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Are price limits really bad for equity markets?

Saikat Sovan Deb [a], Petko S. Kalev [b,*], Vijaya B. Marisetty [c]

[a] School of Accounting, Economics and Finance, Deakin University, Australia
[b] School of Commerce, Division of Business, University of South Australia, Australia
[c] Department of Accounting and Finance, Monash University, Australia

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ABSTRACT

Despite widely documented criticisms, price-limit rules are present in many equity markets around the world. Using a game-theoretic model, we argue that, if the cost of monitoring a market is high, price-limit rules are beneficial. Empirical tests based on a cross section of 43 equity markets across five continents support our theoretical prediction. We find that the probability of the existence of price-limit rules is greater in markets that incur higher monitoring costs due to poorer business disclosure, more corruption and less efficiency in legal, regulatory and technological environments.

1. Introduction

In this paper, we provide a rationale for the popularity of price-limit rules in many equity markets around the world. We investigate the conditions that encourage stock exchange officials to consider rule-based price limits along with discretionary trading halts. We focus on the costs associated with completely replacing rule-based price limits with discretionary trading halts. We argue that, given the high expenses associated with continuous market monitoring, the use of rule-based price limits is determined by the level of maturity of a stock market and the systematic efficiencies in its legal and regulatory environment. In markets where monitoring costs are shared between the firms and the regulator, the use of price-limit rules will be much lower. For example, NASDAQ Stock Market Rules IM-4120-1, 4310(c)(15) and 4320(e)(13) require listed firms to provide full and prompt responses to NASDAQ requests for information related to unusual market activity or to events that may materially impact the trading of its securities. Likewise, the Australian Stock Exchange's (ASX) Rule 3.1B obliges firms to monitor market trading continuously and to explain any abnormal trading activity questioned by the exchange. It should be noted that stock exchanges take several other monitoring and governance measures to enhance the effectiveness and the fairness of equity markets.[1]

We argue that the cost of market monitoring is high when a market has systematic inefficiencies, such as poor business disclosure or lack of infrastructure or legal support. This is consistent with the findings of Frost et al. (2006). Therefore, regulators and exchange officials in such markets are often less informed and less equipped to detect information asymmetry and market abuse. As a result, in these markets, discretionary measures such as trading halts are not only costly, but also inadequate to serve as an optimal price-stabilizing mechanism. There are several instances of equity exchanges and market regulators explicitly stating the use of daily price-limit rules as a means to curb market manipulations. The Philippine Stock Exchange mentions on its website that price limits are used to reduce market manipulation. The Securities Exchange Board of India is currently contemplating an introduction of price

* Corresponding author. Tel.: +61 8 8302 7122; fax: +61 8 8302 0992.
E-mail addresses: saikat.deb@deakin.edu.au (S.S. Deb), petko.kalev@unisa.edu.au (P.S. Kalev), vijay.marisetty@buseco.monash.edu.au (V.B. Marisetty).

[1] Chang et al. (2008) document that day-end price manipulation declines after the adoption of the call market method to opening and closing on the Singapore Exchange (SGX). Chelley-Steeley (2008) observes that after the introduction of the closing call auction by the London Stock Exchange stocks adjust quicker to new information. Lagoarde-Segot (2009) argues that the market development in emerging market microstructures is affected by interrelated economic and political factors.

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limits on the first day of re-listing of suspended stocks to control price manipulative activities.[2]

Our study makes two contributions to the literature. First, to the best of our knowledge, as one of the few studies to model the role of price-limit rules in the context of price manipulations, our paper is the first to explicitly incorporate market monitoring costs into the tradeoff analysis. Second, we support our theory with a comprehensive empirical analysis using price-limit rules data covering more than 80% of the world's stock markets. Consistent with our theoretical predictions, we find that the probability of the existence of price-limit rules is higher in countries that face higher monitoring costs due to poorer business disclosure, higher corruption levels and lower efficiency in the legal, regulatory and technological environments.

A recent paper by Kim and Park (2010) is closely related to this study, in that they also investigate the role of price-limit rules in the presence of price manipulators. Our paper differs from theirs in three important ways. First, the theoretical model of Kim and Park (2010) focuses on how price limits can reduce the profitability of price manipulation. In contrast, our model emphasizes the benefits of price limits to the market regulators and participants. Second, Kim and Park (2010) do not model the costs of market monitoring, which regulators must incur to be effective. Our model incorporates cost and efficiency of market monitoring and shows how these variables may influence the existence of price-limit rules. Third, Kim and Park (2010)'s model is silent about the negative impacts of price-limit rules on market quality. As empirical evidence suggests that price limits affect price discovery and liquidity, we include these costs in the regulator's benefit function. Our model incorporates the possibility that price limits may decrease the profit potential of market manipulators and can make market monitoring more effective but, at the same time, may reduce the regulator's benefits from an orderly market. In a market where monitoring is costly, our model characterizes the conditions under which the benefits of price limits exceed the costs.

The rest of the paper is organized as follows. Section 2 provides the context of our paper in the price limits literature. Section 3 presents the theoretical model. Section 4 defines the econometric model and the data. Section 5 presents the empirical analysis. Section 6 concludes.

2. Background

Rule-based price-stabilizing mechanisms for individual securities, namely, daily price limits, are common to many stock exchanges around the world. Daily price limits are imposed when a given security price crosses above or below a pre-determined value. The existing literature on price-limit rules does not provide a formal theory justifying the existence of price-limit rules in equity markets.[3] The main justification for price limits is that they can reduce price volatility and overreactions. However, these arguments have received limited support from academic researchers. For example, Fama (1989) and Lehmann (1989) criticize price-limit rules, claiming that they cause volatility spillover, delayed price discovery and trading interference.

