Price Clustering and Price Barriers: International Evidence

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ABSTRACT: In this paper, I try to complement the existing literature by empirically examining the effect of price clustering and price barriers based on the international stock market. Evidence suggests that a strong effect of clustering and barriers is observed on last digit 0. Such effect is not robust and persistent on last digit 5. In addition, the cross-country analysis shows that price clustering and barriers become intensified in countries with a more transparent and open environment.

Keywords: Price clustering; Price barriers; International stock market

JEL codes: G02; G15

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1. Introduction

In financial markets, the presence of seemingly number-induced effect gives rise to price clustering and barriers. While price clustering is the concentration of stock prices on some number rather than others (Brown & Mitchell, 2008), price barriers regard some numbers as support or resistance levels (Cai et al., 2007). Individual investors show a great deal of interests to this phenomenon in the stock market over recent years. For example, the phrase of "supporting level", "resistant level", and "psychological barrier" is always seen in the contemporary financial press. The primary aim of the current paper tries to extend previous studies by seeking comprehensive evidence of price clustering and barriers in the international context. Moreover, I further explore the determinants of price clustering and barriers across different countries.

Prior research documents the presence of price clustering with regard to the last digit for the Dow-Jones index (Donaldson and Kim, 1993; Lev and Varian, 1994). Later, Koedijk and Stork (1994) extent the test from the US market to five stock markets. In addition, the test is also performed for the existence of price barriers by calculating unequal passing values of predetermined digits. Based on the observation, this literature implies that price clustering and barriers coexist in the market.

At the first glance, price clustering and barriers seem to be inconsistent with the efficient market hypothesis (Donaldson, 1990; Aitken et al., 1996) and the perception of uniform value in prices (Niederhoffer, 1965; De Grauwe and Decupere, 1992). Mitchell and Izan (2001) provide a detailed overview on the evidence of price clustering and barriers in various stock markets. By the same token, this phenomenon is further explored to currency markets (Goodhart and Curcio, 1991; Sopranzetti and Datar, 2002), derivatives markets (Gwilym et al., 1998), commodity markets (Grossman et al., 1997), bank deposit rates (Kahn et al., 1999), and IPO markets (Kandel et al., 2001).

The focus on the global market is driven by three considerations. First, such comprehensive study on price clustering and barriers in the global market is scarce because previous work merely selects several markets. Second, clustering in individual markets can be directly compared and analyzed. Finally, different characteristics such as culture, country governance, investor protection, information environment, stock market feature, and macroeconomic condition, can be employed to explain the variation in price clustering and barriers.

My results suggest a higher propensity for clustering on ending digit 0 in individual markets. Moreover, the last digit 0 is also found to be a significant resistant point for the global market. On the global level, there is evidence for price clustering and barriers on ending digit 5, but this conclusion fails to retain valid and consistent for several countries. Last, the country-level regression analysis indicates that culture, investor protection, information environment, and stock market feature can explain price clustering and barriers to some extent.

The article is organized as follows. In the next section, I review the literature of why price clustering and barriers may be present in financial markets and anecdotal. Section 3 describes the data selection, variable identification, and measurement of price clustering and barriers. Empirical results are summarized in Section 4. The final section presents the conclusion.

2. Literature review

2.1 Rationale behind clustering and price barriers

If the party involved in the trading is well-informed price setters, a widespread number preference such as price clustering and barriers should not be observed. In order to explore why prices clustering and barriers occur, various work develops different arguments to explain this price behavior, such as process of number development (Mitchell, 2001), behavior theory (Brown & Mitchell, 2008), rational economic incentive (Sugden, 1995), implicit collusion and contractual agreement (Christie et al., 1994), and cultural factors (Brown & Mitchell, 2008). Specifically, price clustering and barriers arise from four diverse sources.

First, price clustering and barriers is due to the adoption of the decimal place-value system. Mitchell (2001) argues that individuals tend to apply the numerousness concept to the decision-making process. Similarly, marketing work (Tversky and Kahneman, 1973; Dehaene and Mehler, 1992; Palmon et al., 2004) shows that round numbers ending in 0 are more cognitive accessible and identified for consumers. In addition to this symbolism, Thaler (1992) even show that cultural factors may drive some form of basic number preference.

Second source of price clustering and barriers is attributable to behavioral reasons. In comparison to precise approximations, human would provide rough estimates by means of simple heuristics. Doing so can allow individuals to simplify the complex external information to achieve a quicker decision (Preece, 1981; Tversky and Kahneman, 1973).

Economic explanation may be another rationale behind clustering and barriers. Following the focal point work (Schelling, 1960; Sugden, 1995), individual would use numbers that are easily recognized and readily discernible to speed up the decision-making process. In this sense, people may operate in a sphere of haziness regarding the value of items (Loomes, 1988). As a result, clustering behavior arises to mitigate this uncertainty.

Final justification for price clustering and barriers is from a natural order of the data series. More specifically, the number progression or the form of the number itself causes price clustering and barriers (Mitchell, 2001).

2.2 Empirical evidence on price clustering and price barriers

Due to human bias and imprecise recognition, market participants are inclined to settle on some numbers ending in 0 in the trading process. Osborne (1962) calls this phenomenon as price clustering on the New York Stock Exchange. Harris (1991) documents the pervasiveness of stock prices over mid-nineteenth to late twentieth century. Furthermore, Aitken et al. (1996), Grossman et al. (1997), and Hameed & Terry (1998) observe a similar phenomenon in Australia, Singapore, and London, respectively. Recently, Brown et al. (2002) extend this research by investigating six Asia-Pacific stock markets.

Another strand of literature demonstrates the presence of price barriers on stock prices. Previous work regarding price barriers focuses on stock indices. Donaldson and Kim (1993) show that round numbers are always viewed as support or resistance levels for the Dow Jones Industrial Average. Ley and Varian (1994) also draw similar conclusion. Later, Koedijk & Stork (1994) further extend the market from US to other international markets and find that round numbers of

stock indices function as strong support or resistance levels in the Belgium, Germany, Japan, and UK markets. This effect is also detected on individual stock prices (Cai et al., 2007). To the best of my knowledge, there is no study to test price clustering and barriers around the world. In addition, the present paper setting allows me to explain price clustering and barriers by means of some important cross-country factors suggested by previous literature.

