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Swing Pricing: Theory and Evidence

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Abstract

Open-end mutual funds offer investors same-day liquidity while holding assets that in some cases take several days to sell. This liquidity transformation creates a potentially destabilizing first-mover advantage: When asset prices fall, investors who exit a fund earlier may pass the liquidation costs generated by their share redemptions to investors who remain in the fund. This incentive becomes particularly acute in periods of market stress, and it can amplify fire-sale spillover losses to other market participants. Swing pricing is a liquidity management tool that targets this first-mover advantage. It allows a fund to adjust or "swing" its net asset value in response to large flows out of or into a mutual fund. This article discusses the industry and regulatory context for swing pricing, and it reviews theory and empirical evidence on the design and effectiveness of swing pricing. The article concludes with directions for further research.

1. INTRODUCTION

From 2000 to 2021, the size of the US mutual fund industry grew from \$5.6 trillion to \$20.3 trillion, and during this time the percentage of the corporate bond market held in open-end mutual funds in the United States grew from 10.48% to 25.06%. With this growth have come questions about whether the size of the mutual fund industry could pose a threat to financial stability.

Unlike banks and hedge funds, open-end mutual funds use little or no balance sheet leverage. Concerns have focused instead on their liquidity transformation. Mutual funds offer investors same-day liquidity while in some cases holding assets that may take several days to liquidate. This liquidity mismatch creates a first-mover advantage: When trading in the underlying assets is costly, investors who redeem fund shares early may exit at a higher share price than those who redeem later. This dynamic creates the risk of a run on the fund, particularly in times of market stress and reduced market liquidity. A run may result in fire-sale liquidation by the fund and spillover losses to other market participants.

Swing pricing is a liquidity management tool for mutual funds that targets this first-mover advantage. This article reviews the theory and practice of its application. We present background information in Section 2, theoretical models in Sections 3 and 4, empirical work in Section 5, and directions for future research in Section 6.

2. BACKGROUND

2.1. Liquidity Transformation and the First-Mover Advantage

To explain swing pricing, we need to take a closer look at the mechanics of open-end mutual funds. We discuss the US context, but similar rules apply in other major jurisdictions.

At the end of each day, a mutual fund calculates a net asset value (NAV) per share, based on the current value of the fund's portfolio. All investors submitting redemption orders during the day will have their shares redeemed at the end-of-day NAV. All investors buying shares will pay the same end-of-day NAV, but we focus on investors exiting the fund.

Although the price per share an investor will receive is fixed the day of the investor's order, the fund's payment to the investor may be made a few days later. During this interval, the fund may sell assets, raising cash to meet redemptions or replenish a cash buffer. If the fund sells illiquid assets, these sales may lower the market prices of the assets, thus lowering the fund's NAV. These liquidation costs are borne by investors who remain in the fund because the NAV guaranteed to redeeming investors does not reflect the costs subsequently incurred. Thus, the mismatch between the liquidity offered to investors and the liquidity of the fund's assets creates an incentive for investors to redeem earlier than they otherwise would.

2.2. Swing Pricing

Swing pricing allows a fund to adjust (swing) its end-of-day NAV in anticipation of future trading costs. On a day with large outflows, a fund that adopts swing pricing may adjust its NAV downward, and on a day with large inflows, it may adjust its NAV upward. If properly applied, these adjustments serve two related purposes. They serve an investor protection objective by reducing trading costs (through reduced redemptions) and more equitably allocating those costs to the investors who generate them. They serve a financial stability objective by reducing the risk of a run on a fund and fire-sale spillovers, particularly in periods of market stress.

US mutual funds became eligible to use swing pricing in November 2018, but it has been available and widely used in several European jurisdictions for much longer. Swing pricing is also permitted and used by some funds in Singapore and Hong Kong.[1] A 2022 Luxembourg survey (ALFI 2022) found that the most widely used form of swing pricing is partial swing pricing, defined by a swing threshold and a swing factor. The threshold is usually specified as a percentage of the fund's assets, and the swing factor as a percentage of the NAV. To illustrate, suppose a fund's unswung NAV is 10 and its swing factor is 2%. If the day's net outflows exceed the fund's threshold (e.g., 1% of the fund's assets), the fund would report an NAV of 9.8, and if the day's net inflows exceed the fund's threshold, the fund would report an NAV of 10.2; otherwise, the fund reports an NAV of 10. Under full swing pricing, the threshold is zero. Funds may also use multiple swing factors with multiple thresholds, and they may use asymmetric swing factors and thresholds in response to inflows and outflows.

Any gains from swing adjustments accrue to the fund, and any expenses from swing pricing are borne by the fund; these are not fees paid to the fund manager. The fund manager may benefit indirectly if swing pricing reduces investor flow volatility and improves fund performance.

Funds that use partial swing pricing rarely disclose their swing threshold, apparently out of fear that some investors could trade on this information, placing orders that keep flows just below the threshold. Funds are required to disclose the fact that they use swing pricing, typically in a prospectus. In some cases (including in the United States), they are required to disclose the cumulative impact of NAV adjustments in their financial statements. But funds do not disclose specific instances of NAV adjustments.[2] An investor seeing an NAV of 9.8 has no way to know if this is an unswung value or the result of a swing up or down. To the extent that swing pricing is intended to remove distorted incentives, opacity in its implementation may prevent investors from understanding the incentives they face and may therefore reduce the effectiveness of swing pricing. We return to this point in Section 6.

2.3. Regulatory and Industry Developments

Swing pricing has been used for several years in multiple European jurisdictions, including Luxembourg, the United Kingdom, France, Ireland, Switzerland, the Netherlands, and, most recently, Germany. Section 5.3.2 of the European Securities and Markets Authority Report (ESMA 2020) includes a list of European Union jurisdictions that allow swing pricing.

The Association of the Luxembourg Fund Industry (ALFI) developed its first guidelines on swing pricing in 2006 and has conducted surveys over the years on its adoption. The 2022 survey (ALFI 2022) estimates that 65% (by assets) of the Luxembourg mutual fund industry has adopted swing pricing, and the regulatory statistics in Lewrick et al. (2022) show that 43% of funds applied swing pricing in 2020. Most of the swing pricing funds in the ALFI survey use a swing factor in the range of 1–3%. While the factor is typically recalculated monthly or quarterly, during the market turbulence of March 2020 more than two-thirds of asset managers reviewed it daily. The survey also found that most funds use a (confidential) swing threshold between 1% and 3%, but some use a threshold of 10% or greater.