Subrahmanyam (1994) shows that rule-based price-stabilizing mechanisms increase market volatility and reduce liquidity. Empirical studies such as Chen (1993), George and Hwang (1995) and Kim and Rhee (1997) provide evidence that price-limit rules make markets more volatile over longer periods and interfere with liquidity and the price discovery process. Cho et al. (2003) report evidence of "magnet effects," in which the mere existence of price-limit rules can accelerate the speed at which large price movements are realized.

In summary, the existing evidence does not support the reasons that have been put forward for the use of price-limit rules in equity markets. However, as reported in Table 1, stock exchanges in 41 out of 58 countries that comprise our initial data sample impose such rules. The puzzling existence of price-limit rules in numerous equity markets motivates us to investigate the conditions that lead stock exchange officials to impose price limits on equity markets.

3. The model

This section describes our reduced-form model of the interactions between the regulator and manipulators in an equity market. The regulator in our model can be viewed as a stock exchange. It is important to note, however, that some functions of market regulatory authorities (e.g., US Securities Exchange Commission (SEC)) overlap with those of stock exchanges. We define a manipulator as an individual (or a group of individuals) who destabilizes security prices in the market for private gain. Examples of such manipulators include the colluding market intermediaries described in Khwaja and Mian (2005), fraudulent traders such as Jonathan Lebed[4] and other manipulators of the internet bubble era, as described in Leinweber and Madhavan (2001).

To model the strategic game between the regulator and manipulators, we use a variant of the inspection game. In the literature, inspection games have applications in areas ranging from environmental regulation and crime control to accounting and economics.[5] We assume that in equity markets there is one group of traders, which can manipulate security prices for its own benefit. This group is called "manipulators". Other traders are aware of the possibility that manipulators may be present in the market; accordingly, a regulator who ensures the fairness of the market's trading process is essential in providing the confidence that genuine traders (those who do not manipulate price) require to trade. In this model, the regulator represents the market's genuine traders. Although the market includes many securities, without loss of generality, the model describes a single representative security.

The regulator's objective is to keep order in the market. In an orderly market, traders are expected to earn a daily normal return, r. Mahoney (1997) discusses the economic incentives for a stock exchange to provide an orderly market to investors. The regulator's net benefit from an orderly market is v, which is closely related to the market's liquidity and price efficiency. We do not use explicit variables that represent the market's price discovery and liquidity. Instead, the higher value of the market regulator's net benefit (v) from the orderly market implicitly reflects greater liquidity and better price discovery in the market. The regulator knows that manipulators can manipulate security prices to earn an abnormal profit ($p > r$) at the expense of other traders. Rather than rely on any specific form of market manipulation, we assume that market manipulators can be of any generic form discussed in Allen and Gale (1992). We also assume that manipulators can manipulate

[2] Please refer to FAQ section of the Philippine Stock Exchange website http://www.pse.com.ph/html/Faq/faqs.html. For detail information regarding price limits and price manipulation on first day of re-listing in the Indian market, refer to the news article titled "KGN relists after 7 years, zooms to Rs. 55,000," published on 22nd May 2008 in Business Line, an Indian business daily: http://www.thehindubusinessline.com/2008/05/22/stories/2008052252090100.htm.

[3] Brennan (1986), Kodres and O'Brien (1994) and Anshuman and Subrahmanyam (1999) provide theoretical models explaining the existence of price-limit rules in futures markets, while Harris (1998) offers a political economy explanation for the existence of market-wide circuit breakers.

[4] Fifteen-year-old Jonathan Lebed manipulated the US stock market between September 1999 and February 2000 using a pump-and-dump strategy. The SEC charged him on 11 separate occasions (Schroeder et al., 2000).

[5] Avenhaus et al. (1998) provide a detailed survey of various forms of the inspection game and their applications.

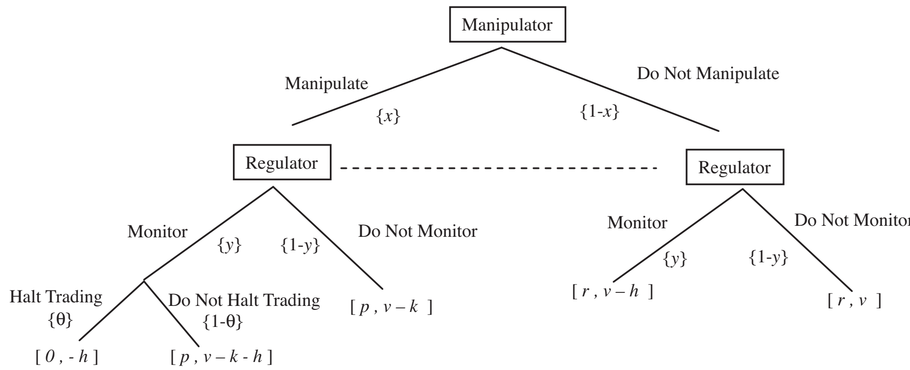

Fig. 1. Strategic game between the market manipulator and regulator. This figure describes the strategic game between the market manipulator and the regulator. The pure strategies for the manipulator are "Manipulate" and "Do Not Manipulate" while the regulator's strategic options are "Monitor" and "Do Not Monitor." If the regulator detects any possibility of price manipulation, he imposes a trading halt. θ is the probability that the regulator successfully detects manipulation. The values given in curly brackets represent the equilibrium probability associated with each option. The first value in each square bracket is the payoff for the manipulator and the second value is the payoff for the regulator.

the market within one trading day.[6] This is not an unrealistic assumption in light of the various incidents of price manipulation cited by Leinweber and Madhavan (2001).

Edelen and Gervais (2003) show that fraudulent and manipulative trading activities discourage genuine traders from participating in the market. Subsequent losses of reputation may cause market liquidity to drop or cause the market to lose new customers and listings. Hence, market manipulation is costly for genuine traders and regulators alike. This is captured in our model by a cost k that gets deducted from the regulator's net benefit.