3. Data and measurement

3.1 Data selection

In order to test price clustering and price barriers, I manually collect the closing price (P, expressed in local currency) for each stocks from Datastream. My primary data sample comprises the trades of the common stock from major exchanges, which the majority of stocks in that country are listed. By doing so, I can obtain a maximum breadth to mitigate sample selection bias in each country. For the U.S., I use data on NYSE, AMEX, and NASDAQ. For a few countries, I include data from two stock exchanges: Canada (Toronto and TSX Ventures), China (Shanghai and Shenzhen), Ecuador (Guayaquil and Quito), India (Bombay and National India), South Korea (Korea and KOSDAQ), U.A.E. (Abu Dhabi and Dubai), and Vietnam (Hanoi STC and Ho Chi Minh). The final data used in this study consists of 35,328 stocks traded on 68 countries over the period from 1 Jan 2000 to 31 Dec 2009. Due to the limited availability of data in Datastream, the starting dates for some countries vary from each other. For Bahrain, the starting date is 1 Jan 2004; for Jordan, 1 Oct 2005; for Kazakhstan, 1 Apr 2009; for Kuwait, 1 Sep 2003; for Oman, 1 May 2004; for Qatar, 1 Jan 2004; for Serbia, 1 Apr 2009; for U.A.E., 1 Jan 2004; for Ukraine, 1 Mar 2006; and for Vietnam, 1 Jan 2007.

3.2 Variable measurement

In accordance to Cai et al. (2007), I measure price clustering based on the observed frequency of each digits for each stock. Specifically, it can be calculated as follows:

$$PC_{j,i} = N_{j,i} \Big/ \sum_{i=0}^{9} N_{j,i} \tag{1}$$

where $N_{j,i}$ is the number of closing prices whose ending digit is i for stock j.

As suggested by Cai et al. (2007), the major difference between price clustering and barriers is the direction of price movement. In order to gauge price barriers, I firstly classify paths of daily closing price movements into up-up (*UU*), up-down (*UD*), down-up (*DU*), and down-down (*DD*). For stock *j*, if the closing price at day *t+1* is greater that at day *t* and the closing price at day *t+2* is greater that at day *t+1*, the path of price movement would be assigned to the category of UU. After paths are categorized, price barriers can be measured by the relative statistics of the four movements for each digit.

First, for stock *j*, the number of each type of paths ($N_{j,i,path}$) is counted for digit *i*. Then, the frequency of each type of price movements for each digit is defined by the number of a specific path over the total number of paths of this digit.

$$F_{j,i,path} = \frac{N_{j,i,path}}{N_{j,i,UU} + N_{j,i,UD} + N_{j,i,DU} + N_{j,i,DD}} \tag{2}$$

where $N_{j,i,path,}$ is the number of a specific price movement (e.g. *UU*, *UD*, *DU*, *DD*) for digit *i* of stock *j*.

Then, I employ the following ratio between the reverses (*UD* and *DU*) and the crosses (*UU* and *DD*) to capture the effect of price barriers.

$$PB = \frac{F_{j,i,UD} + F_{j,i,DU}}{F_{j,i,UU} + F_{j,i,DD}} \tag{3}$$

where $F_{j,i,UD}$ is the frequency of up-down movements for digit *i* of stock *j*, $F_{j,i,DU}$ is the frequency of down-up movements for digit *i* of stock *j*, $F_{j,i,UU}$ is the frequency of up-up movements for digit *i* of stock *j*, and $F_{j,i,DD}$ is the frequency of down-down movements for digit *i* of stock *j*. Whether *PB* is smaller or greater than 1 can be used to evaluate the extent of price barrier/resistance. Concretely, if *PB* for any digit is larger than 1, price with this ending digit would be treated as strong barriers.

4. Empirical results

4.1 Evidence on prices clustering and price barriers

In the absence of price clustering, the expected frequency of the last digit of closing prices should follow a uniform distribution. The price clustering measure (*PC*) from 0 to 9 is reported in Table 1 for 68 markets. If looking at the results of individual countries, I fail to find a uniform distribution of last digits. Instead, closing prices in each country most tend to cluster at 0 as their ending digits, while the second highest frequency falls on the ending digit of 5. Overall, as seen in the last row of Table 1, nearly 31.4% and 12.0% of 1,929,296 closing prices end with 0 and 5, respectively. However, some *PC* measures for 5 are not significantly larger than 0.1. Compared to the clustering effect on 0 and 5, other last digits are less frequently observed. My empirical findings appear to be in line with prior literature (Aitken et al., 1996; Grossman et al., 1997; Hameed & Terry, 1998; Brown et al., 2002), indicating a market tendency for prices to cluster at round numbers such as 0.

