETRA and at the NYSE

For making a statement about the extent of stock price clustering it is necessary to have a detailed look at the Dollar-prices that are obtained by converting the Euro-prices. This has been done by multiplying the Euro-prices observed at XETRA with the appropriate Euro-Dollar-exchange rate and rounding these translated prices to the next possible Dollar-price.

[3] The hypothesis of a uniform distribution can be rejected at any significance level using a chi-squared test.

The resulting frequency distributions of the last digits of those into Dollar converted Euro-prices and of the last digits of the actually observed Dollar-prices at the NYSE are presented in Figure 3.

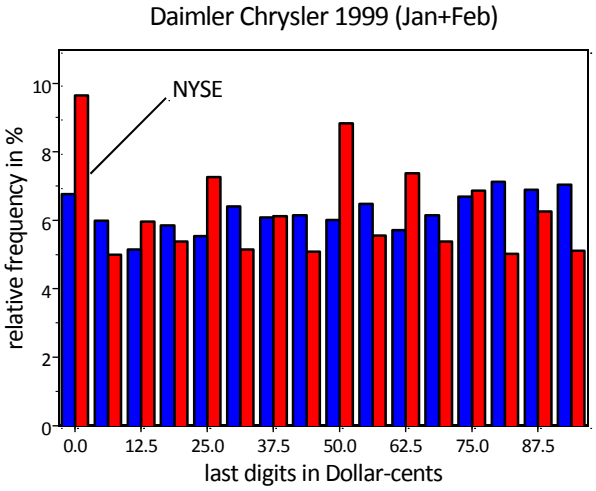

Figure 3: Frequency distributions of the last digits of the stock prices of Daimler Chrysler at the NYSE (red) and of the last digits of the Dollar-prices that result from converting the Euro-prices (blue) observed at XETRA in January and February 1999 (38 trading days, time period 9:30 am to 11 am or 3:30 pm to 5 pm, respectively).

We do not observe stock price clustering in the last digits of the converted Euro-prices in contrast to the last digits of the Dollar-prices. This result supports Hypothesis 1, meaning the Dollar-prices of German stocks that are traded simultaneously at both stock markets XETRA and the NYSE are not obtained by converting and rounding the Euro-prices to the next possible Dollar-price.[4]

Furthermore, the last digits of the converted Euro-prices seem to be uniformly distributed[5]. But this uniform distribution of the last digits corresponds to the extent of stock price clustering observed at XETRA for these are the same prices, only in different currencies. This leads to the conclusion that the lack of observable stock price clustering at the NYSE does not necessarily imply a uniform distribution of the 'real' prices. Traders would like to trade at other prices (as it can be seen at XETRA), but there is no chance because of the minimum tick size of 1/16 of a Dollar at the NYSE.

Figure 1 shows that most prices of Daimler Chrysler at XETRA have 0 or 5 Euro-cents as the last digit. Assuming that traders also have these preferences for Daimler Chrysler at the NYSE, they have to place their trades at multiples of 12.5 Dollar-cents (as 10 Dollar-cents is not possible) or at multiples of 6.25 Dollar-cents. These multiples contain all sixteenth, which is an explanation for the vanishing stock price clustering in Dollar-prices that result from converting the Euro-prices. But what can actually be observed at the NYSE is not a uniform distribution (see Figure 2 and Figure 3).

[4] Using the daily Euro-Dollar-exchange rate does not influence the observed clustering. Simulations with normally distributed Euro-Dollar-exchange rates lead to the same results.

[5] The hypothesis of a uniform distribution cannot be rejected.

Figure 4 emphasizes this statement, showing the relative frequencies of even and odd sixteenth for both, the last digits of the converted Euro-prices and the last digits of the Dollar-prices. The Dollar-prices imply a preference of even sixteenth while the converted Euro-prices imply a uniform distribution[6].