The regulator can monitor the market to curb price manipulation, and manipulators are aware of this possibility. Monitoring a market is costly, as it involves collecting and analyzing information in real time. In addition to the infrastructure and human resource costs for continuous market surveillance, monitoring costs also depend on the market's business disclosure practices and its legal and regulatory environment. In the model, h denotes the regulator's daily cost of market monitoring.

If the regulator detects any manipulation, he imposes a trading halt. By imposing a halt, he forgoes the utility he could have earned had trading continued, and his losses are given by h. The trading halt prevents the manipulator from earning even the normal market return on that day. In our model, θ is the probability that the regulator can detect signs of likely price manipulation before the manipulator finishes implementing his strategy.[7] Therefore, θ can be interpreted as the efficiency of the market monitoring system. Market monitoring by the regulator is defined to be "perfect" if $\theta = 1$.

In this two-player strategic game setting, both players have their own strategies and move simultaneously. The two pure strategies for manipulators are "Manipulate" or "Do Not Manipulate," while the pure strategies for the market regulator are "Monitor" or "Do Not Monitor." Fig. 1 describes the game, along with the strategy options and associated payoffs for the manipulators (first value in square brackets) and the regulator (second value in square brackets).

The "Monitor" strategy is feasible for the regulator only if[8]

$$h \leqslant (k - v)\theta. \tag{1}$$

Eq. (1) suggests that, to the regulator, the cost of monitoring should be less than or, equal to the loss due to market manipulation. Otherwise, the strategy of market monitoring is not feasible. Eq. (1) also implies that we must assume that

$$k > v, \tag{2}$$

as monitoring is costly, i.e., $h > 0$.

Market monitoring is "ineffective" if the manipulators prefer to manipulate the market when the regulator is monitoring. This is the case when

$$p(1 - \theta) \geqslant r. \tag{3}$$

Since there is no strategic interaction between the regulator and the manipulator when Eq. (3) holds, we assume that $p(1 - \theta) < r$ for the rest of our analysis.

3.1. Equilibrium conditions

Under the assumption of complete information, there is no pure-strategy Nash equilibrium in this game because, if the regulator always chooses to monitor, the manipulator is better off always choosing not to manipulate. On the other hand, if the manipulator always chooses not to manipulate, the regulator is better off not monitoring. Therefore, both players will use mixed strategies. In equilibrium, the probability of the manipulator choosing the "Manipulate" strategy is x, and the probability of the regulator choosing the "Monitor" strategy is y. In the game's mixed-strategy Nash equilibrium, the regulator and the manipulator each randomize their strategies in such a way that the other will be indifferent to his strategies. For example, the manipulator will be indifferent about manipulation if his gain from the manipulation just offsets his loss due to trading halts. Accordingly, the equilibrium level of market monitoring is[9]

$$y = (p - r)/p\theta. \tag{4}$$

[6] For our model, if the manipulator takes more than one day to implement his strategy of manipulation, his chances of being detected by the regulator increases, since the regulator monitors the market on a daily basis. The implementation risk of the manipulator's strategy can also increase substantially because of investment requirements; he may need more than one day to execute his strategy, but the market may not allow traders to carry forward their positions overnight. Moreover, overnight trading halts give investors time to re-evaluate their positions in the market. As a result, price manipulators will find it difficult to sustain the effect of their strategy on the market over several days.

[7] If the regulator continuously monitors the market, as it is done in many countries through the surveillance divisions of stock exchanges, he can observe the signs of an intended market manipulation and can also prevent the probable manipulation. For example, NYSE's StockWatch, NASDAQ's MarketWatch and ASX's Surveillance of Market Activity (SOMA) are computer systems used to continuously monitor trading activity in their respective markets.

[8] For the regulator, monitoring is feasible if the effective cost of monitoring, $-h\theta + (1-\theta)(v-k-h)$, is less than or at least equal to the cost of market manipulation, $v - k$. Therefore, monitoring is feasible only if $-h\theta + (1-\theta)(v-k-h) \leqslant v - k$, which reduces to Eq. (1).

[9] Please refer to Appendix A for details.

Table 1
Details of price-limit rules of equity exchanges from 58 countries. *Source*: Rulebooks and websites of the exchanges as of December 2004.