Table 1 Price clustering

Country	Obs	Last Digit									
		0	1	2	3	4	5	6	7	8	9
Argentina	4781	0.425***	0.054***	0.056***	0.050***	0.056***	0.131***	0.049***	0.055***	0.072	0.053***
Australia	84493	0.310***	0.067***	0.067***	0.069***	0.070**	0.133***	0.072*	0.070**	0.073*	0.070**
Austria	2093	0.593***	0.041***	0.046**	0.031***	0.044**	0.063	0.034***	0.057	0.036***	0.057
Bahrain	161	0.774***	0.028	0.025*	0.037	0.025**	0.033	0.024*	0.014	0.020	0.023*
Bangladesh	11507	0.318***	0.063	0.064	0.071***	0.061	0.153***	0.064	0.072***	0.073***	0.061
Belgium	6401	0.490***	0.056	0.055	0.055	0.053	0.072	0.056	0.052*	0.052**	0.060
Brazil	28417	0.314***	0.080**	0.083*	0.062	0.066	0.114***	0.062	0.071	0.071	0.077***
Bulgaria	5459	0.406***	0.074	0.046*	0.098	0.066	0.065	0.037***	0.089	0.042**	0.076
Canada	138305	0.501***	0.042***	0.049***	0.043***	0.045***	0.139***	0.046***	0.043***	0.049***	0.044***
Chile	6867	0.579***	0.041***	0.041***	0.045***	0.054**	0.044	0.051**	0.052*	0.049**	0.044***
China	124319	0.117***	0.095***	0.097***	0.098**	0.092***	0.107***	0.093***	0.096***	0.103***	0.102
Cyprus	8612	0.105**	0.101	0.107***	0.100	0.104***	0.096	0.094*	0.099*	0.096**	0.098***
Czech	1087	0.384***	0.060*	0.061*	0.066	0.072	0.115***	0.069	0.048***	0.071	0.055***
Denmark	11323	0.430***	0.047***	0.058***	0.053***	0.053***	0.142***	0.054***	0.060***	0.052***	0.051***
Ecuador	739	0.296***	0.107	0.056	0.059**	0.077**	0.119***	0.118***	0.074**	0.042	0.052
Egypt	9313	0.139***	0.096	0.095	0.091	0.092	0.102***	0.094	0.099	0.095	0.098
Estonia	947	0.186***	0.079**	0.095	0.096	0.076**	0.139***	0.073***	0.087*	0.090	0.080***
Finland	11770	0.279***	0.069***	0.072***	0.070***	0.068***	0.150***	0.068***	0.075***	0.074***	0.075***
France	25141	0.467***	0.057*	0.055*	0.059	0.052**	0.083	0.058	0.055*	0.057	0.058**
Germany	61996	0.472***	0.056***	0.055**	0.065	0.053***	0.073	0.056***	0.061	0.054***	0.055***
Greece	22720	0.155***	0.078***	0.107***	0.082***	0.106***	0.089	0.104***	0.083***	0.113***	0.083***
Hong Kong	77248	0.176***	0.079***	0.093	0.082***	0.083***	0.130***	0.088	0.091	0.093***	0.084**
Hungary	903	0.446***	0.050***	0.053***	0.041***	0.046***	0.154***	0.040***	0.043***	0.048***	0.079

India	67701	0.290***	0.055***	0.069	0.061**	0.054***	0.231***	0.056***	0.072	0.055***	0.056***
Indonesia	17947	0.277***	0.059***	0.077	0.064	0.065	0.185***	0.064	0.078	0.064	0.068
Ireland	2310	0.462***	0.067	0.061	0.056*	0.050***	0.088	0.055**	0.055**	0.052**	0.054**
Israel	44455	0.292***	0.076***	0.075***	0.073***	0.071***	0.098	0.073***	0.073***	0.079***	0.090
Italy	20499	0.317***	0.068***	0.074***	0.069***	0.068***	0.123***	0.067***	0.074***	0.070***	0.071***
Japan	240120	0.240***	0.079***	0.077***	0.078***	0.072***	0.145***	0.078***	0.073***	0.079***	0.079***
Jordan	9916	0.163***	0.086	0.090	0.091	0.089	0.118***	0.090	0.086**	0.093	0.094
Kazakhstan	73	0.276***	0.027	0.118	0.098	0.103	0.074	0.145	0.146	0.005	0.009
Kenya	2225	0.345***	0.063	0.064	0.075*	0.056***	0.136***	0.058*	0.076**	0.061*	0.064
Kuwait	5625	0.110***	0.093	0.094	0.092	0.102	0.101	0.098	0.098	0.102	0.109
Lebanon	624	0.223***	0.072	0.060	0.078	0.068	0.155***	0.095	0.085	0.103	0.061
Lithuania	3069	0.317***	0.067***	0.071**	0.063***	0.061***	0.155***	0.071**	0.060***	0.065***	0.071***
Malaysia	43524	0.480***	0.048***	0.061***	0.054***	0.055***	0.076	0.057**	0.053***	0.064***	0.051***
Mexico	8737	0.306***	0.064***	0.066**	0.067***	0.072	0.115***	0.072	0.081	0.081	0.076
Netherlands	4334	0.442***	0.050**	0.058	0.072	0.050**	0.097	0.068	0.056	0.054	0.051**
New Zealand	8522	0.264***	0.068***	0.080**	0.074***	0.077**	0.133***	0.080***	0.073***	0.080*	0.071***
Norway	6164	0.452***	0.054***	0.054***	0.058**	0.054**	0.088	0.057**	0.055***	0.059**	0.070
Oman	3536	0.189***	0.090**	0.076	0.077	0.088*	0.124***	0.086	0.081	0.090**	0.099*
Pakistan	14789	0.302***	0.071	0.072	0.076	0.072	0.119***	0.067**	0.078	0.072	0.071
Philippines	10679	0.386***	0.058*	0.073	0.057**	0.069	0.110***	0.072	0.050***	0.070	0.055**
Poland	10537	0.348***	0.064***	0.071	0.059***	0.061***	0.131***	0.066**	0.060***	0.067***	0.073**
Portugal	2258	0.451***	0.059	0.056	0.062	0.055*	0.085	0.061	0.057	0.056	0.059
Qatar	1396	0.213**	0.100	0.099	0.106	0.097	0.103	0.097	0.106	0.037***	0.042
Romania	4370	0.374***	0.058***	0.060***	0.058***	0.059***	0.155***	0.062***	0.056***	0.058***	0.059***
Russia	2589	0.265***	0.121	0.118***	0.075***	0.070***	0.110***	0.069***	0.057**	0.057***	0.057
Saudi	4829	0.206***	0.065***	0.106**	0.087	0.071**	0.138***	0.080	0.099*	0.077	0.072
Serbia	252	0.339***	0.149	0.017	0.122	0.045	0.108	0.024	0.024	0.024	0.147
Singapore	28142	0.254***	0.064	0.072	0.073	0.068	0.195***	0.068	0.070	0.070	0.066
Slovakia	1331	0.118**	0.095**	0.093	0.089	0.091	0.094	0.117*	0.096*	0.118**	0.089*
Slovenia	1946	0.213*	0.084*	0.111***	0.077*	0.082	0.098	0.079	0.088	0.081*	0.087
South Africa	23609	0.373***	0.059***	0.056***	0.060***	0.053***	0.162***	0.059***	0.059***	0.062***	0.057***
South Korea	100179	0.318***	0.062***	0.064***	0.065***	0.063***	0.171***	0.064***	0.063***	0.065***	0.064***
Spain	10267	0.185***	0.087***	0.087***	0.084***	0.088***	0.123***	0.086***	0.082***	0.089***	0.089***
Sri Lanka	12219	0.282***	0.063	0.090***	0.072	0.076**	0.119***	0.070	0.089***	0.074	0.066
Switzerland	15458	0.366***	0.064***	0.066***	0.061***	0.064***	0.116***	0.063***	0.066***	0.065***	0.069***
Taiwan	59549	0.184***	0.084**	0.086**	0.087*	0.084**	0.132***	0.085**	0.086*	0.085**	0.086**
Thailand	30419	0.271***	0.064***	0.088***	0.060***	0.078	0.141***	0.079	0.076	0.078	0.065***
Turkey	24945	0.164***	0.085**	0.094**	0.088	0.093*	0.109***	0.093	0.093	0.093	0.087*
U.A.E.	2504	0.157**	0.092	0.108	0.104	0.104	0.114	0.056	0.052	0.116	0.097
Ukraine	2606	0.220***	0.141	0.130***	0.079**	0.073**	0.109**	0.064*	0.062	0.073	0.049
U.K.	43631	0.393***	0.059	0.055*	0.072***	0.056*	0.126***	0.058	0.056	0.070***	0.056*
U.S.	372094	0.214***	0.080***	0.085***	0.079***	0.074***	0.147***	0.083***	0.080***	0.082***	0.076***
Venezuela	2549	0.206***	0.067**	0.094***	0.081***	0.086***	0.116***	0.087***	0.066**	0.120***	0.076***
Vietnam	9417	0.139**	0.108	0.109	0.110	0.090	0.122	0.092	0.085	0.036	0.109
Zimbabwe	2747	0.334***	0.107	0.084	0.062	0.055	0.197*	0.048	0.041	0.042	0.030***
Average	28372	0.314***	0.072	0.075**	0.071	0.069	0.120***	0.070	0.070	0.070	0.068