In the United Kingdom, the Financial Services Authority adopted rules that allow funds to implement swing pricing in 2002. A survey conducted jointly with the Bank of England in August and September 2020 found that swing pricing is now the most commonly adopted liquidity

[1]Among the most recent jurisdictions to introduce swing pricing is India, where the new rules took effect in May 2022. Swing pricing is now mandatory in India in periods of market stress for certain high-risk funds.

[2]A September 2021 study by BlackRock reports monthly statistics on the use of swing pricing by some of its European funds (BlackRock 2021). The study shows spikes in the use of swing pricing in March 2020.

management tool by UK mutual funds: Out of the 272 funds that participated in the survey, 202 had the option to apply swing pricing in place (Bank of England 2021).

During the COVID-19 period of market stress in February and March 2020, fund managers in Europe made much greater use of swing pricing than of redemption suspensions. According to ESMA (2020) (see the case study in section 5.2), funds that activated swing pricing experienced slightly higher outflows (6.7%) compared to funds that chose not to do so despite having the option (6.3%). However, the funds that activated swing pricing had on average fewer high-quality liquid assets, suggesting that they were more vulnerable to outflows. Claessens & Lewrick (2021) and Bank of England (2021) find no significant difference in redemptions during the COVID-19 shock when comparing funds with and without swing pricing.

In the United States, mutual funds gained permission to use swing pricing in November 2018, following an amendment by the Securities and Exchange Commission (SEC) of Rule 22c-1 of the Investment Company Act (SEC 2016). As defined in the SEC's rule, a fund's swing pricing policy specifies a swing threshold and a swing factor. The threshold is required to account for historical fund flows, the liquidity of the fund's portfolio, its cash holdings, and the transaction costs associated with the fund's investments. The swing factor should only account for the near-term costs that the fund expects to incur in response to investors' redemptions (bid-ask spreads, transaction fees, borrowing costs, etc.). A fund must set and disclose an upper limit to its swing factor, which cannot exceed 2%. Multiple thresholds triggering different swing factors are allowed.

Under the SEC (2016) rule, funds that adopt swing pricing must provide a description of the impact of swing pricing on the fund's performance with their financial statements. A fund's swing pricing policies must be approved and annually reviewed by the fund's board of directors.

The original rule change that allowed US mutual funds to use swing pricing excluded money market funds. Following the disruption of short-term funding markets in March 2020 due to the COVID-19 shock, the SEC proposed new rules in December 2021 that would require institutional prime and institutional municipal money market funds to adopt swing pricing. An earlier round of reforms provided for institutional money market funds to use fees and gates to manage the risk of a sudden increase in withdrawals. Funds proved reluctant to use these tools during the COVID-19 shock,[3] prompting the proposed requirement that they use swing pricing.

No US mutual fund has implemented swing pricing since the option became available in 2018 (SEC 2022, p. 18), despite the fact that several major US asset managers use swing pricing in their European-domiciled funds, and some have advocated its use in the United States. The obstacle is at least partly operational. In the United States, a large fraction of redemption and subscription orders for mutual fund shares flow through intermediaries, particularly in the case of funds held in retirement accounts. These orders might not be transmitted to the mutual funds themselves for hours or even until the next day, but they must be met at the end-of-day NAV on the day they were submitted by investors. A study by the Investment Company Institute estimates that 30% of a fund's daily trade flow may not yet be visible to a fund at the time it sets its NAV, making it difficult for a fund to apply an appropriate adjustment (Invest. Co. Inst. 2017). In addition, investors in US funds are generally allowed to submit orders later in the day (typically until 4 pm) than investors in European funds (often until 12 pm or 2 pm) while still receiving the end-of-day NAV for their shares; this difference gives European funds a wider window to determine appropriate NAV adjustments.[4]

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[3] Cipriani & La Spada (2020) find that funds that were more likely to impose gates and fees experienced greater outflows.

[4] For further discussion of order management processes relevant to swing pricing and differences between practices in the United States and Europe, see Section III.B.2 of SEC (2022).

In November 2022, the SEC proposed rules (SEC 2022) that would require most open-end mutual funds to adopt swing pricing. The proposed rules would set a swing threshold of 1% for net redemptions and 2% for net subscriptions, with the view that large outflows are more disruptive than large inflows. To determine a swing factor, the rules would require a fund to make "good faith estimates of the transaction costs of selling or purchasing a pro rata amount of its portfolio investments" (SEC 2022, p. 36). The proposed rules also call for a hard close, under which an investor order processed by intermediaries would transact at the current day's NAV only if the order is received by the fund before the fund sets its NAV. This provision is intended to provide funds with more timely information on investor flows and to overcome the operational obstacle to swing pricing created by delays in the transmission of orders from intermediaries to funds.

Exchange-traded funds (ETFs) are excluded from the proposed swing pricing requirement in SEC (2022), and they were not permitted to use swing pricing under the earlier rule in SEC (2016). ETFs involve two types of transactions: buying and selling among investors, and transactions between the ETF sponsor and authorized participants, who arbitrage differences between the ETF share price and an underlying basket of securities. The first type of trade takes place at the market-clearing price and is therefore not subject to the potential distortion in the NAV calculated by a mutual fund. Fire-sale concerns are more relevant to trades by authorized participants. But when authorized participants redeem shares with the sponsor, they often receive payment in kind, which mitigates concerns for fire-sale liquidations by eliminating the need for the sponsor to raise cash, and the ETF may impose fees for payment in cash to defray liquidation costs (SEC 2016, p. 22). These fees serve a similar purpose as swing pricing.

2.4. Background: Research on Mutual Fund Runs

Chen, Goldstein & Jiang (2010) provide empirical evidence for the first-mover advantage generated by mutual funds' liquidity transformation. Using data from US equity funds, they show that the sensitivity of outflows to past negative performance is 52% higher in funds holding illiquid assets (e.g., small-cap or emerging market stocks) relative to that in liquid funds. Trading costs following redemptions are higher for illiquid funds, reinforcing the incentive for other investors to exit the fund and avoid bearing the costs generated by those who exited earlier. Illiquid funds' performance is vulnerable to the impact of heavy redemptions: Large outflows lower returns of the least liquid quartile of funds by 19 basis points in the following month, while no impact is detectable for liquid funds.