Country	Exchange (s)	Price limit exists (in main trading session)	Limit details
Australia	ASX	No	–
Austria	Wiener Borse AG	Yes	5%
Bahamas[a]	Bahamas International SE	No	–
Bangladesh	Dhaka SE, Chittagong SE	Yes	3%, 5%, 7.5%, 10%, 15%
Barbados[a]	Barbados SE	No	–
Belgium	Euronext Brussels	Yes	10%
Bermuda[a]	Bermuda SE	No	–
Brazil	Sao Paulo SE, Rio de Janeiro SE	No	–
Bulgaria[a]	Bulgarian SE	Yes	15%, 30%
Canada	Toronto SE	No	–
China	Shanghai SE, Shenzhen SE	Yes	10%
Croatia	Zagreb SE, Varaždin SE	No	–
Czech Republic	Prague SE	Yes	5%, 8%, 50%
Denmark	Copenhagen SE	No	–
Ecuador	Guayaquil SE	Yes	10–20%
Egypt	Cairo & Alexandria SE	Yes	5%, 20%
Estonia	Tallinn SE	Yes	15%
Finland	Helsinki SE	Yes	15%
France	Euronext Paris	Yes	10%
Germany	Frankfurt SE	Yes	Undisclosed[b]
Greece	Athens SE	Yes	8%
Hong Kong	Hong Kong SE	No	–
Hungary	Budapest SE	Yes	15%, 20%
Iceland[a]	Iceland SE	No	–
India	National SE, Bombay SE	Yes	2%, 5%, 10%, 20%
Indonesia	Jakarta SE	Yes	20%, 25%, 30%, 35%, 50%
Ireland[a]	Irish SE	Yes	2%, 3%, 5%, 6%, 10%, 205%
Israel	Tel Aviv SE[c]	No	–
Italy	Borsa Italiana S.p.A.	Yes	5–10%
Jamaica	Jamaica SE	Yes	15% + 5%[d]
Japan	Tokyo SE	Yes	10–50%
Kenya	Nairobi SE	Yes	10%
Korea[a]	Korea SE	Yes	15%
Latvia[a]	Riga SE	Yes	–
Lithuania	Vilnius SE	Yes	15%
Luxemburg[a]	Luxembourg SE	No	–
Malaysia	Bursa Malaysia	Yes	30%
Mauritius[a]	SE of Mauritius	Yes	15% to 20%
Mexico	Mexican SE	Yes	10%
Netherlands	Euronext Amsterdam	Yes	10%
New Zealand	New Zealand SE	No	–
Norway	Oslo SE	No	–
Pakistan[a]	Lahore SE, Karachi SE	Yes	5%
Peru	Lima SE	Yes	15%
Philippine	Philippine SE	Yes	Upper: 50%, lower: 40%
Poland[a]	Warsaw SE	Yes	10%
Portugal[a]	Euronext Lisbon	Yes	10%
Romania	Bucharest SE	Yes	15%
Singapore	Singapore SE	No	–
South Africa	Johannesburg SE	Yes	5%, 10% and no limit
Spain	Madrid SE/ BME Spanish	Yes	10% + 20%[d]
Sweden[a]	Stockholm SE	No	–
Switzerland	SWX-Swiss	Yes	2%, 25%
Taiwan[a]	Taiwan SE	Yes	7%
Thailand	SE of Thailand	Yes	30%, 100%
Turkey	Istanbul SE	Yes	10%
UK	London SE	No	–
US	NYSE, NASDAQ, AMEX	No	–

[a] Not included in final sample.
[b] Dynamic and static price ranges are not disclosed in the exchange rulebook or website.
[c] 15% price limit during opening session only.
[d] Price limits of "A% + B%" format refer to an initial price limit of A% followed by a trading halt and an additional price limit of B% in post-trading-halt session.

Similarly, the regulator will be indifferent to monitoring the market if his gain from an orderly market just covers the cost of market monitoring. Therefore, the equilibrium level of price manipulation is[10]

$$x = \frac{h}{(k - v)\theta}. \tag{5}$$

In equilibrium, the expected payoff to the regulator from the game is

$$\pi = v - kx. \tag{6}$$

In the game discussed above, the market regulator uses only trading halts to discourage price manipulators. To further decrease the incentive for price manipulation, however, the regulator could also limit the daily profit potential from market manipulation by introducing daily price-limit rules. Therefore, price-limit rules

[10] Please refer to Appendix A for details.

may help regulators to keep order in the market. The following subsection discusses the interaction between the regulator and the manipulators in a market with price-limit rules.

3.2. Market monitoring with price limits

Let us now consider the game mentioned in the previous subsection in a market where price limits exist. Assume that the regulator chooses $l > r$ as the limit on price fluctuation in the market for one day. In such a market, the potential daily return from market manipulation will have an upper bound, as the imposed limit will bar the manipulator from moving the price beyond the specified maximum. Assuming that the manipulator will always maximize his abnormal returns through manipulation, then in such markets $p = l$.

The existing theoretical and empirical literature on price limits (Subrahmanyam, 1994, 1995; Kim and Rhee, 1997) suggests that price-limit rules interfere with a market's liquidity and its price discovery process. Accordingly, we assume that the regulator's utility (v_l) from an ordered market with price limits can be expressed as a function of the price limit l such that v_l is an increasing function of l and $\lim_{l\to\infty} v_l = v$. For analytical tractability, we assume that

$$v_l = v - \frac{a}{l}, \tag{7}$$

where a is a positive constant. If the price limit is set so that $l = r$, then there would be no motivation to manipulate prices; this would preclude the need for market monitoring. Therefore, at $l = r$, we assume $v_l = -h$, which implies

$$a = (v + h)r. \tag{8}$$

The rest of the set-up of the game remains the same as described in Fig. 1. In the presence of price limits, the strategy of market monitoring remains feasible and effective for regulators.

Proposition 1. *Daily price limits can increase equilibrium payoff for the market regulator as long as the cost of market monitoring satisfies*

$$\frac{h}{\theta} > (k - v)\left(1 - \frac{v_l}{k}\right). \tag{P1}$$

Proof. Please refer to Appendix. □

Although price limits generally reduce the regulator's benefit from an orderly market, Proposition 1 suggests that, where the cost of monitoring is sufficiently high compared to the efficiency of monitoring, regulators can apply price limits to increase their equilibrium payoff. In the special case of a market with perfect monitoring, condition (P1) reduces to $h > (k - v)(1 - \frac{v_l}{k})$. The condition (P1) can also be expressed as

$$\theta < \frac{x_p k}{k - v_l}, \tag{P1a}$$

where x_p is the equilibrium level of market manipulation under perfect monitoring without price limits. The condition (P1a) provides the upper bound of the monitoring efficiency that allows the use of price limits to improve the regulator's equilibrium payoff. This suggests that, if the efficiency of market monitoring is sufficiently low, price-limit rules can be useful.

Proposition 1 specifies the general necessary condition for a daily price limit to be useful for the market regulators, but it does not specify how regulators in such a market would decide on the appropriate price limit. The following proposition discusses the optimal price limit in such markets, as well as the necessary and sufficient conditions for the existence of such optimality.