Note: This table shows the total observation (Obs) and the relative frequency with which daily closing prices clustered on each last digit. The sample period is from 1/1/2001 through 31/12/2009. ***, **, and * denote significance at the 1%, 5%, and 10% level.

The analysis of price barriers for each digit relies on comparisons of price movements between reverses and crosses. The *PB* ratio developed in the above section is the key statistic to examine the degree of the resistance level based on specific digits. Similarly, Table 2 summarizes the result for such analysis arranged by different countries. With regard to each market, digit 0 has a *PB* ratio that is significantly greater than 1 from the statistical perspective, implying that closing prices ending in 0 are viewed as a strong resistance level in every country. It is true if taking the global market as a whole. In a nutshell, when approaching digit 0, closing prices are more likely to reverse than to cross this price level. This is consistent with Cai et al. (2007). In addition, there is little evidence for 5 to serve as a resistance point, because most *PB* ratios for 5 are insignificant and even less than 1.

Table 2 Price barriers

Country	Obs	Last Digit									
		0	1	2	3	4	5	6	7	8	9
Argentina	3987	1.096**	1.036	1.031	0.962	1.001	0.961	1.018	0.979	0.982	1.066
Australia	70026	1.018***	0.977***	0.997***	1.004	0.986***	1.002***	1.014	1.005	0.992***	1.005
Austria	1572	1.098***	1.081	0.722***	0.830	1.124	0.935	1.155	0.946	1.079	1.031
Bahrain	97	2.216***	0.242	0.484	1.210	0.000	1.089	2.904	1.452	0.161	0.242
Bangladesh	10964	1.097*	1.002	1.006	0.962	1.013	0.960	1.025	1.034	0.974	1.044
Belgium	5392	1.154***	0.916***	1.055	0.965***	1.055	0.949	0.927***	0.979***	1.028	0.971***