Corporate bond mutual funds hold less-liquid assets and therefore exhibit even stronger strategic complementarities, as shown by Goldstein, Jiang & Ng (2017). They find that the relationship between flow and performance is concave for corporate bond funds, meaning that outflows are more sensitive to bad performance than inflows are to good performance. This pattern (which does not extend to equity funds) suggests that the impact of redemptions on fund returns is a concern to investors in less liquid funds. In periods of market stress, typically characterized by reduced liquidity, the response of investors to fund underperformance is more severe. Hence, strategic complementarities are exacerbated exactly when markets are most fragile. Furthermore, corporate bond funds holding illiquid assets experience more redemptions in response to underperformance than liquid funds.

In a study of daily flows in prime money market mutual funds (MMMFs) during September 15–19, 2008—the week after the bankruptcy of Lehman Brothers–Schmidt, Timmermann & Wermers (2016) find strategic complementarity among MMMF investors, and they find that investor sophistication strengthens this effect. Sophisticated investors are proxied by investors in institutional fund share classes with lower expense ratios, as these share classes typically require a large initial investment. Following the failure of Lehman Brothers, redemptions from sophisticated investors were significantly larger than those from other investors, and outflows were even stronger in funds with a high fraction of sophisticated investors. [Cipriani & La Spada (2020) find similar patterns during the COVID-19 market shock.] Such investors are more attentive to market dynamics, have better information on fund holdings, and can anticipate other investors' behavior. In particular, they have a stronger incentive to redeem when other investors in the same fund are also sophisticated. Due to concerns that a fixed NAV makes a fund vulnerable to runs, institutional prime MMMFs have been required to use a floating NAV since October 2016.

The disruption of bond markets during the COVID-19 crisis provided a case study to assess whether mutual funds' liquidity transformation contributes to financial fragility. In typical periods of market stress, investors engage in a flight to safety, which leads to a decline in Treasury yields. Ma, Xiao & Zeng (2022) show that selling pressure stemming from mutual fund redemptions caused significant increases in Treasury yields as funds sold bonds to raise cash. Fixed-income funds with more illiquid holdings experienced larger redemptions during the COVID-19 crisis, supporting the hypothesis that funds' liquidity transformation amplifies outflows in times of stress.

Li, O'Hara & Zhou (2022) study how mutual fund ownership affects financial fragility in the context of municipal bonds. Mutual funds hold only approximately one-quarter of municipal bond issues, which allows for a comparison between price movements of bonds primarily owned by funds and those of bonds owned by other investors during the COVID-19 crisis. During the period March 9–23, 2020, trading volume in bonds was mostly driven by fund flows. Price pressure was also higher for bonds held by funds. Yields of fund-owned bonds were higher than yields of other bonds in the period between May and September 2020, suggesting that market participants were demanding a premium for the risks posed by mutual fund ownership. To study the effect of funds' liquidity transformation on bond markets, Jiang et al. (2022) introduce a novel measure of bond fragility: A bond is fragile if it is primarily owned by funds holding illiquid portfolios. Liquidity transformation is stronger among illiquid funds, and hence, these bonds are more vulnerable to liquidation due to redemptions. In fact, current bond fragility predicts higher return volatility over the next quarter. During the COVID-19 crisis, fragile bonds suffered significantly larger price drops than nonfragile bonds, and after the Federal Reserve announced the Secondary Market Corporate Credit Facility on March 23, 2020, they experienced a stronger rebound in prices.

These studies support the notion that mutual funds' institutional structure adds fragility to financial markets. However, Choi et al. (2020) argue that concerns about financial stability risk from mutual funds are overstated. They match bond issues liquidated by distressed funds to similar bonds issued by the same firm that are not subject to fire sales and do not find a significant difference in returns between these bonds, suggesting that price impact from fire sales does not materially affect bond returns. They conclude that liquidity management strategies by corporate bond funds are effective in minimizing liquidation costs; corporate bond funds hold adequate cash buffers and are more likely to sell liquid assets to meet redemptions.

3. A REDUCED-FORM MODEL FOR SWING PRICING

With the background of the previous section, we develop a simple model in which to isolate the role of swing pricing, based on the work by Capponi, Glasserman & Weber (2020). We develop the model in three stages. We start in a setting in which mutual fund structure has no effect on the size or allocation of liquidation costs. We then introduce the cost externality created by the end-of-day NAV guarantee provided by mutual funds. In the third stage, we introduce investors who liquidate more than they otherwise would because of the cost externality, thus amplifying fire-sale losses. The goal of swing pricing will be to offset the effects of these first-mover investors.

To keep the setting as simple as possible, we consider a single fund holding shares of a single asset. (Adding a cash buffer requires only minor modification.) We use the following notation, typically with time subscripts:

$$q = \text{number of asset shares held by fund;}$$

$$n = \text{number of fund shares issued by fund;}$$

$$p = \text{price of asset share;}$$

$$s = \text{price of fund share (the fund's NAV).}$$

The fund share price (NAV) satisfies

$$s = \frac{qp}{n} = \frac{\text{total asset value}}{\text{number of fund shares}}. \quad 1.$$

We are mainly concerned with declines in these variables. To make the direction of change explicit, we write a price decline as $p - \Delta p$, for some $\Delta p > 0$, and similarly for the other variables.

We make two standing assumptions: Investors are sensitive to the fund's performance, and the asset held by the fund is illiquid, in the sense that trading the asset moves its price.

- Investors sell shares when the fund loses value. In our base case specification, we assume that when the fund's share price declines by an amount $\Delta s > 0$,

$$\text{number of shares redeemed} = \Delta n = \beta \Delta s, \quad 2.$$

  where $\beta \geq 0$ measures the flow sensitivity to performance. After Δn shares are redeemed, $n - \Delta n$ shares remain outstanding. We will also consider variants of Equation 2. In expressions like Equation 2, we implicitly cap Δn at n; if all shares are redeemed, the fund shuts down.
- The asset held by the fund is illiquid. Selling $\Delta q > 0$ asset shares moves the asset price down by an amount

$$\text{decline in price per share of asset} = \Delta p = \gamma \Delta q, \quad 3.$$

  making the new price $p - \Delta p$.

The basic timeline will be as follows: The asset held by the fund experiences an exogenous drop; investors redeem fund shares in response to the price drop; the fund sells assets to pay the redeeming investors; and the fund's sales further lower the price of the asset. The three settings we consider will differ in the timing of these events.