Proposition 2. *If condition (P1) is satisfied, then there exists an optimal price limit, l^*, that maximizes the regulator's equilibrium payoff. The optimal price limit in such a market is*

$$l^* = \frac{r(v + h)\sqrt{\theta}}{\sqrt{kh} - (k - v)\sqrt{\theta}}. \tag{P2}$$

Proof. Please refer to Appendix. □

Proposition 2 asserts that the regulator may prefer to keep an optimal price limit, l^*, to maximize the equilibrium payoff if the cost of market monitoring is high enough to satisfy the necessary and sufficient conditions. This implies that, for a market with perfect monitoring, the optimal price limit is

$$l^* = \frac{r(v + h)}{v + \sqrt{kh} - k} \tag{11}$$

and the regulator's benefit from an orderly market is

$$v_l^* = k - \sqrt{kh}. \tag{12}$$

In such a market, v_l^* is always greater than zero since the cost of market manipulation (k) is always greater than the cost of market monitoring (h). The equilibrium payoff for the regulator is then given by

$$\pi_l^* = k - 2\sqrt{kh}. \tag{13}$$

Therefore, the benefit of price-limit rules in terms of the regulator's increase in equilibrium payoff can be expressed as

$$\Delta\pi = \pi_l^* - \pi = \frac{\left(v + \sqrt{kh} - k\right)^2}{k - v}. \tag{14}$$

Eq. (14) reflects that, as long as condition Eq. (P1) is satisfied, the regulator's motivation ($\Delta\pi$) to keep an optimal price limit increases with the increase in the cost of monitoring.

Our model assumes away the possibility for the regulator to impose penalties on manipulators and with sufficiently large penalties, to completely dissuade the manipulators from manipulating the market. However, we argue that, in practice, effectiveness of provisions for penalties depends on the efficiency of prosecutions. Mere existence of laws may not indicate their implementation. As shown by Bhattacharya and Daouk (2002) in the context of insider trading laws, enforcement of the law is more important than its existence. We also argue that the effectiveness of penalties is linked to systematic factors related to the law and enforcement environment of the market. Furthermore, if we follow the classification of market manipulations by Allen and Gale (1992), then "trade-based manipulations" can never be eliminated from the market through penalties or laws. Therefore, our model appropriately describes a market where trade-based manipulations take place.

Both Propositions 1 and 2 suggest that, if the cost of monitoring is sufficiently high compared to the efficiency of the monitoring system, regulators may prefer to keep price-limit rules to make market monitoring more effective and, therefore, to maximize their payoff from the game.

Hence, we hypothesize that in markets prone to price manipulation, price-limit rules are beneficial if the cost of market monitoring is high.

4. Econometric model and data

The hypothesis stated in the previous section suggests that the regulator's incentives to keep price limits in a market increase as the cost of monitoring increases. The cost and efficiency of market monitoring may depend on various systematic factors reflecting the quality of the market, such as the quality of business disclosure, the level of corruption and the efficiency of the legal system.[11]

Based on our theory, we expect a negative association between existence of price-limit rules and indicators of market quality. To test the empirical implications, we estimate standard binary choice models with both symmetric and asymmetric link functions. The dependent variable, an indicator variable for the existence of price-limit rules in a given market, takes on a value of 1 for markets with price limits and 0 otherwise. The independent variables are the proxies of the quality of business disclosure, the standard of the legal system, the quality of the regulations, the level of corruption and the level of technological development in the economy.

Price limit and trading-halt data were hand collected from the rulebooks and official websites of stock exchanges. We obtained Business Disclosure Index (BDI), Rule of Law (ROL) and Regulatory Quality (RQ)[12] data from the World Bank database services. Data on Corruption Perception Index (CPI) were obtained from Transparency International (http://www.transparency.org) and the Technology Index (TI) was obtained from the Global Competitiveness Report published by the World Economic Forum (http://www.weforum.org). All data are for the year 2004.

BDI measures the business disclosure practices of countries on a seven-point scale; higher ratings indicate greater transparency. This index reflects the degree to which investors in a market are protected through disclosure of ownership and financial information.

ROL and RQ are two of the six governance indicators[13] constructed by Kaufmann et al. (2005). ROL measures a legal system's efficiency, while RQ indicates the quality of an economy's regulatory policies. Kaufmann et al. (2003) define ROL as a composite measure representing society's confidence in its legal system. It reflects the extent to which the economic agents abide by the rules of law. It is an aggregate measure for perceptions of the incidence of crime, the effectiveness and predictability of the judiciary and the enforceability of contracts. RQ captures the incidence of market-unfriendly policies as well as perceptions of the cost of excessive regulation on various areas of the business environment. Higher scores on these indicators reflect greater efficiency of the legal system and regulatory policies.

The CPI focuses on corruption in the public sector. It is a composite index based on the data from expert surveys reflecting the views of business people and analysts from around the world. CPI measures an economy's level of corruption; higher scores on its 10-point scale reflect less corruption.

TI is a component of the Growth Competitiveness Index developed by Jeffrey D. Sachs and John W. McArthur. TI reflects a country's level of technological readiness. The index is constructed using a combination of data from opinion surveys and publicly available secondary data such as the level of penetration of new technologies, usage of mobile phones, internet access, etc. A higher rank in TI represents better application and development of technologies in an economy.

As Seasholes and Wu (2007) argue, stocks that hit upper price limits on the Shanghai Stock Exchange, apart from experiencing high return, typically exhibit two other features: high volumes and strong news coverage. Therefore in our analysis as control variables, we use the aggregate market turnover ratio as a proxy of market liquidity from the World Bank database and market risk (standard deviation of daily market return) calculated using Morgan Stanley Capital International (MSCI) market indices from Datastream International. Although data related to price-limit rules are available for 58 countries, data for the other variables are available for only 43 countries—31 (12) with (without) daily price-limit rules. The details of these countries and their price-limit rules are reported in Table 1.