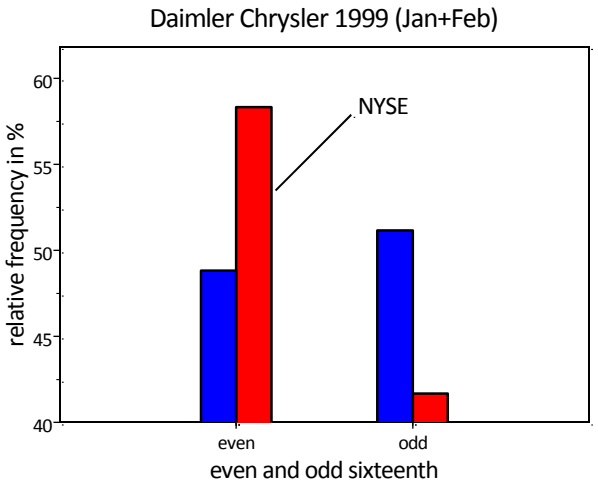

Figure 4: Frequency distributions of the even and odd sixteenth of the stock prices of Daimler Chrysler at the NYSE (red) and of the even and odd sixteenth of the Dollar-prices that result from converting the Euro-prices of Daimler Chrysler (blue) observed at XETRA in January and February 1999 (38 trading days, time period 9:30 am to 11 am or 3:30 pm to 5 pm, respectively).

The uniform distribution of the last digits of the converted Euro-prices corresponds to the extent of stock price clustering noted at XETRA. The observed clustering at the NYSE (as it is shown in Figure 3 and Figure 4) provides empirical support of a much higher degree of stock price clustering at the NYSE compared to XETRA, i.e. an additional stock price clustering. That means the detailed analysis of stocks that are traded at both exchanges XETRA and the NYSE simultaneously leads to results that support the hypothesis of a higher degree of stock price clustering at the NYSE compared to XETRA and therefore Hypothesis 2: XETRA is a more efficient stock market compared to the NYSE.

Figure 5 presents the frequency distribution of the differences in relative frequencies of the last digits between converted Euro-prices and Dollar-prices and emphasizes the conclusion of an additional stock price clustering at the NYSE compared to XETRA (and therefore emphasizes Hypothesis 2).

[6] For the last digits of the converted Euro-prices, the hypothesis of a uniform distribution cannot be rejected while for the last digits of the Dollar-prices this hypothesis can be rejected at any significance level (using a chi-squared test).

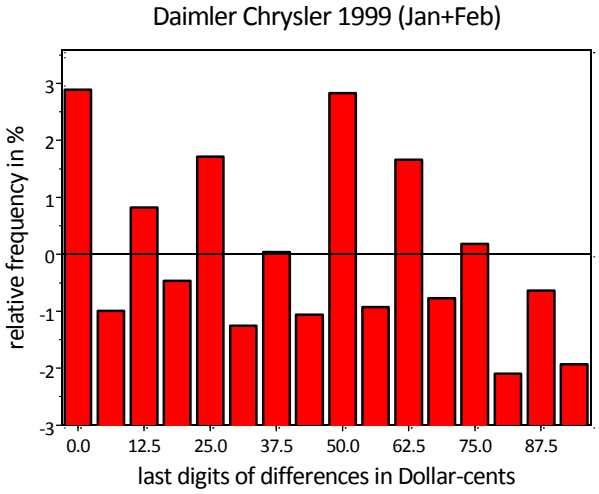

Figure 5: Frequency distribution of the differences between the relative frequencies of the last digits of Daimler Chrysler of Dollar-prices that result from converting the Euro-prices observed at XETRA and Dollar-prices observed at the NYSE in January and February 1999 (38 trading days, time period 9:30 am to 11 am or 3:30 pm to 5 pm, respectively).

Figures 3, 4, and 5 provide empirical evidence supporting Hypothesis 1 that the Dollar-prices are not obtained by converting and rounding the Euro-prices to the next possible Dollar-price. Of course there are trading costs that have not been considered when converting Euro-prices into Dollar-prices. But these costs do not have any influence on the degree of price clustering. Therefore, the results support Hypothesis 2: stock prices at the NYSE are much more clustered than at XETRA. This leads to the conclusion that XETRA is a more efficient stock market compared to the NYSE.