3.1. Asset Liquidation Before the NAV Is Fixed

To highlight the timing of events, we separate events into different days. The fund's NAV is fixed at the end of each day.

Day 0

1. Initially, $q_0 = n_0$ so $s_0 = p_0$.
2. An exogenous shock $\delta > 0$ lowers the asset price to $p_0 - \delta$ and lowers the fund's NAV to $p_0 - \delta$.

Day 1

3. Investors react to the drop in NAV by redeeming $\Delta n_1 = \beta\delta > 0$ fund shares.
4. The fund sells Δq_1 asset shares to raise cash, with $\Delta q_1 = \Delta n_1 > 0$.

5. The asset sale lowers the asset price by the amount $\Delta p_1 = \gamma \Delta q_1 > 0$ to $p_1 = p_0 - \delta - \Delta p_1$.
6. The cash raised by the sale is $p_1 \Delta q_1$, and this amount is paid to redeeming investors.
7. The fund's NAV at the end of Day 1 becomes

$$s_1 = \frac{(q_0 - \Delta q_1)p_1}{n_0 - \Delta n_1} = p_1 = p_0 - \delta - \gamma\beta\delta, \tag{4}$$

for a total decline since the beginning of Day 0 of

$$s_0 - s_1 = (1 + \gamma\beta)\delta. \tag{5}$$

The key feature of this timeline is that the liquidation costs incurred by the fund (in raising cash to pay redeeming investors) are reflected in the NAV used to redeem shares. The redeeming investors receive $s_1 = p_1$ per fund share, and p_1 incorporates the price impact of selling asset shares to raise cash. Redeeming investors bear their share of the liquidation costs.

The total drop in Equation 5 in the fund's NAV is greater than the exogenous shock δ because of the combination of investors' flow sensitivity and the asset's illiquidity. However, in the scenario described by this timeline, the mutual fund structure has no effect. If n_0 investors held the asset shares directly and a portion $\beta\delta$ of them sold in response to the exogenous shock, they would all experience the loss per share in Equation 5. The mutual fund structure does not amplify losses in this setting.

So long as the number of asset shares sold Δq remains equal to the number of fund shares redeemed Δn, the fund's NAV will remain equal to the asset price p. But once Δq deviates from Δn, as it will in the next scenario, we will have $s \neq p$.

3.2. Asset Liquidation After the NAV Is Fixed

The mutual fund structure becomes important when liquidation costs are incurred after the NAV is fixed. Redemption requests are paid at the NAV that applies at the end of the day on which the redemption request is submitted. If redemption requests are submitted near the end of the day, the fund may not be able to sell assets until the following day. This means that the NAV at which redeeming investors are compensated does not reflect the liquidation costs that will be incurred in raising cash to pay the redeeming investors.

If redeeming investors are paid at a higher NAV, the fund needs to sell more assets to raise sufficient cash to meet the redemptions. Selling Δq shares moves the asset price from p to $p - \gamma\Delta q$, so

$$\text{cash raised} = \Delta q \cdot (p - \gamma \Delta q). \tag{6}$$

Let

$$\Delta q^*(c, p) = \text{ number of asset shares sold to raise cash } c \text{ if asset price is initially } p.$$

Setting Equation 6 equal to c yields a quadratic equation in Δq. We assume the fund sells the least amount necessary, given by the smaller root

$$\Delta q^*(c, p) = \frac{p - \sqrt{p^2 - 4\gamma c}}{2\gamma}. \tag{7}$$

We assume $4\gamma c \leq p^2$ and $\Delta q^*(c, p) \leq q$; otherwise, the fund is unable to raise the required cash and must be liquidated.

Day 0

1. Initially, $q_0 = n_0$ so $s_0 = p_0$.
2. An exogenous shock $\delta > 0$ lowers the asset price to $p_0 - \delta$.

3. Investors redeem $\Delta n_1 = \beta\delta > 0$ fund shares near the end of the day.
4. Day 0 ends with a fund NAV of $p_0 - \delta$.

Day 1

5. The fund sells $\Delta q_1^* = \Delta q^*(c, p_0 - \delta)$ asset shares, with $c = \beta\delta(p_0 - \delta)$ to meet redemptions.
6. The asset sale lowers the asset price by the amount $\Delta p_1 = \gamma\Delta q_1^* > 0$ to $p_1 = p_0 - \delta - \Delta p_1$.
7. The cash raised by the sale is $p_1\Delta q_1^* = \beta\delta(p_0 - \delta)$ and is paid to redeeming investors.
8. The fund's NAV at the end of Day 1 becomes

$$s_1 = \frac{(q_0 - \Delta q_1^*)p_1}{n_0 - \Delta n_1} = \frac{q_0(p_0 - \delta - \gamma\Delta q_1^*) - \beta\delta(p_0 - \delta)}{q_0 - \beta\delta}. \qquad 8.$$

In Step 3, investors are redeeming shares before the fund publishes an updated NAV. In this timeline, investors anticipate a drop in the end-of-day NAV, perhaps because of intraday news about the value of the underlying asset.

In Step 6 of Section 3.1, the cash raised by the fund is only $\Delta n_1 p_1 = \beta\delta(p_0 - \delta - \Delta p_1)$, where the Δp_1 term reflects the price impact of liquidation. In the timeline of this section, the fund is raising strictly more cash because it needs to meet redemptions at a higher NAV of $p_0 - \delta$ rather than $p_0 - \delta - \Delta p_1$. The fund therefore needs to sell strictly more shares, $\Delta q_1^* > \Delta q_1$. The resulting price drop $\Delta p_1 = \gamma\Delta q_1^*$ is consequently larger than before, and the final NAV in Equation 8 is lower than the previous value in Equation 4.

In the last expression for the NAV in Equation 8, the first term in the numerator is the final value of the fund's initial shares; the price per share is lower than in Equation 4 because of the fund's increased liquidation. The second term in the numerator is the cash paid to redeeming investors. This amount is greater than before because the $\beta\delta$ redeemed shares receive an NAV of $p_0 - \delta$ in Equation 8 but only $p_0 - \delta - \gamma\beta\delta$ in Equation 4. Because of the NAV guarantee, investors who exit early benefit at the expense of the other investors when prices are falling. The cost to remaining investors is greater than the benefit to redeeming investors because of the increased liquidation costs.