Table 2 provides descriptive statistics of the above-discussed indicators for all 43 countries. Panel A provides summary statistics for the independent variables for all the countries in our sample, for markets with price limits and for markets without price limits. The univariate results are consistent with our hypothesis that, on average, countries without price limits are more transparent and have higher technical advancements and lower corruption. Panel B shows that the average values for these indicators in the countries with price-limit rules are significantly lower than that of countries without price limits. The correlation matrix for these indicators, reported in Panel C, indicates that all variables representing market quality correlate very highly with one another, with the exception of BDI. The multi-colinearity problem would likely prevent us from getting any meaningful estimate in case of joint estimation with all independent variables; to avoid this situation we estimate several models using a combination of two independent variables of interest (BDI being a variable common to all models) along the control variables.

5. Analysis of results

Table 3 reports the results of the estimation of the binary choice model described in the previous section. As previously mentioned, four different models are estimated using a combination of BDI and one of the other systematic factors (CPI, ROL, RQ and TI) controlling for liquidity and risk of the market. The table reports coefficients of each variable in the models estimated, using both a probit model and a binary choice model with cumulative extreme value distribution as the link function.[14]

Consistent with our hypothesis, the results indicate that the coefficients of the independent variables representing different systematic factors are negative in all models and statistically significant in most models. The level of corruption in the system is very significant in explaining the existence of price-limit rules, with CPI being highly significant at the 1% level. Rule of law and the regulatory quality of an economy are also highly significant in their respective models; the coefficients of ROL and RQ are significant at the 5% level. The results show that countries with better legal systems and better regulatory quality have lower probabilities of keeping price limits in their equity markets. An economy's technological development also explains the existence of price-limit rules. Our results show that the coefficient of TI is negative and significant at the 10% level in the presence of the control variables and BDI. Transparency in the business environment, as measured by BDI, is found also to be significant at the 10% level for all models except those using TI. These results indicate that price-limit rules are used less in markets with higher levels of corporate transparency.

The coefficient of market liquidity is positive in all of the models and is marginally significant in only one model. Though higher liquidity should in general reduce market manipulation, in the context of our model, a greater liquidity may put more pressure on the limited resources of the regulator, making market monitoring

[11] La Porta et al. (1998, 1999) use similar measures in their papers on law and finance, and on corporate ownership patterns around the world.

[12] Several recent studies have used these indicators as a proxy of market quality, for example, regulatory quality is used by Aggarwal and Goodell (2009).

[13] Please refer to Kaufmann et al. (2003, 2005) for details on construction and interpretation of the indicators.

[14] For a robustness check, we have also estimated binary choice models with one market quality variable (i.e., BDI, CPI, ROL, RQ or TI) and both control variables (i.e., market liquidity and market risk). The results of these estimations are qualitatively similar to the results reported in Table 3 and can be provided on request.

Table 2
Univariate analysis. This table provides summary statistics, results of tests for two-sample mean/median differences and correlation analysis of the governance indicators used in the study. Panel A provides summary statistics for the variables Business Disclosure Index (BDI) from World Development Indicators; Corruption Perception Index (CPI) from Transparency International World Bank database; Rule of Law (ROL) and Regulatory Quality (RQ) from World Bank Governance Indicators; and Technology Index (TI) from Global Competitiveness Report, World Economic Forum. These measure, respectively, a country's quality of business disclosure, an economy's level of corruption, the effectiveness of its legal system, the efficiency of its regulatory mechanisms and its technological development. Higher (lower) values of CPI reflect less (more) corruption. For all the other variables, higher (lower) values reflect higher (lower) quality and efficiency. All data are for the year 2004 and for a cross section of 43 countries across five continents. Panel B reports the mean/median differences of the variables between those markets with price-limit rules and those without, based on both parametric and non-parametric tests. The null hypothesis for the tests is that there is no significant difference between the groups' respective mean/medians. Panel C shows the correlation matrix of the variables mentioned above.

Markets		BDI	CPI	ROL	RQ	TI
Panel A: Summary statistics of independent variables						
All markets	Mean	4.814	5.672	0.705	0.741	4.516
	Median	5	4.8	0.75	0.97	4.64
	Variance	2.393	6.687	0.944	0.708	0.544
Markets with price limit	Mean	4.452	4.880	0.445	0.521	4.334
	Median	5	4.332	0.52	0.55	4.37
	Variance	2.456	5.474	0.864	0.670	0.539
Markets without price limit	Mean	5.750	7.718	1.377	1.311	4.986
	Median	5.5	8.583	1.73	1.595	5.01
	Variance	1.114	4.269	0.564	0.385	0.273
Panel B: Test for differences in central tendencies						
Test for equality of means						
Parametric *t* test	*t*-stat	−2.638	−3.678	−3.097	−3.016	−2.805
	p-value	0.0059	0.0003	0.0018	0.0022	0.0038
Test for equality of median						
Non-parametric (Wilcoxon–Mann–Whitney) test	*Z*-stat	−2.366	−3.181	−2.884	−3.060	−2.775
	p-value	0.018	0.001	0.004	0.002	0.006
Panel C: Correlation analysis						
BDI		1				
CPI		0.565	1			
ROL		0.582	0.969	1		
RQ		0.616	0.913	0.923	1	
TI		0.654	0.812	0.844	0.828	1

more difficult. Positive coefficients of market liquidity in our models may, therefore, reflect the higher cost of market monitoring for the regulators.

The pseudo-R^2 values for the estimated models range from 23.3% to 35%. The figures for correct prediction with the estimated models range from 71.3% to 90.48%. The Hosmer–Lameshow χ^2 statistics also support our models' specification. In summary, these results suggest that the existence of price-limit rules in equity markets can be explained by low business disclosure, high corruption, inferior legal standards, low regulatory quality and low standards of technological development.

5.1. Robustness check[15]

A casual look at our data suggests that the likelihood of observing price limits is greater in smaller countries and in economies with low per capita income. La Porta et al. (1998) report that countries with a high per capita income have a better legal environment and suffer less from corruption; therefore, per capita GDP may also affect the cost of market monitoring. Hence, we include the per capita GDP of the country (GDPC) in the binary choice models for robustness analysis. We expect GDPC to be negatively correlated with the existence of price limit rules.