5.4 Discussion about the Theoretical Explanations of Stock Price Clustering

An examination of the stock prices of the two German stocks Daimler Chrysler and SAP that are traded simultaneously at both stock exchanges XETRA and the NYSE enables us to compare our results with respect to the different explanations for stock price clustering stated in Section 2.

The ease of negotiation hypothesis predicts that price clustering will occur if traders use discrete price sets to simplify their negotiations (Harris, 1991). In that case, we would expect clustering within a market to increase with stock prices, but we would not expect it to differ between XETRA and the NYSE for the same stocks. Thus this hypothesis alone cannot be an explanation for the higher degree of stock price clustering observed at the NYSE compared to XETRA.

The convenience and rounding hypothesis would be an explanation for vanishing stock price clustering effects at the NYSE compared to XETRA if stock prices were obtained by converting and rounding Euro-prices to the next possible Dollar-price. The analyzed stock prices reveal empirical evidence that contradicts this hypothesis.

The attraction hypothesis would also explain the stock price effect at XETRA and the NYSE to the same extent, but it cannot account for vanishing stock price clustering. Because we observe stock price clustering on both exchanges to different extents, there have to be further explanations.

The odd price hypothesis implies that people have no absolute measure of value for currencies. When converting currencies, there is direct adaptation to new currencies. In line with this hypothesis goes the fact that stock price clustering should only be observable when looking at Euro-prices at XETRA, but not for Dollar-prices at the NYSE, and that those Dollar-prices should be obtained by converting and rounding the Euro-price to the next possible Dollar-price. Sonnemans (2006) analyzed the stock price clustering effect after the change in trading currency from Guilders to Euros for stocks traded at the Dutch stock market in the period 1990-2001. Converting the Euro-prices (with highly observable stock price clustering) into Guilders (currency of daily life until 2002) leads to similar results as observed for our data. There is no observable price clustering for Guilder-prices that result from converting the Euro-prices. Therefore, Sonnemans' (2006) results support the odd price hypothesis. Our analyses show vanishing stock price clustering effects when converting the Euro-prices of Daimler Chrysler and SAP (with highly observable stock price clustering) into Dollar-prices using the daily exchange rate (for January and February 1999 and November and December 1999). Thus, our results are in line with those of Sonnemans (2006) and support the odd price hypothesis. But having a closer look at the Dollar-prices for which these stocks are actually traded at the NYSE provides empirical evidence that these prices cannot be obtained by converting and rounding the Euro-prices to the next possible Dollar-price. Figure 3 reveals that converting the Euro-prices into Dollar-prices would lead to a frequency distribution of the last digits (multiples of 1/16 of a Dollar) that looks uniform. But looking at the last digits of Dollar-prices observed at the NYSE, we can notice the stock price clustering phenomenon. Our data and analyses lead to the result that vanishing clustering effects caused by converting currencies are no evidence for the odd price hypothesis, since stock price clustering can still be observed when looking at the NYSE data. Furthermore, the stock price clustering effect is not simply vanishing when thinking and trading in different currencies. According to converting and rounding effects, we observe a uniform distribution of the last digits, but the above analyses point out that this does not describe what people think and how people behave.

The aspiration level hypothesis predicts that people have a certain measure of value when converting currencies. After the translation, they still think in the currency they are accustomed to, at least for a certain time. This hypothesis could only explain stock price clustering effects at XETRA and the NYSE to the same extent (thus, our data does not support this hypothesis) and it cannot account for vanishing price clustering. According to Sonnemans (2006), the aspiration level predicts that round number effects in Guilders will only slowly disappear after the transition of the Euro. Because of the

vanishing stock price clustering when converting Euro-prices into Guilders, the results of that paper do not support the aspiration level hypothesis.

Another possibility to check the aspiration level hypothesis is to compare the prices of stocks traded at the NYSE in 1999 and 2004. There has been a change of the smallest trading unit between these years from 1/16 of a Dollar (6.25 Dollar-cents) to 1 Dollar-cent in 2001, and we can observe whether people need time to adopt that change or not. Comparing for example, the relative frequencies of the last digits of the stock Y (Alleghany Corporation) in November and December 1999 and November and December 2004 (on a Dollar scale) we get the following result.