Brazil	18792	1.096***	0.991***	0.992***	0.963**	1.001	0.948	1.023	1.017	1.029	1.069
Bulgaria	3290	1.078**	0.919	0.978	0.891	0.933	1.005	0.777	0.941	1.134	1.342
Canada	116837	1.283***	0.952***	0.969***	0.976***	0.961***	1.005***	0.978***	0.948***	0.991***	0.936***
Chile	4556	1.010***	1.032	0.968***	1.085	0.871***	0.937	0.968***	1.109	0.924***	1.097
China	123620	1.099***	0.996***	1.008	1.000	1.013	0.994	1.002	1.009	0.990***	0.997***
Cyprus	5772	1.092**	0.991***	1.014	1.033	0.996***	0.948	0.995***	1.034	1.014	1.053
Czech	837	1.062**	1.110	0.995	0.922**	0.997	0.888	1.013	0.988	1.025	0.999
Denmark	8814	1.114***	0.987***	0.968***	0.954***	0.939***	1.089***	0.998***	0.946***	1.015	0.990***
Ecuador	143	1.091**	0.545**	1.444	1.479	0.833	0.850	1.292	0.852	0.822	0.977
Egypt	8614	1.099**	1.053	0.980**	1.041	1.008	0.963	0.982	0.984	0.978*	1.014
Estonia	845	1.096***	0.957**	1.056	1.050	1.074	0.924	1.010	0.815***	1.083	1.068
Finland	10674	1.101***	0.993***	0.983***	0.996***	0.990***	0.986	0.985***	0.963***	0.978***	1.026
France	22556	1.098***	1.034	1.035	1.011	1.009	0.972	0.980***	0.988***	0.995***	0.991***
Germany	51548	1.097***	1.019	1.015	0.987***	1.006	1.028***	0.991***	0.994***	0.992***	0.995***
Greece	22261	1.098*	1.038	0.992**	1.002	0.993*	0.981	0.979*	0.998*	0.998**	1.034
Hong Kong	69949	1.099***	0.995***	0.996***	1.004	0.990***	0.987	1.002	1.003	1.013	1.013
Hungary	799	1.089***	1.227	0.839***	0.913**	0.995**	0.909	1.056	1.155	0.920***	1.094
India	65211	1.098*	1.003	0.994*	1.008	1.014	0.970	1.005	1.009	1.014	1.001
Indonesia	14277	1.169**	0.883	0.999	0.963	1.000	1.169	0.922	0.996	0.931	0.969
Ireland	1940	1.081***	0.979**	1.013	0.940**	0.979***	1.038***	1.025	0.960***	0.962***	1.023
Israel	38270	1.099***	0.984***	0.980***	0.989***	0.990***	1.017**	1.021	0.992***	1.026	1.008
Italy	19794	1.094***	0.984***	1.005	1.021	1.005	0.979	1.003	0.997***	1.028	1.030
Japan	229405	1.094***	1.016	1.011	1.007	1.010	0.965	1.010	1.019	1.005	1.015
Jordan	8939	1.041*	0.930	0.955	0.973	1.024	1.074***	0.965	0.990	1.022	1.025
Kazakhstan	18	3.658***	0.870	0.000	0.000	0.000	0.000	0.000	2.984	1.492	0.995
Kenya	1860	1.091**	1.171	1.006	0.959**	1.126	1.041	0.857	0.933	0.958	1.030
Kuwait	4176	1.085**	0.953**	1.036	0.931**	0.921***	1.046***	0.984***	1.091	0.953***	1.000
Lebanon	363	1.076**	0.960	0.753	1.356	0.905	0.622	1.197	1.512	1.006	0.931
Lithuania	2477	1.026**	0.989**	1.144	1.026	0.936	1.097***	0.936	0.955*	1.044	0.847
Malaysia	39863	1.271***	0.986***	0.992***	0.948***	0.938***	0.978	0.970***	0.950***	0.980***	0.988***
Mexico	6492	1.006**	0.984***	0.962*	0.933***	0.985*	1.006*	0.997**	1.044	1.041	1.041
Netherlands	4047	1.031***	1.045	0.976***	1.051	0.980**	1.037**	0.951***	1.012	0.956***	0.962**
New Zealand	6735	1.037***	0.991***	0.962***	1.051	0.996***	0.956	0.959***	0.983***	0.999***	1.067
Norway	5391	1.079***	1.039	0.979***	1.010	0.959***	0.976	0.980***	1.014	0.990***	0.973**
Oman	1863	1.138**	0.987	1.164	0.809	1.155	0.802	1.058	1.074	0.787	1.026
Pakistan	12986	1.021***	0.978*	0.961*	0.938	0.976**	1.064***	1.045	1.015	1.024	0.979**
Philippines	7235	1.201***	0.975***	1.057	0.998**	0.971***	1.004***	0.946***	0.913**	0.939***	0.997***
Poland	9747	1.095**	1.019	1.010	0.995***	1.071	0.981	0.971**	1.025	0.991***	0.986***
Portugal	1973	1.044***	1.017	0.903**	0.968***	0.969***	1.031***	1.102	0.992***	1.012	0.963**
Qatar	1324	1.017**	1.043	1.010	0.981	0.877	1.002	0.963	1.061	1.036	1.009
Romania	3638	1.115***	0.953***	0.942***	0.987**	0.960**	1.025***	1.132	0.953**	0.974***	0.959**
Russia	581	1.013***	0.558***	0.654***	0.794***	1.358	0.794	1.013	1.614	1.127	1.075
Saudi	4605	1.095***	0.939	0.926**	0.950**	1.007	1.011***	0.976***	1.052	1.117	1.069
Serbia	97	1.066**	1.661	0.328	1.398	1.095	0.648	0.744	1.045	2.036	0.384
Singapore	24711	1.178***	0.964***	0.951***	0.980***	0.922***	1.173***	0.943***	0.958***	0.956***	0.976***
Slovakia	427	1.183***	1.189	0.882	0.919	0.857	0.852	0.959	0.928	1.153	1.079
Slovenia	1686	1.006***	1.045	0.927*	1.006	1.034	0.984	0.983**	0.989*	1.025	1.004
South Africa	17854	1.044***	1.028	0.947***	0.993***	0.970**	1.027***	1.045	0.961**	0.957**	1.027
South Korea	96724	1.096***	0.990***	1.003	0.998***	1.018	0.984	1.010	1.007	1.020	1.008
Spain	9835	1.097***	0.976***	1.006	1.029	1.043	0.988	0.955***	0.972***	0.976***	1.078
Sri Lanka	9224	1.099***	0.955***	1.036	0.983***	0.959***	1.012***	1.078	1.010	0.987***	0.989***
Switzerland	13962	1.027***	1.024	1.011	0.938***	1.028	0.986	1.005	1.006	0.959***	1.016
Taiwan	58825	1.099***	1.005	1.000	1.008	0.994***	0.993	1.009	0.997***	0.996***	1.010
Thailand	26378	1.012***	1.022	1.008	0.942***	1.004	1.021***	1.010	0.974***	1.007	0.999***
Turkey	24375	1.099***	1.008	1.000	1.000	0.997***	0.995	0.988***	1.000	1.022	0.997***
U.A.E.	2163	1.093**	1.065	1.002	1.024	1.017	0.942	0.974	0.985	1.048	1.006
Ukraine	1219	1.229**	1.084	0.944	0.918	0.959	0.955	0.925	0.966	0.962	1.059
U.K.	38678	1.089***	1.041	0.984***	0.984***	1.013	0.977	1.064	0.988**	1.001	1.060
U.S.	360252	1.095***	1.013	1.016	1.018	1.004	0.965	1.015	1.009	1.011	1.000
Venezuela	1177	1.024**	0.983	1.018	0.910	1.035	1.080	0.866	0.953	0.969	1.162
Vietnam	9138	1.034**	1.028	0.977	0.940	0.966	1.039	1.044	0.949	0.965	1.059
Zimbabwe	1462	1.046***	0.835***	0.958***	0.870***	0.884***	1.064***	1.150	1.103	1.340	0.749***
Average	25784	1.128***	0.993	0.986	0.991	0.996	1.098***	1.004	1.005	1.002	1.011

Note: This table shows the total observation (Obs) and the reverses to crosses ratio for daily closing prices on each last digit. First, the frequency measures are calculated for four different price movement patterns for each digit (Up-Up, UU; Up-Down, UD; Down-Up, DU; Down-Down, DD). Then the PB ratio is defined as the frequency of reverses (UD+DU) over that of crosses (UU+DD) for each digit. The sample period is from 1/1/2001 through 31/12/2009. ***, **, and * denote significance at the 1%, 5%, and 10% level.