3.3. Introducing First Movers

We now combine the mechanisms of Sections 3.1 and 3.2 with two types of investors. We suppose that a fraction $\pi \in (0, 1)$ of investors recognize the advantage of redeeming early; we call these investors first movers. The remaining fraction $1 - \pi$ (the second movers) will react later, as in Section 3.1. A first mover understands that fund shares redeemed earlier will be paid at a higher NAV. A first mover also understands that shares remaining in the fund at the end will be valued at a lower NAV. The second observation creates an incentive for first movers to sell still more shares.

We capture this idea through an adjustment to the flow sensitivity relation (Equation 2). We posit that first movers respond to the total anticipated change in NAV, and not just the realized price shock δ, as follows:

$$\text{number of shares redeemed by first movers} = \pi\beta\Delta s^*, \qquad 9.$$

where $\Delta s^* > 0$ is the (as yet undetermined) final decline in NAV.

The timeline is now as follows:

Day 0

1. Initially, $q_0 = n_0$ so $s_0 = p_0$.
2. An exogenous shock $\delta > 0$ lowers the asset price to $p_0 - \delta$ and lowers the fund's NAV to $p_0 - \delta$.

3. First movers redeem $\Delta n_{1,1} = \pi\beta\Delta s^* > 0$ fund shares near the end of the day.
4. Day 0 ends with an asset price of $p_0 - \delta$ and a fund NAV of $p_0 - \delta$.

Day 1

5. Second movers react to the drop in NAV by redeeming $\Delta n_{1,2} = (1-\pi)\beta\delta$ fund shares; the total number of fund shares redeemed by first and second movers is $\Delta n_1 = \Delta n_{1,1} + \Delta n_{1,2}$.
6. The fund sells $\Delta q^*_{1,1} = \Delta q^*(c, p_0 - \delta)$ asset shares to raise cash to meet the first-mover redemptions, with $c = \Delta n_{1,1}(p_0 - \delta)$ the amount due to first movers.
7. The asset sale lowers the asset price by the amount $\Delta p_{1,1} = \gamma\Delta q^*_{1,1}$ to $p_{1,1} = p_0 - \delta - \Delta p_{1,1}$.
8. The cash raised by the sale is $p_{1,1}\Delta q^*_{1,1}$, and this amount is paid to redeeming first movers.
9. The fund sells an additional $\Delta q_{1,2} = \Delta n_{1,2}$ asset shares to meet second-mover redemptions, bringing the total number of asset shares sold to $\Delta q^*_1 = \Delta q^*_{1,1} + \Delta q_{1,2}$.
10. The asset sale further lowers the asset price by the amount $\Delta p_{1,2} = \gamma\Delta q_{1,2}$ to $p_1 = p_0 - \delta - \Delta p_{1,1} - \Delta p_{1,2}$.
11. The cash raised by the sale is $p_1\Delta q_{1,2}$, and this amount is paid to redeeming second movers.
12. Day 1 ends with an asset price of p_1 and a fund NAV of

$$s_1 = \frac{(q_0 - \Delta q^*_1)p_1}{n_0 - \Delta n_1}. \qquad 10.$$

The anticipated NAV decline Δs^* to which first movers responded in Equation 3 is determined to be

$$\Delta s^* = s_0 - s_1. \qquad 11.$$

Several remarks are in order:

- Because first movers submit their redemptions at the end of the day (Day 0), they are paid at an NAV that does not reflect the liquidation costs generated by their redemptions. Second movers submit in the morning (of Day 1), so the end-of-day NAV they receive reflects their own liquidation costs as well as those of the first movers.
- The timeline of this section combines elements of the timelines of Sections 3.1 and 3.2. Second movers behave like the investors of Section 3.1; first movers are similar to the investors of Section 3.2, but they react to the full NAV decline Δs^*, anticipating liquidation costs, and not just to the realized shock δ. By exiting at the Day 0 NAV of $p_0 - \delta$, they impose their liquidation costs on other investors, and anticipating the reduced value of their remaining fund shares, they redeem more shares than they would if they held the asset directly.
- In the final NAV s_1 in Equation 10, the quantities on the right (other than q_0 and n_0) are functions of Δs^*, the NAV change anticipated by first movers. But Δs^* depends on the final NAV s_1. Thus, Δs^* is the solution to a fixed-point problem.

Figure 1 compares the total asset price decline $p_0 - p_1$ produced by a shock δ with first movers and without first movers. The red dotted line is simply $(1 + \gamma\beta)\delta$, in accordance with Equation 5. (Without first movers, the asset price and the fund's NAV coincide.) For the blue solid line, we solve numerically for the fixed point Δs^* for each value of δ and calculate p_1 according to the timeline of this section. [A multi-asset, multi-fund version of the fixed-point problem is studied by Capponi, Glasserman & Weber (2022).] In both cases, the initial shock δ is amplified, but the amplification becomes substantially larger in the model with first movers. The blue solid line in the figure is actually slightly convex, meaning that the degree of amplification becomes larger for larger shocks.

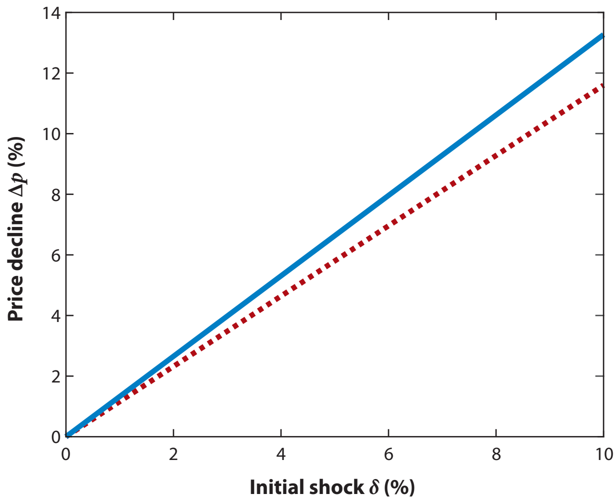

Figure 1

Total asset price decline $p_0 - p_1$ produced by an initial shock δ with first movers (*blue solid line*) and without first movers (*red dotted line*). The figure uses parameters $\pi = 0.15$, $\beta = 0.8$, and $\gamma = 0.2$, and the normalization $q_0 = n_0 = p_0 = s_0 = 1$.