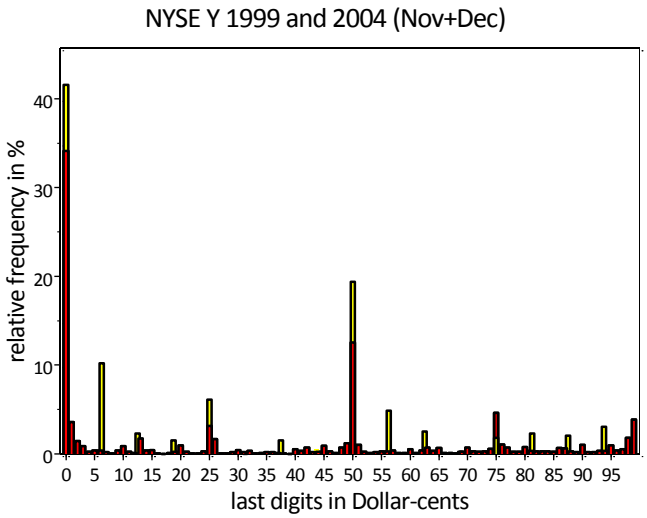

Figure 6: Frequency distributions of the last digits of the stock prices of Y observed at the NYSE in November and December 1999 (yellow) and November and December 2004 (red).

Plotting the relative frequencies of the last two digits of the stock prices in 2004 reveals the fact that we can still observe higher peaks at 25 Dollar-cents and 75 Dollar-cents compared to 10, 20, 30, 40, 60, 70, 80, and 90 Dollar-cents. This is an effect one cannot observe at the German stock market XETRA in 2004, although both have the same smallest trading unit of 1 Euro-cent. But XETRA already had the tick size of 1 cent in 1999 while at the NYSE it had been 1/16 of a Dollar. In 1999, the stock price clustering at the NYSE predicts round numbers being more common than halves, followed by quarters (25 and 75 Dollar-cents), and so on. The clustering effect for the last digit in the decimal system predicts 0 cent (10 cents) as more frequent than 5 cents followed by 2,3,7,8 and 1,4,6,9. Therefore, one should not observe the relative high peaks at 25 Dollar-cents and 75 Dollar-cents. A possible explanation is that people still have the smallest trading unit of 1/16 of a Dollar and resulting target prices in mind, and the effect will only slowly disappear. These findings therefore would support the aspiration level hypothesis.

Our empirical findings do not strictly contradict or support the odd price hypothesis and the aspiration level hypothesis. In addition, these two explanations for stock price clustering are evidently not competing hypotheses.

Our data and findings provide empirical evidence that the hypotheses for stock price clustering discussed in this subsection cannot alone explain this effect. There have to be further or expanded explanations concerning the stock price clustering phenomenon.

6. Conclusion

We analyzed the stock price clustering phenomenon using high frequency data (all intraday trades) of the German stocks Daimler Chrysler and SAP that are traded at the German stock market XETRA and the New York Stock Exchange (NYSE) in 1999. We considered the month January and February 1999 and November and December 1999 with the trading days and the time period for which both stock markets XETRA and the NYSE are open simultaneously. In 1999 stock prices at XETRA were listed in Euros with a tick size of 1 Euro-cent while at the NYSE prices were listed in Dollar with a tick size of 6.25 Dollar-cents (1/16 of a Dollar).

First, we studied the stock price clustering phenomenon for the last digits of Euro-prices observed at XETRA in January and February 1999 and noted that 58% of the prices of Daimler Chrysler and 86% of the prices of SAP had 0 or 5 Euro-cents as the last digit. Furthermore, we analyzed the last digits of the Dollar-prices observed at the NYSE (for the same period) and found 19.5% of the prices of Daimler Chrysler and 15% of the prices of SAP to end with 0/16 or 8/16 of a Dollar.