To check the robustness of my result, I need to take into account of the regulation of tick size on individual exchanges in each country. As shown in Table 3, tick size varies within different price ranges across some markets. But tick size would not contaminate my finding in Table 1 and 2 for 34 countries including Bangladesh, Brazil, Bulgaria, Chile, China, Czech, Ecuador, Egypt, Estonia, Finland, Hungary, Ireland, Israel, Jordan, Kazakhstan, Kenya, Kuwait, Lithuania, New Zealand, Oman, Pakistan, Qatar, Russia, Serbia, Slovakia, Slovenia, South Africa, Sri Lanka,

Ukraine, U.K., U.S., Venezuela, Vietnam, and Zimbabwe. As for other countries, I repeat the same analysis on the subsample which satisfies the following criteria: tick size over the price range allows me to examine price clustering and barriers at each integer from 0 to 9. Taking Hong Kong as an example, I construct the subsamples with prices ranging 0-0.250, 0.51-10.00, 100.01-200.00, and 1000.01-2000.00. The results on subsamples yield similar conclusion as Table 1 and 2.

Table 3 Regulation in tick size by country

Country	Exchange	Trading Currency	Price Range	Tick Size
			0-1.000	0.001
Argentina	Buenos Aires	ARS	1.01-10.00	0.01
			10.01+	0.05
			0.001-0.099	0.001
Australia	Australian	AUD	0.100-1.995	0.005
			2.00-999.00	0.01
			0.001-9.999	0.001
			10.000-49.995	0.005
Austria	Vienna	EUR	50.00-99.99	0.01
			100.00+	0.05
			0.001-0.200	0.001
			0.201-0.500	0.002
Bahrain	Bahrain	BHD	0.501-1.000	0.005
			1.001-2.500	0.01
			2.501+	0.02
Bangladesh	Dhaka	BDT	All	0.01
			0-9.999	0.001
			10.000-49.995	0.005
Belgium	Euronext Brussels	EUR	50.00-99.99	0.01
			100.00+	0.05
Brazil	Sao Paulo	BRL	All	0.01
Bulgaria	Sofia	BGN	All	0.001
	Toronto	CAD	0-0.500	0.005
Canada			0.501+	0.01
	TSX Ventures	CAD	0-0.500	0.005
			0.501+	0.01
			0-99.999	0.001
Chile	Santiago	CLP	100.00-999.99	0.01
			1000.0-9999.9	0.1
			10000+	1
China	Shanghai	CNY	All	0.01
	Shenzhen	CNY	All	0.01
			0.01-2.99	0.01
Cyprus	Cyprus	EUR	3.00-59.98	0.02
			60.00+	0.05
			0-199.99	0.01
Czech	Prague	CZK	200.0-999.9	0.1
			1000+	1
			0.00-4.99	0.01
			5.00-9.95	0.05
			10.00-49.90	0.1
			50.00-249.75	0.25
Denmark	Copenhagen	DKK	250.0-499.5	0.5
			500-4999	1
			5000-19990	10
			20000+	100
Ecuador	Guayaquil	USD	All	0.01
	Quito	USD	All	0.01
Egypt	Cairo	EGP	All	0.01
Estonia	Tallinn	EEK	All	0.01
Finland	Helsinki	EUR	All	0.01
			0-9.999	0.001
			10.000-49.995	0.005
France	Euronext Paris	EUR	50.00-99.99	0.01
			100.00+	0.05
			0-9.999	0.001
			10.000-49.995	0.005
Germany	Frankfurt	EUR	50.00-99.99	0.01
			100.00+	0.05
			0.01-2.99	0.01
Greece	Athens	EUR	3.00-59.98	0.02
			60.00+	0.05
			0-0.250	0.001
Hong Kong	Hong Kong	HKD	0.251-0.500	0.005

			0.51-10.00	0.01
			10.01-20.00	0.02
			20.01-100.00	0.05
			100.01-200.00	0.1
			200.01-500.00	0.2
			500.01-1000.00	0.5
			1000.01-2000.00	1
			2000.01-5000.00	2
			5000.01-9995.00	5
Hungary	Budapest	HUF	All	1
India	Bombay	INR	All	0.01
	National India	INR	All	0.05
			0-200	1
			200-499	5
Indonesia	Indonesia	IDR	500-1999	10
			2000-4999	25
			5000+	50
Ireland	Dublin	EUR	All	0.001
			0-4.999	0.001
			5.00-49.99	0.01
Israel	Tel Aviv	ILS	50.0-499.9	0.1
			500+	1
			0-0.2500	0.0001
			0.2501-1.0000	0.0005
			1.0001-2.0000	0.001
Italy	Milan	EUR	2.0001-5.0000	0.0025
			5.0001-10.0000	0.005
			10.00+	0.01
			0-2000	1
			2000-2999	5
			3000-29999	10
			30000-49999	50
Japan	Tokyo	JPY	50000-99999	100
			100000-999999	1000
			1000000-19999999	10000
			20000000-30000000	50000
			30000000+	100000
Jordan	Amman	JOD	All	0.01
Kazakhstan	Kazakhstan	KZT	All	0.01
Kenya	Nairobi	KES	All	0.01
Kuwait	Kuwait City	KWD	All	0.01
			0-49.99	0.01
Lebanon	Beirut	USD	50.00-99.99	0.05
			100.0-499.9	0.1
			500.0+	0.5
Lithuania	Lithuania	LTL	All	0.01
			0-0.995	0.005
			1.00-9.99	0.01
Malaysia	Kuala Lumpur	MYR	10.00-99.98	0.02
			100.0+	0.1
			0-0.200	0.001
			0.21-5.00	0.01
Mexico	Mexico	MXN	5.02-20.00	0.02
			20.05-50.00	0.05
			50.1+	0.1
			0-9.999	0.001
			10.000-49.995	0.005
Netherlands	Euronext Amsterdam	EUR	50.00-99.99	0.01
			100.00+	0.05
			0-0.199	0.001
New Zealand	New Zealand	NZD	0.20+	0.01
			0-0.4999	0.0001
			0.5000-0.9995	0.0005
			1.000-4.999	0.001
			5.000-9.995	0.005
			10.00-49.99	0.01
Norway	Oslo	NOK	50.00-99.95	0.05
			100.0-499.9	0.1
			500.0-999.5	0.5
			1000-4999	1
			5000-9995	5
			10000+	10
Oman	Muscat	OMR	All	0.01
Pakistan	Karachi	PKR	All	0.01
			0.0001-0.0099	0.0001
			0.010-0.249	0.001
Philippines	Philippine	PHP	0.250-0.495	0.005
			0.50-9.99	0.01
			10.00-19.98	0.02
			20.00-99.95	0.05