3.4. Swing Pricing

The timelines of Sections 3.2 and 3.3 illustrate the motivation for swing pricing. When prices are falling, investors benefit from redeeming early because by doing so they avoid liquidation costs the fund will incur later; the NAV guarantee provided by mutual funds creates an incentive for investors to redeem more shares than they would otherwise, and this selling pressure amplifies fire sales. Swing pricing seeks to offset these incentives by adjusting the NAV at which shares are redeemed.

Put succinctly, we take the objective of swing pricing to be removing the first-mover advantage. We develop this idea within the timeline of Section 3.3. Recall that the first movers submit redemption requests for $\Delta n_{1,1}$ shares near the end of Day 0 and are guaranteed an NAV of $p_0 - \delta$. Under swing pricing, the mutual fund, after observing the large redemptions, will adjust (swing) the NAV by an amount $\sigma > 0$, resulting in a Day 0 NAV of $p_0 - \delta - \sigma$ and making early redemption less attractive.

How large should the swing factor σ be? If we want to (just) eliminate the first-mover advantage, σ should lead the first movers to internalize their liquidation costs—to the extent that they would if all investors held the underlying asset directly. We are not trying to eliminate all liquidation costs (by, for example, locking investors in the fund); the goal is to eliminate the distortion created by redeeming shares at an NAV that does not reflect liquidation costs.

The final drop in NAV Δs^* in Equation 11 depends on the fraction π of first movers and now on the swing factor σ. Write $\Delta s^*(\pi, \sigma)$ to make this dependence explicit. An ideal swing price satisfies

$$\Delta s^*(\pi, \sigma) = \Delta s^*(0, 0). \quad 12.$$

In other words, imposing the swing factor σ should result in the same final NAV as if all investors behaved like second movers and the fund made no swing adjustment. We know from the analysis of Section 3.1 that in the absence of first movers the total drop in NAV would be $\Delta s^*(0, 0) = \delta(1 + \gamma\beta)$, so this is our target for $\Delta s^*(\pi, \sigma)$.

We revisit the timeline of Section 3.3 with a swing factor of σ. Day 0 now ends with a published NAV of $p_0 - \delta - \sigma$, although the market price of an asset share is $p_0 - \delta$. We choose a swing factor

$$\sigma = \pi\gamma\beta \cdot \Delta s^* = \pi\gamma\beta \cdot [\delta(1 + \gamma\beta) + o(\gamma\beta)], \tag{13.}$$

where $o(\gamma\beta)$ denotes terms of higher order in $\gamma\beta$. We will explain this choice of σ (and the approximation on the right) after showing its consequences. Notice that this swing factor is proportional to the number of fund shares $\Delta n_{1,1}$ to be redeemed by first movers on Day 0. Notice also that this choice targets a value of Δs^* (the total drop in NAV) of approximately $\delta(1 + \gamma\beta)$, as required for Equation 12.

On Day 1, the $\Delta n_{1,1}$ shares redeemed by first movers need to be paid at a swung NAV of $p_0 - \delta - \sigma$. The number of asset shares the fund needs to sell $\Delta q^*_{1,1}$ is determined by equating the cash raised and the cash needed,

$$\Delta q^*_{1,1}(p_0 - \delta - \gamma\Delta q^*_{1,1}) = \Delta n_{1,1}(p_0 - \delta - \sigma).$$

But Equation 13 implies that $\sigma = \gamma\Delta n_{1,1}$, so we may take $\Delta q^*_{1,1} = \Delta n_{1,1}$ in this equation, for a price impact of $\Delta p_{1,1} = \gamma\Delta q^*_{1,1} = \gamma\Delta n_{1,1}$. In other words, our choice of swing factor exactly anticipates the price impact from meeting first-mover redemptions.

Second movers observe that Day 0 ended with an NAV decline of $\delta + \sigma$. They redeem $\Delta n_{1,2} = \beta(\delta + \sigma)$ fund shares. The fund sells $\Delta q_{1,2} = \Delta n_{1,2}$ asset shares to raise cash, with a price impact of

$$\Delta p_{1,2} = \gamma\Delta q_{1,2} = (1 - \pi)\gamma\beta(\delta + \sigma). \tag{14.}$$

The asset price becomes $p_0 - \delta - \Delta p_{1,1} - \Delta p_{1,2}$, and this is also the fund's NAV at the end of Day 1 because the number of asset shares sold equals the number of fund shares redeemed. Thus, the total NAV decline is

$$\begin{aligned}
\Delta s^* &= \delta + \Delta p_{1,1} + \Delta p_{1,2} \\
&= \delta + \gamma\Delta n_{1,1} + (1 - \pi)\gamma\beta(\delta + \sigma) \\
&= \delta + \pi\gamma\beta\Delta s^* + (1 - \pi)\gamma\beta\delta + (1 - \pi)\pi\gamma^2\beta^2\Delta s^*,
\end{aligned}$$

so

$$\Delta s^* = \frac{\delta + (1 - \pi)\gamma\beta\delta}{1 - \pi\gamma\beta - (1 - \pi)\pi\gamma^2\beta^2} = (\delta + (1 - \pi)\gamma\beta\delta)(1 + \pi\gamma\beta + o(\gamma\beta)) = \delta + \gamma\beta\delta + o(\gamma\beta),$$

which confirms the conjectured value for Δs^* in Equation 13. More importantly, this choice of swing price has achieved (up to higher order terms) the objective of bringing the NAV decline Δs^* with first movers to its value $\delta(1 + \gamma\beta)$ without first movers. This was the objective in Equation 12 of offsetting the first-mover advantage.

The swing factor in Equation 13 depends on model parameters in an intuitive way: It is increasing in the size δ of the initial shock, the illiquidity γ, the performance sensitivity β, and the proportion of first movers π. In the next section, we remove the small approximation error that appears in Equation 13.