The detailed analysis of stock price clustering of Euro-prices observed at XETRA, Dollar-prices observed at the NYSE, and Dollar-prices that result from converting the Euro-prices (using the daily exchange rate) provides empirical support that the US-prices cannot be obtained by converting the German-prices. Additionally, our findings contradict the statement that the NYSE reveals only little stock price clustering and, therefore, is more efficient especially when comparing different stock exchanges. Our study shows that XETRA is a more efficient stock market compared to the NYSE.

Furthermore, this study examines prices of a stock traded at the NYSE in 1999 and 2004. There has been a change in the smallest trading unit from 1/16 of a Dollar (6.25 Dollar-cents) to 1 Dollar-cent in 2001 and we can observe whether people need time to adopt that change or not.

The results of this examination and the detailed analysis of German stocks that are traded simultaneously at both exchanges XETRA and the NYSE are discussed with respect to the different explanations for stock price clustering such as ease of negotiation, convenience and rounding, attraction, odd pricing, and aspiration level. As a result, we conclude that no model is able to capture all of our empirical observations.

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Appendix

A. SAP January and February 1999

An analysis of the stock prices of SAP in January and February 1999 leads to the same results outlined in Section 5 and can formally be described by the following figures.

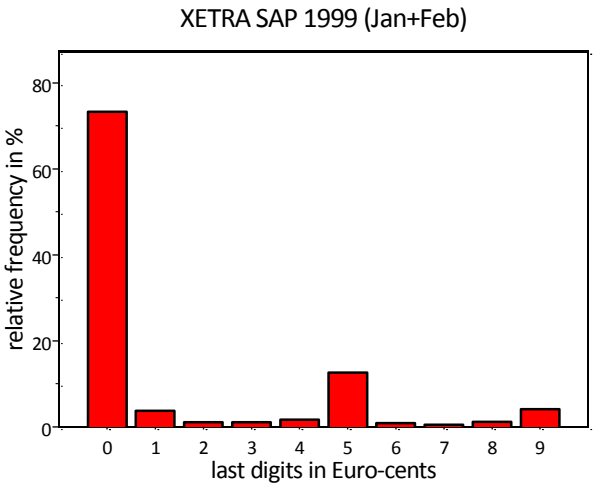

Figure 7: Frequency distributions of the last digits of the stock prices of SAP at XETRA in January and February 1999 (38 trading days, time period 3:30 pm to 5 pm).

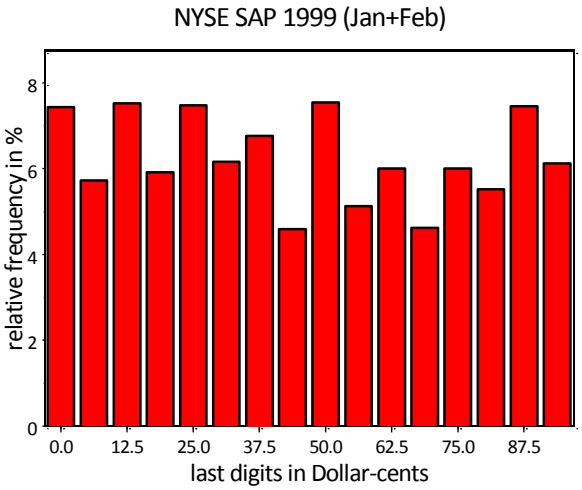

Figure 8: Frequency distributions of the last digits of the stock prices of SAP at the NYSE in January and February 1999 (38 trading days, time period 9:30 am to 11 am).

B. SAP and Daimler Chrysler in November and December 1999

An analysis of the stock prices of SAP and Daimler Chrysler in November and December 1999 leads to the same results outlined in Section 5 and can formally be described by the following figures.