			100.0-199.9	0.1
			200.0-499.8	0.2
			500.0-999.5	0.5
			1000-1999	1
			2000-4998	2
			5000+	5
			0-49.99	0.01
Poland	Warsaw	PLN	50.00-99.95	0.05
			100.0-499.9	0.1
			500.0+	0.5
			0-9.999	0.001
Portugal	Euronext Lisbon	EUR	10.000-49.995	0.005
			50.00-99.99	0.01
			100.00+	0.05
Qatar	Doha	QAR	All	0.01
			0-0.0999	0.0001
			0.100-0.499	0.001
Romania	Bucharest	RON	0.500-0.995	0.005
			1.00-4.99	0.01
			5.00-9.95	0.05
			10.0+	0.1
Russia	Russian Trading System	USD	All	0.01
			0-25.00	0.05
Saudi Arabia	Riyadh	SAR	25.01-50.00	0.1
			50.01+	0.25
Serbia	Belgrade	RSD	All	1
			0-0.995	0.005
Singapore	Singapore	SGD	1.00-9.99	0.01
			10.00+	0.02
Slovakia	Bratislava	EUR	All	0.01
Slovenia	Ljubljana	EUR	All	0.01
South Africa	Johannesburg	ZAR	All	0.01
			1-5000	5
			5000-10000	10
	Korea	KRW	10000-50000	50
			50000-100000	100
			100000-500000	500
South Korea			500000+	1000
			0-5000	5
	KOSDAQ	KRW	5000-10000	10
			10000-50000	50
			50000+	100
			0-50.00	0.01
Spain	Madrid SIBE	EUR	50.00+	0.05
Sri Lanka	Colombo	LKR	All	0.1
			0-0.4999	0.0001
			0.5000-0.9995	0.0005
			1.000-4.999	0.001
			5.000-9.995	0.005
			10.00-49.99	0.01
Switzerland	SIX Swiss	CHF	50.00-99.95	0.05
			100.0-499.9	0.1
			500.0-999.5	0.5
			1000-4999	1
			5000-9995	5
			10000+	10
			0-9.99	0.01
			10.00-49.95	0.05
Taiwan	Taiwan	TWD	50.0-99.9	0.1
			100.0-499.5	0.5
			500-999	1
			1000+	5
			0-1.99	0.01
			2.00-4.98	0.02
			5.00-9.95	0.05
			10.00-24.90	0.1
Thailand	Bangkok	THB	25.00-49.75	0.25
			50.0-99.5	0.5
			100-199	1
			200-399	2
			400-799	4
			800+	6
			0.01-5.00	0.01
			5.02-10.00	0.02
Turkey	Istanbul	TRY	10.05-25.00	0.05
			25.01-50.00	0.1
			50.25-100.00	0.25
Ukraine	Kiev	UAH	All	0.01
U.A.E.	Abu Dhabi	AED	0.01-10.00	0.01
			10.05-100.00	0.05

			100.1+	0.1
			0-0.999	0.001
	Dubai	AED	1.00-9.99	0.01
			10.00+	0.05
U.K.	London	GBP	All	0.01
U.S.	NASDAQ	USD	0-0.9999	0.0001
			1.00+	0.01
	NYSE	USD	All	0.01
	AMEX	USD	All	0.01
Venezuela	Caracas	VEF	All	0.01
Vietnam	Hanoi STC	VND	All	100
	Ho Chi Minh	VND	All	100
Zimbabwe	Zimbabwe	ZWD	All	0.01

Note: This table presents tick size at different price ranges on the stock exchange for 68 countries. The tick size and prices are expressed in local currencies for each country.

4.2 Determinants of prices clustering and barriers

Next, to explain the variation of price clustering and barriers among different countries, I perform cross-sectional regressions involving a rich set of variables that could potentially impact price clustering and barriers. Country-level variables are chosen from many sources that have been used in the prior international literature. Specifically, six groups of variables are considered: culture, country governance, investor protection, information environment, stock market feature, and macroeconomic condition. In the following analysis, I first briefly introduce my choice of independent variables and then proceed with univariate regressions as follow:

$$PC_i\,(PB_i) = a + bX_i + \varepsilon_i \tag{4}$$

Where PC_i (PB_i) is the effect of price clustering (barriers), X_i represents a series of cross-country independent variables.

To measure culture values, I obtain data on Power Distance Index (*PDI*), Individualism (*IDV*), Masculinity (*MAS*), and Uncertainty Avoidance Index (*UAI*) that are theoretically relevant to investors' behavior from Griffin et al. (2009). I also collect data on the percentage of the population of each country that belonged to Roman Catholic (*Catho*), Muslim (*Muslim*), and Protestant (*Protmg*) religion in 1980 from LaPorta et al. (2006). Inspired by the findings of Ferreira and Matos (2008), a dummy (*Language*) to capture whether English is the official language is investigated as well.

Following the World Governance Indicators dataset produced by Kaufmann et al. (2006), I include six aggregate measures of governance quality and see their impact on the return differentials, namely voice and accountability (*VA*), political stability and absence of violence (PV), governance effectiveness (*GE*), regulatory quality (*RQ*), rule of law (*RL*), and control of corruption (*CC*).

To proxy for investor protection in each country, a set of measures are used. The anti-self-dealing index (*IP*) which gauges the legal protection of minority shareholders against expropriation by corporate insiders is taken from Djankov et al. (2008). Another measure (*SL*) is constructed by taking average of the disclosure requirements index, the liability standard index, and the public enforcement index, all of which are retrieved from LaPorta et al. (2006). *Extent_IT* is taken from LaPorta et al. (2006) to measure the extent of insider trading in individual country's stock markets. Two dummy variables (*SS_F* and *PO_E*) from Charoenrook and Daouk (2009) are also included to capture whether short selling or put option trading is

allowed. Following LaPorta et al. (2006), *Legal* is used to reflect the effect of English legal origin.