3.5. Multiple Rounds of Redemptions

The dynamics outlined in Sections 3.1 and 3.3 can continue for multiple days, with multiple rounds of investor redemptions and asset sales. In the timeline of Section 3.1, Day 0 ends with the fund's NAV having dropped by δ, and Day 1 ends with a further drop of $\gamma\beta\delta$. If we continue the process, then on the morning of Day 2 investors would respond to the new drop of $\gamma\beta\delta$ and redeem more shares, driving down the NAV by a further $\gamma^2\beta^2\delta$ by the end of the day. The cumulative effect would extend the one-day price change in Equation 5 to a cumulative price decline of

$$(1 + \gamma\beta + \gamma^2\beta^2 + \cdots)\delta = \frac{\delta}{1 - \gamma\beta}. \quad 15.$$

We can similarly extend the timeline of Section 3.3 through multiple rounds of second-mover redemptions. We assume that in each day $2, 3, \ldots$, second movers react to the drop in NAV from the previous day. The first movers acted on Day 0 and play no further role in subsequent rounds.

Suppose the fund reduced the NAV by the swing factor σ in Equation 13, for a Day 0 NAV of $p_0 - \delta - \sigma$. We saw in Section 3.4 that the Day 1 NAV is then $p_0 - \delta - \sigma - \Delta p_{1,2}$, so the change in NAV is $\Delta p_{1,2}$. This leads to a further NAV decline the next day of $(1 - \pi)\gamma\beta\Delta p_{1,2}$. We also saw in Equation 14 that $\Delta p_{1,2} = (1 - \pi)\gamma\beta(\delta + \sigma)$. The cumulative change in NAV becomes

$$\Delta s^* = (\delta + \sigma) + (1 - \pi)\gamma\beta(\delta + \sigma) + (1 - \pi)^2\gamma^2\beta^2(\delta + \sigma) + \cdots = \frac{\delta + \sigma}{1 - (1 - \pi)\gamma\beta}.$$

Replacing σ with the value $\pi\gamma\beta\Delta s^*$ in Equation 13 and solving for Δs^*, we get

$$\Delta s^* = \frac{\delta}{1 - \gamma\beta}, \quad 16.$$

which matches Equation 15 exactly. Plugging this value into the formula $\sigma = \pi\gamma\beta\Delta s^*$ yields the swing price

$$\sigma = \frac{\pi\gamma\beta\delta}{1 - \gamma\beta}. \quad 17.$$

In other words, over repeated rounds of redemptions, the swing price (Equation 17) ensures that the cumulative NAV decline (Equation 16) with first movers equals the cumulative NAV decline (Equation 15) without first movers. We have achieved the objective in Equation 12. The approximation error we saw in Equation 13 decreases with each round of redemptions and eventually vanishes.

3.6. Cash Buffers

Investors' withdrawals may not force asset liquidation, if funds hold sufficient cash buffers to meet these redemptions. Morris, Shim & Shin (2017) and Shek, Shim & Shin (2018) show that funds invested in illiquid assets—in their empirical analysis, emerging market bonds—increase their cash position following redemptions rather than reduce it, a behavior they call "cash hoarding." This means that these funds sell more assets than necessary to meet redemptions. For example, for every \$100 of asset sales due to investor flow, funds invested in emerging market government bonds liquidate an additional \$7 worth of assets, arguably in anticipation of future redemptions. Even though cash hoarding exacerbates current selling pressure, it may reduce the likelihood of future fire sales, hence its effect on financial stability is not clear. In the model by Zeng (2017), the anticipated rebuilding of cash buffers prompts investors to run.

Chernenko & Sunderam (2016) analyze data on cash holdings of equity and long-term corporate bond funds. They find that funds engaged in substantial liquidity transformation hold large cash buffers. However, their study concludes that mutual fund cash holdings are not sufficiently large to completely mitigate the negative externalities caused by asset sales and liquidity transformation. Cash buffers reduce, but do not eliminate, the first-mover advantage that swing pricing addresses directly.

3.7. Redemptions in Kind

Redemption in kind provides a more extreme mechanism for dealing with illiquid assets. It allows a fund to deliver a portfolio of securities, instead of cash, to investors making large redemptions. In this way, a fund passes on the cost of liquidation to redeeming investors. Agarwal et al. (2023) document a substantial increase in the proportion of US domestic equity funds that reserve the right to make redemptions in kind, from 27.9% in 1997 to 41.8% in 2017. As discussed by Agarwal et al. (2023), redemptions in kind present investors and the fund with trade-offs. The fund faces a trade-off between a reduced outflow during bad times and a potentially lower net inflow during good times. The investor's trade-off is between reduced strategic complementarities once redemptions in kind begin and the risk of receiving illiquid securities when they most need cash.

4. LIQUIDITY SHOCKS AND EQUILIBRIUM MUTUAL FUND RUNS

In the framework of Section 3, investor outflows are triggered by an exogenous price shock and subsequent NAV declines. This modeling choice is based on the empirical literature into the relationship between fund flows and fund performance. An alternative approach, building on the Diamond & Dybvig (1983) model of bank runs, grounds investor outflows in an exogenous liquidity shock or a shock leading some investors to prefer to consume sooner rather than later.

4.1. The Lewrick–Schanz Model

The literature offers several extensions of the Diamond–Dybvig model to nonbank intermediaries. We focus on the model of Lewrick & Schanz (2017b) because it directly addresses swing pricing. We use some notation and terminology that emphasizes connections with Section 3; for example, we refer to "investors" rather than "households." As a description of equilibrium behavior, the model requires specifying more features of the environment than the reduced-form model of Section 3.

The model has three periods, 0, 1, and 2. Investors have an endowment of 1 at time 0. An illiquid asset pays a fixed return of R per unit of period 0 investment if held to period 2. The asset may not be traded in period 1, but claims on the asset may be traded at an endogenous market price denoted by p.

Investors have the choice to invest in the asset in period 0 or to invest in a mutual fund. Mutual funds issue fund shares to investors. They use the proceeds to invest in the asset and hold a cash buffer. Fund investors may redeem shares in periods 1 and 2.

Some investors are risk neutral, and some are risk averse. In the equilibrium studied by Lewrick & Schanz (2017b), risk-neutral investors invest only in the asset, and risk-averse investors invest only in the mutual fund. Thus, the risk-neutral investors primarily function as potential trading counterparties for the mutual fund in period 1.

Each risk-averse investor becomes an early consumer with probability $\lambda \in (0, 1)$ and a late consumer with probability $1 - \lambda$. Given potential consumption levels c_1 and c_2 in periods 1 and 2, a risk-averse investor's utility takes the form

$$u_A(c_1, c_2) = \begin{cases} u(c_1), & \text{with probability } \lambda, \\ u(c_2), & \text{with probability } 1 - \lambda, \end{cases}$$

for some well-behaved utility function $u(\cdot)$. The quantities c_1 and c_2 will be the amount paid by a mutual fund to investors who redeem their fund shares in period 1 or hold their fund shares until period 2. A late consumer may choose to redeem shares in period 1 and store the proceeds for consumption in period 2.