The results of this analysis, reported in Panel A of Table 4, show that BDI and CPI are negative and significant, even after the introduction of the new control variable GDPC. As per our expectation, GDPC is negative and significant in the first model in absence of BDI and CPI. However, GDPC is negative but not significant in the presence of BDI and CPI. Overall, the results of our robustness analysis with cross-sectional data support our initial findings.

As a robustness check, we also conduct a pooled data analysis using available cross section and time series data. We report results of this analysis in Panel B of Table 4. The World Bank governance indices used in this analysis are published bi-annually. In this analysis we use data from 1996 to 2004 (five time series observations for each market). Time series data on BDI, TI and CPI are unavailable for many markets in our sample and so we could not include these variables in this analysis. However, we use the Control on Corruption (COC) index from the database of Governance Indicators of the World Bank as a substitute for CPI. The control variables are market liquidity, GDPC and time dummies for each year. Results from this robustness analysis show that COC, ROL and RQ are significant in explaining existence of price-limit rules in the pooled data. These results also confirm the findings of our initial cross-sectional analysis.

Our analysis so far uses the presence (or absence) of price limits as a dependent variable. In particular, it does not make use of the tightness of these limits around current prices. Since we would expect tighter limits to be employed in markets that are more difficult to monitor, we use ordered probit analysis to find out whether cost of market monitoring can differentiate markets with narrow price limits from markets with wider price limits. For the purpose of this analysis we use cross section data for the year 2004. We focus on tightness of the price limits relative to the market volatility. In these models, the dependent variable takes a value of 1 if the average daily price limit for the market is less than or equal to 2 standard deviations of daily market return. It takes a value of 2 if the average daily price limit is greater than 2 standard

[15] We thank an anonymous referee for suggesting these robustness analyses.

Table 3

Binary choice models for price-limit rules in equity markets. This table reports maximum likelihood regression coefficients with their *p*-values in parentheses for binary choice models estimated with both normal cumulative distribution function (CDF) and type I extreme value CDF as a link function, along with pseudo-R^2, percentage of correct prediction and Hosmer–Lameshow χ^2 statistics with their *p*-values. The dependent variable is based on a dummy variable that takes the value of 1 for countries where price-limit rules exist in equity markets. All the models use two control variables: market liquidity (measured by the market's turnover statistics) and market risk (measured by the standard deviation of daily market returns). The independent variables are: Business Disclosure Index (BDI) from World Development Indicators, World Bank database; Corruption Perception Index (CPI) from Transparency International; Rule of Law (ROL) and Regulatory Quality (RQ) from World Bank Governance Indicators; and Technology Index (TI) from Global Competitiveness Report, World Economic Forum. They measure, respectively, the quality of business disclosure, the economy's level of corruption, effectiveness of the legal system, efficiency of regulatory mechanisms, and technological development in the country. Higher (lower) values of CPI reflect less (more) corruption in the system. For all other variables, higher (lower) values reflect higher (lower) quality and efficiency. All data are for the year 2004 and for a cross section of 43 countries across five continents. The null hypothesis for the Hosmer–Lameshow test is that the model is correctly specified.

Estimation method	Independent variables								Goodness of fit statistics		
	Intercept	BDI	CPI	ROL	RQ	TI	Market liquidity	Market risk	Pseudo-R^2	Correct prediction % (cut off = 0.5)	Hosmer–Lameshow χ^2
Dependent variable: Price limit dummy											
Probit	6.814 (0.172)	−0.61 (0.06)	−0.439 (0.007)				0.013 (0.094)	−72.791 (0.268)	0.35	83.33	2.375 (0.967)
Extreme value	8.53 (0.019)	−0.756 (0.062)	−0.540 (0.008)				0.013 (0.134)	−48.427 (0.581)	0.349	88.10	6.351 (0.608)
Probit	4.42 (0.054)	−0.543 (0.074)		−0.972 (0.025)			0.011 (0.148)	−52.472 (0.403)	0.289	83.33	5.742 (0.676)
Extreme value	5.654 (0.053)	−0.674 (0.076)		−1.255 (0.029)			0.010 (0.207)	−25.560 (0.766)	0.289	90.48	10.919 (0.206)
Probit	4.3 (0.053)	−0.486 (0.096)			−1.022 (0.040)		0.0064 (0.339)	−41.122 (0.493)	0.264	83.33	10.84 (0.2106)
Extreme value	5.583 (0.043)	−0.640 (0.088)			−1.497 (0.033)		0.006 (0.421)	5.366 (0.946)	0.282	85.71	8.772 (0.361)
Probit	6.737 (0.039)	−0.413 (0.159)				−0.969 (0.081)	0.008 (0.261)	−0.214 (0.996)	0.233	71.3	7.337 (0.5)
Extreme value	8.8 (0.03)	−0.59 (0.114)				−1.207 (0.076)	0.010 (0.293)	31.220 (0.699)	0.237	73.81	2.602 (0.956)

Table 4

Robustness analysis. This table reports estimated regression coefficients (with their *p*-values in parentheses) along with the pseudo-R^2 values. Panels A and B provide estimated binary probit models using cross section and pooled data respectively. Panel C reports coefficients of ordered probit models. The dependent variable in Panels A and B takes the value of 1 for countries where price-limit rules exist and zero otherwise. In Panel C, the dependent variable takes the value of 1 (2) for countries where average price limit is less than or equal to (greater than) 2 standard deviation of daily market return. It takes the value of 3 if there is no price limit in the market. The control variables used in the robustness analyses are market liquidity (measured by the market's turnover ratio), market risk (measured by standard deviation of daily market returns), per capita GDP of the country (GDPC). Other independent variables are Business Disclosure Index (BDI) from World Development Indicators, World Bank database; Corruption Perception Index (CPI) from Transparency International; Control on Corruption (COC), Rule of Law (ROL); Regulatory Quality (RQ) from World Bank Governance Indicators; and Technology Index (TI) from Global Competitiveness Report, World Economic Forum. These variables measure, respectively, the quality of business disclosure, country's level of corruption (CPI and COC), effectiveness of the legal system, efficiency of regulatory mechanisms and technological development in the country. High (low) values of CPI and COC reflect less (more) corruption in the system. For all other indicators, higher (lower) values reflect higher (lower) quality and efficiency. To control for year-wise variations, dummy variables are included in the pooled data analysis. To save space, intercepts and coefficients of dummy variables are not reported. All data are from a sample of 43 countries; Panels A and C use data for the year 2004; Panel C uses bi-annual data for the period 1996–2004.