To characterize the information environment, I select CIFAR index (*Cifar*), disclosure extent (*Discl*), and media development (*Media*) from Bushman et al. (2004). Another measurement is daily newspaper in circulation (*News*) from WDI database.

In terms of stock market feature, the data on the size of equity mutual fund (*Ind_GDP*) is taken from Khorana et al. (2005) to control for ownership structure. I collect the time length of exchange establishment (*Estb*) and the adoption of electronic system (*Elec*) from Jain (2005). As a proxy for the market efficiency, I obtain data on the analyst coverage (*Analyst*) and on the price efficiency (*Delay*) in different countries from Griffin et al. (2010). In addition, I involve the data on the price to earnings ratio (*PE*) from Bekaert et al. (2007). The last two are retrieved from Lane & Milesi-Ferretti (2007) to control for stock market liberalization.

Finally I include the following seven control variables to proxy for macroeconomic condition: the bank credit (Credit), the market capitalization (MCR), the dummy to denote developed/emerging economies (*DEI*), the gross domestic product (GDP), the global competitive index (GCI), the surface area (*Size*), and the measure of the intensity of capital account liberalization (*TD_Open*). Table 4 gives an overview of the definitions and sources of the above variables.

Table 4 Determinants of price clustering and price resistance

	Definition	Source	Clustering	Barriers
Culture				
PDI	Power distance index	Hofstede (2001)	-0.003	-0.018
IDV	Individualism	Hofstede (2001)	0.010	0.022*
MAS	Masculinity	Hofstede (2001)	-0.013	-0.016
UAI	Uncertainty avoidance index	Hofstede (2001)	0.012	-0.047***
Catho	Population with Roman Catholic religion	LaPorta et al. (2006)	0.026***	-0.010
Muslim	Population with Muslim religion	LaPorta et al. (2006)	-0.026***	0.006
Protmg	Population with Protestant religion	LaPorta et al. (2006)	0.009	0.024*
Language	Dummy variable for English-speaking countries	Language Map of the World	0.196	0.795
Country Governance				
VA	Voice and accountability	Kaufmann et al. (2006)	0.205	0.814**
PV	Political stability and absence of violence	Kaufmann et al. (2006)	0.069	1.197***
GE	Government effectiveness	Kaufmann et al. (2006)	-0.019	1.375***
RQ	Regulatory quality	Kaufmann et al. (2006)	-0.173	1.527***
RL	Rule of law	Kaufmann et al. (2006)	-0.134	1.316***
CC	Control of corruption	Kaufmann et al. (2006)	-0.015	1.164***
Investor Protection				
IP	Anti-self-dealing index	Djankov et al. (2008)	-0.822	3.854***
SL	Effectiveness of securities regulation	LaPorta et al. (2006)	-2.195	6.027***
Extent_IT	Insider trading measure	LaPorta et al. (2006)	0.515*	0.807*
SS_F	Dummy variable for short selling	Charoenrook & Daouk (2009)	1.232**	0.387
PO_E	Dummy variable for put options trading	Charoenrook & Daouk (2009)	0.857*	0.465
Legal	Dummy variable for English legal origin	LaPorta et al. (2006)	-0.159	0.940
Information Environment				
Cifar	CIFAR Index	Bushman et al. (2004)	0.025	0.061
Discl	Assessment of the disclosure prevalence	Bushman et al. (2004)	0.028*	0.052**
Media	Media development	Bushman et al. (2004)	0.004	0.041**
News	Daily newspapers in circulation	WDI	0.002	0.005**
Stock Market Feature				
Ind_GDP	Size of mutual fund	Khorana et al. (2005)	0.399	1.678*
Estb	Time of exchange establishment	Jain (2005)	0.007**	0.001
Elec	Dummy variable for electronic system	Jain (2005)	-0.029	0.148**
Analyst	Analyst coverage	Griffin et al (2010)	0.090	0.346***
Delay	Market efficiency	Griffin et al (2010)	0.191**	0.039
PE	Price to earnings ratio	Bekaert et al. (2007)	-0.227	2.938**
GEQGDP	Stock market liberalization	Lane & Milesi-Ferretti (2007)	0.373	1.802***
IFIGDP	Capital account liberalization	Lane & Milesi-Ferretti (2007)	0.230**	0.177*
Macroeconomic Condition				
Credit	Bank credit	Beck & Al-Hussainy (2007)	-1.011	2.404**
MCR	Market capitalization	Beck & Al-Hussainy (2007)	-0.334	1.542***

DEI	Developed and Emerging Market indicator	MSCI	0.590	2.070***
GDP	Gross domestic product	WDI	0.059	0.562**
GCI	Global competitive Index	Global Competitiveness Report	-0.308	1.796***
Size	Surface area	U.N. Environmental Indicators	0.030	-0.306**
TD_Open	Openness measured by international trade	WDI	-0.001	0.020***

Note: This table shows the results of univariate regressions explaining price clustering and price resistance at zero. The independent variables are classified into six categories including culture, country governance, investor protection, information environment, stock market feature, and macroeconomic condition. Within each category, a variety of variables are used to capture the cross-country effect in light of previous literature. The standard errors are robust to heteroskedasticity. ***, **, and * denote significance at the 1%, 5%, and 10% level.

Since the clustering and barriers effects are only robust and persistent on ending digit 0, I take the *PC* and *PB* ratios for 0 as the dependent variables. The estimation results of univariate regressions are presented in Table 4 as well. The finding indicates that both price clustering and barriers for last digit 0 are associated with extent of insider trading, disclosure level, and capital account liberation, respectively. This suggests that a more transparent and open environment should encourage the clustering and barriers effect. In addition, price barriers seem to be related to more potential variables than price clustering, especially for country governance and macroeconomic condition.

5. Conclusion

The purpose of this paper is to investigate price clustering and barriers and explore their determinants across 68 countries. My findings clearly indicate a higher propensity to cluster and resist on last digit 0. Even though such effects are also detected on last digit 5, the result is not robust and persistent. After conducting the regression analysis on price clustering and barriers, I find that this phenomenon is more conspicuous and stronger in countries with timely disclosure and effective dissemination of information.

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