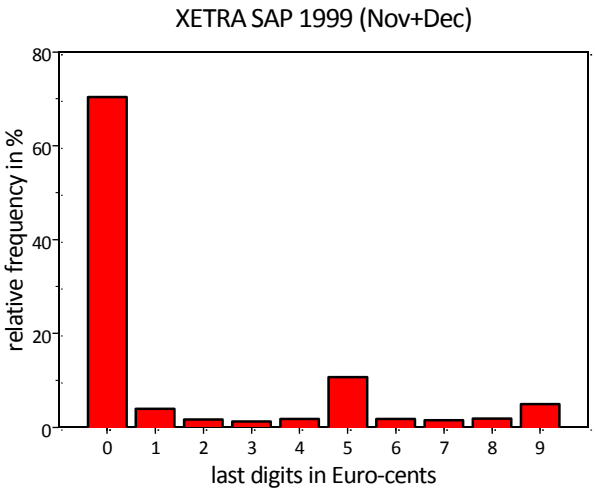

Figure 9: Frequency distributions of the last digits of the stock prices of SAP at XETRA in November and December 1999 (41 trading days, time period 3:30 pm to 5:30 pm).

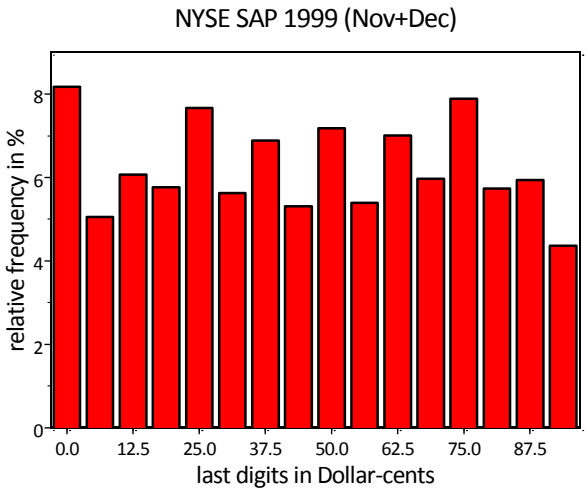

Figure 10: Frequency distributions of the last digits of the stock prices of SAP at the NYSE in November and December 1999 (41 trading days, time period 9:30 am to 11:30 am).

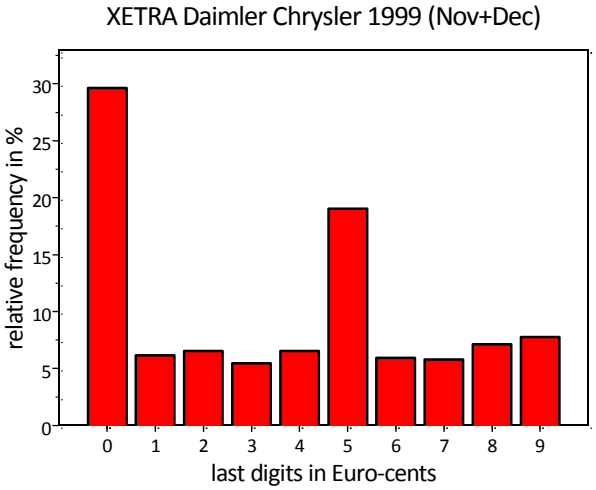

Figure 11: Frequency distributions of the last digits of the stock prices of Daimler Chrysler at XETRA in November and December 1999 (41 trading days, time period 3:30 pm to 5:30 pm).

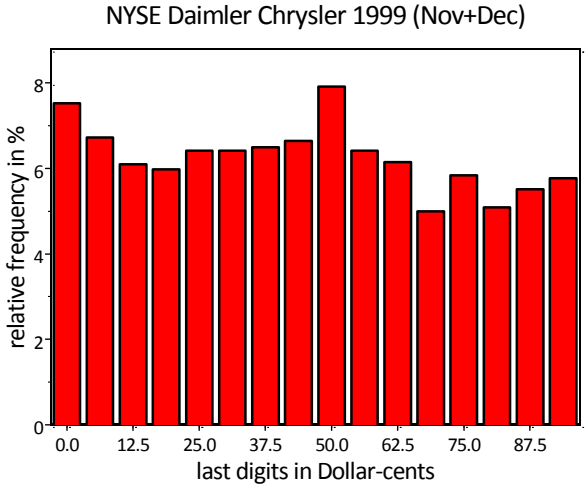

Figure 12: Frequency distributions of the last digits of the stock prices of Daimler Chrysler at the NYSE in November and December 1999 (41 trading days, time period 9:30 am to 11:30 am).