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Equilibrium theory of stock market crashes ☆

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ABSTRACT

We consider an equilibrium in illiquid stock market in which liquidity suppliers trade with investors and face significant trading costs. A similar situation was observed during the recent financial crisis. We find that the expected risk premium on the stock and its Sharpe ratio are positive and very large, while the expected stock return volatility is a few times bigger than in the liquid market. Investors sell stock shares due to their excessive leverage, whereas market makers try to compensate their trading costs with the profits expected from buying the stock shares with very high Sharpe ratio. Moreover, the short-term stock returns exhibit either a strong overreaction or a momentum effect depending on the state of the economy.

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1. Introduction

It has been well documented that selling pressure from investors in the stock market rises during financial crises, while the expected volatility of the stock market returns undergoes a substantial increase.[1] Moreover, despite the realized decrease of the stock market price during financial crises, its *expected* return and the conditional Sharpe ratio rise dramatically during these times.[2] The goal of this paper is to show that these stylized facts can be explained in a general equilibrium framework without assuming irrationality of investors.

Our explanation is based on the assumption that liquidity providers suffer significant trading costs during financial distresses. To be general we assume that a liquidity provider could be a specialist, a dealer, a financial institution, or an individual investor, all of which we call market makers. A market maker trades with investors and supplies liquidity by either closing all transactions or placing limit orders. Consequently, market makers face losses due to opportunity costs, as well as inventory and search costs. While these costs are not significant during normal times, they become dramatically aggravated during financial crises.[3] Moreover, market

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[1] For example, the CBOE S&P 500 implied volatility index (VIX), which is used to measure short-term expected volatility of the stock market returns increased by about three times during the financial crisis of 2008.

[2] See, for example, Graham and Harvey (2010).

[3] The losses of market makers during a recent financial crisis were especially high in the OTC markets. Many market makers bought an excessive number of illiquid securities, which they had hard time selling. Some dealers continued buying risky assets and borrowing, while being close to their

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makers often finance their liquidity supply by borrowing, which can become problematic during crises and cause further deterioration of their solvency.[4] On the opposite trading side, investors post market orders and also face increased transaction costs in terms of higher bid–ask spreads. Given the numerous stories of dramatic trading costs of market makers during financial turmoil, we assume that these costs are bigger than those of the investors that we neglect for the purpose of tractability.[5] Facing significant transaction costs makes market makers less willing to trade. On the other hand, investors, who face smaller trading costs, have strong incentives to trade. Therefore, the prices have to be substantially adjusted to make market makers willing to trade more. We find that the risk premium, the expected Sharpe ratio, and the return volatility of the stock market behave in the same way in which they are observed during financial crises.

For tractability, we ignore a microstructure of trading and devise losses of market makers on providing liquidity in the stock market by using exogenous convex transaction costs. Convexity of the costs is intuitive in illiquid market: as the size of the transaction increases, the market maker closes a deal with more difficulty, and, therefore his losses per share of providing liquidity increases with the size of a trade. Moreover, because we treat economy in continuous time, the convexity in the number of stock shares is converted into the convexity in the rate of share trading. Consequently, a market maker endogenously chooses to delay his investments and is not able to adjust his allocations quickly enough in response to systematic shocks. It follows that convex transaction costs result in a slow capital movement and could be used to model the opportunity costs of not transacting, investment delay costs and inventory and search costs. Moreover, assuming self-financing portfolios, the convex costs could be related to the losses due to the borrowing limits faced by market makers.[6] Furthermore, Duffie (2010) argues that a slow capital movement could be the reason for price distortions observed during the recent financial crisis. Our model confirms this expectation by linking capital inertia with mispricings of securities. Note that convex costs have been used to model illiquidity and trading delays by both practitioners[7] and academia researchers.[8]

Investors and market makers behave competitively. Moreover, investors could be of the two types: those who have logarithmic preferences or those who have exponential preferences. The exponential investors can sustain large negative shocks to the stock market price and allow logarithmic investors to avoid default through risk sharing. Most investors have logarithmic preferences while investors with exponential preferences are introduced for the technical reasons so that equilibrium will exist at all times. Overall, logarithmic investors comprise a marginal agent in the economy who defines the behavior of stock prices in most states of the economy.

The stock market is considered to be less liquid during financial turmoils than during regular times. Therefore, we call our economy illiquid, where illiquidity is defined by the presence of trading costs. As a benchmark case, we also consider an economy with a perfectly liquid stock market (with no trading costs).

Investors and market makers in our economy trade for the purpose of risk sharing. Market makers face significant transaction costs and are not able to quickly unwind the positions of investors. We find that the illiquid economy could be in states in which investors have very long positions in the stock market. Investors are willing to hold these positions only if the stock market has a large risk premium and Sharpe ratio. In these states investors sell stock shares to market makers and buy liquid T-bills. On the other side of trades, market makers have small positions in the stock market. They are willing to be underexposed to securities with abnormally high expected Sharpe ratios, since buying them quickly is too costly. Market makers partly compensate their risk underexposure by buying the stock market that is expected to be underpriced. Note that investors do not become excessively leveraged in a perfectly liquid stock market since they can immediately adjust their allocations by trading with market makers.

If the aggregate investor is sufficiently wealthy, and has significantly long or short positions in the stock, then stock return volatility becomes very large. This happens because of the wealth effect on this investor. If his position is long (short) and becomes longer (shorter), then the stock price decreases (increases), causing the aggregate investor to lose money on his current position in the stock market. The losses make the aggregate investor sell stock shares when stock price is falling and buy them when the stock price is rising. Therefore, he further decreases the stock price when it falls or increases it when it rises, causing an increase in stock return volatility. These results explain the increase in stock return volatility observed during the financial crises when volatility jumped to at least twice the level it was before these distresses. Notice that in a liquid market the wealth effect from the aggregate investor is offset by a substitution effect from market makers that makes the stock return volatility remain approximately the same across all states of the economy. The wealth effect on the

(*footnote continued*)
capacity, and some even withdrew from the markets. See, for example, "Markets: Exchange or Over-the-Counter" by Randall Dodd at http://www.imf.org see also Choi and Shachar (2013) and Han and Wang (2014).

[4] In 2008, there was the equivalent of a bank run on the money market funds, which frequently invest in commercial paper issued by corporations to fund their operations. The TED spread, an indicator of perceived credit risk in the general economy, spiked in July 2007, remained volatile for a year, before spiking even higher in September 2008, reaching a record 4.65% on October 10, 2008. Nearly one-third of the U.S. lending mechanism was frozen and continued to be frozen until at least June 2009.

[5] Even though the median quoted bid–ask spread of S&P 500 increased during financial crisis of 2007–2009, it did so by less than two times and the total quoted spread remained quite low. See, for example, Angel et al. (2011). The quoted bid–ask spread in the OTC markets increases more significantly during the crisis but was still reasonably low. See, for example, "Got Liquidity?" at https://www.blackrock.com.

[6] For a self-financed portfolio, the value of traded stocks must be equal to the negative value of traded T-bills. Therefore, if an investor cannot borrow fast, she will not be able to buy enough stock shares.

[7] For example, see Grinold and Kahn (2000).

[8] See Heaton and Lucas (1996), Isaenko (2010), Rogers and Singh (2010), Garleanu and Pedersen (2013), and Vayanos and Woolley (2013).

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