BDI	CPI	COC	ROL	RQ	TI	Market risk	Market liquidity	GDPC	Pseudo-R^2
Panel A: Binary probit analysis									
						23.112(0.585)	0.007(0.261)	−64.611(0.013)	0.224
−0.628 (0.057)	−0.359 (0.086)					−77.934 (0.253)	0.015 (0.08)	−24.906 (0.531)	0.361
Panel B: Pooled data analysis									
		−0.795 (5.28×10^{-06})					0.003 (0.136)	5.506	0.222 (0.693)
			−0.623 (0.002)				0.002 (0.189)	−9.634 (0.503)	0.176
				−0.647 (0.003)			0.002 (0.241)	−23.011 (0.036)s	0.176
Panel C: Ordered probit analysis									
0.374 (0.0278)	0.224 (0.015)						−0.0042 (0.4)		0.221
0.379 (0.025)			0.527 (0.034)				−0.004 (0.415)		0.204
0.354 (0.041)				0.598 (0.04)			−0.002 (0.727)		0.201
0.345 (0.048)					0.757 (0.034)		−0.003 (0.474)		0.204

deviations of daily market return and a value of 3 if there are no price limits. The independent variables remain the same as in the initial binary choice models reported in Table 3, however, we exclude the market risk as the tightness of price limits is defined relative to market risk. Panel C of Table 4 reports results of this analysis. The result shows that BDI, CPI, ROL, RQ and TI are strongly significant in all the models. The results of this ordered probit analysis suggest that markets with greater cost of monitoring prefer narrower price limits. In general, these results support our findings from the initial binary choice models.

6. Summary and conclusion

We provide an explanation why regulators of some equity markets use daily price-limit rules even though many theoretical and empirical studies criticize their usefulness. Using a game-theoretic framework, we analyze the interaction between a market regulator and price manipulators. Our model shows that, in a market prone to price manipulations and characterized by high monitoring costs, price-limit rules can actually increase monitoring efficiency and benefit regulators and traders alike.

The empirical evidence supports our theoretical argument. Analyzing a sample of 43 countries across five continents, we find that the probability of imposing price-limit rules is greater in countries that incur higher monitoring costs due to poorer business disclosure, higher corruption level and lower efficiency in the legal, regulatory and technological environments.

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Appendix A

A.1. Equilibrium level of monitoring

At equilibrium level of monitoring, the manipulator will be indifferent to market manipulation, as his gain from manipulation will be just offset by his loss due to trading halts. Therefore at equilibrium,

$$[r-(1-\theta)p]y=(p-r)(1-y)\Rightarrow[p\theta-(p-r)]y=(p-r)(1-y)$$
$$\Rightarrow y=p-r/p\theta.$$

A.2. Equilibrium level of manipulation

At equilibrium level of manipulation, the regulator is indifferent to monitoring, as his gain from an orderly market just offsets his loss due to manipulation. Therefore, at equilibrium,

$$[k-v-h+(k-v)(1-\theta)]x=[v-v+h](1-x)\Rightarrow x=\frac{h}{(k-v)\theta}.$$

A.3. Proof of Proposition 1

If π_l is the equilibrium payoff for the regulator in a market with price limit l, then the excess payoff the regulator earns at equilibrium in the presence of a price limit is

$$\pi_l-\pi=(v_l-v)+k\left(\frac{h}{(k-v)\theta}-\frac{h}{(k-v_l)\theta}\right). \tag{A1}$$

After rearrangement, $\pi_l-\pi>0$ if

$$\begin{aligned}&\frac{h}{\theta}>(k-v)\left(1-\frac{v_l}{k}\right),\\&\frac{1}{\theta}>\frac{(k-v)}{h}\left(1-\frac{v_l}{k}\right),\\&\frac{1}{\theta}>\frac{1}{x_p}\left(1-\frac{v_l}{k}\right),\\&\theta<\frac{x_pk}{k-v_l},\end{aligned} \tag{A2}$$

where, x_p is the equilibrium level of market manipulation under the condition of perfect monitoring without price-limits.

This completes the proof of Proposition 1. □

A.4. Proof of Proposition 2

In a market with price-limit rules, the equilibrium payoff is

$$\pi_l=v_l-\frac{kh}{(k-v_l)\theta}. \tag{A3}$$

After substituting for the value of v_l from Eq. (7) and differentiating w.r.t. l.

F.O.C. $\partial\pi_l=0$ provides that

$$l^*=\frac{a\sqrt{\theta}}{\sqrt{kh}-(k-v)\sqrt{\theta}}. \tag{A4}$$

Therefore, replacing the value of a from Eq. (7) into Eq. (A4), we have maxima at

$$l^*=\frac{r(v+h)\sqrt{\theta}}{\sqrt{kh}-(k-v)\sqrt{\theta}}, \tag{A5}$$

as long as

$$h>\frac{(k-v)^2\theta}{k}. \tag{A6}$$

The second-order condition (A5) is both a necessary and sufficient condition for a maxima at l^*.

As $v_l<v$ for all finite values of l, it is easy to prove that condition (A5) will be satisfied if condition (P1) is true. This completes the proof of Proposition 2. □

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