Table 1 How the swing adjustment changes with model parameters

Section 3	Lewrick & Schanz (2017b)
↑ in trading cost γ	↑ in trading cost γ
↑ in first movers π	↑ in early consumers λ
↑ in price shock δ	
↑ in flow sensitivity β	
	↓ in risk aversion

The random assignment of investors to the early and late categories is the model's only source of uncertainty. It creates a purpose for the mutual fund because the fund enables risk-averse investors to smooth the uncertainty from becoming an early or late investor. The fund accomplishes this purpose by transforming the illiquid underlying asset into fund shares that can be redeemed in period 1.

Each mutual fund chooses an initial cash buffer and an NAV to publish [called a settlement price by Lewrick & Schanz (2017b)]. For a fund holding a cash buffer $\omega \in (0, 1)$, the "true" or accounting-based NAV in period 1 is

$$\omega + (1 - \omega)p, \qquad 18.$$

recalling that p is the price of an asset share in period 1. The fund's published NAV may deviate from this level—in other words, the fund may use swing pricing. Each fund chooses its initial cash buffer and swing adjustment to maximize the utility of its investors.

The market is subject to two frictions. Contracts cannot be made contingent on the outcome of an investor's liquidity shock, so investors cannot completely hedge the risk from these shocks. And trading in the asset-share market in period 1 is costly: Selling one share of the asset yields $(1 - \gamma)p$ in cash, and buying one share of the asset costs $p/(1 - \gamma)$. The parameter $\gamma \in (0, 1)$ thus has the same impact here as in Equation 3.

Lewrick & Schanz (2017b) characterize the actions of investors and funds in a particular equilibrium, and their characterization includes the NAV adjustment used by funds. Their results have both similarities and differences with Section 3.[5]

Table 1 summarizes some qualitative properties of the two settings. An up arrow indicates an increase in the magnitude of a downward price adjustment and, thus, a decrease in a fund's published NAV. In both settings, the swing adjustment is larger when trading costs are larger and also when π (the proportion of first movers) or λ (the proportion of early consumers) increases. The parameter λ can also be seen as the size of the shock and thus compared to δ or $\beta\delta$. Lewrick & Schanz (2017b) explain that with more risk-averse investors, a fund will seek to level payouts across time periods, muting the swing in period 1, at least in the case of a constant relative risk aversion (CRRA) utility function.

An interesting feature of the Lewrick & Schanz (2017b) equilibrium is that the initial cash buffer selected by a mutual fund exactly equals the cash needed to redeem the shares of early consumers in period 1. In particular, the funds do not sell asset shares in period 1, so no trading occurs in the market for asset shares.

But the trading costs, though never incurred, are nevertheless important in shaping the equilibrium. Early consumers, like first movers, do not bear their full liquidation costs when the fund

[5]The results in Lewrick & Schanz (2017b) also treat the symmetric case of an upward swing adjustment that raises the NAV to discourage an inflow of investors. We focus on the case of downward adjustments used to deter runs.

sells asset shares; the fund lowers its published NAV to deter excess redemptions in period 1 and thus avoids costly trading.

At the same time, Lewrick & Schanz (2017b) ensure that the swing factor is not so large that investors may arbitrage the difference between fund shares and asset shares. The costs of trading asset shares create a no-arbitrage interval for the published NAV and constrains the range of swing factors. Fear of dilution from swinging the NAV too low is indeed likely to be an important practical consideration for funds using swing pricing.[6]

Lewrick & Schanz (2017b) also show that swing pricing can eliminate fund runs, which are scenarios in which some of the $1 - \lambda$ late consumers choose instead to redeem shares in period 1. They caution that this conclusion relies on the fund manager knowing λ, and the corresponding caveat applies in Section 3.

4.2. Run-Proof Contracts

Allen & Walther (2021) develop a general extension of the Diamond–Dybvig model for nonbank intermediaries, including mutual funds. The model is similar in several respects to the model by Lewrick & Schanz (2017b). Investors are subject to a random shock through which a fraction λ become early consumers and the rest are late consumers. An intermediary promises payouts c_1 and c_2 to its investors who withdraw in periods 1 and 2, respectively. The intermediary holds assets that pay a fixed return if held to period 2 and that may be liquidated at a cost in period 1. Whether the intermediary can deliver the payouts c_1 and c_2 when λ investors withdraw early depends on the liquidation costs and the fixed return on the asset.

Depending on the contract, some of the $1 - \lambda$ late consumers may find it preferable to withdraw early. Let $c_1(\eta)$ and $c_2(\eta)$ be the payouts in the two periods when a fraction $\eta \in [0, 1]$ of investors redeems early. In the case of a mutual fund, $c_1(\eta)$ is always equal to the fund's NAV $F(\eta)$; a fund's payout to a redeeming investor in period 1 is precisely the fund's NAV in that period.

Allen & Walther (2021) call an intermediary contract run-proof if $c_1(\eta) \leq c_2(\eta)$, for all η. This condition rules out strategic complementarity in early withdrawal: No matter how many other investors have already chosen to withdraw early, waiting until period 2 always results in a higher payout. Allen & Walther (2021) then show that an intermediary contract is run-proof if and only if $c_1(\eta) \leq F(\eta)$, for all η, where $F(\eta)$ is the period 1 NAV for a mutual fund holding the same asset.

This condition is automatically satisfied by mutual funds, for which $c_1(\eta) \equiv F(\eta)$. The result of Allen & Walther (2021) may therefore seem to imply that mutual funds are run-proof and, by extension, that liquidity management tools like swing pricing are unnecessary. But this apparent contradiction with our earlier discussion is resolved by considering the Allen & Walther (2021) definition of the NAV $F(\eta)$ in period 1. Their definition is not the book value in Equations 1 or 18; instead, it is the value per fund share after accounting for the trading costs incurred in raising sufficient cash to meet period 1 redemptions. It is the NAV that would apply, as in the timeline of Section 3.1, if the NAV delivered to redeeming investors were determined after the fund incurred liquidation costs.[7]

[6]In a separate analysis, Lewrick & Schanz (2017a) argue that concern for dilution restrains fund managers from fully passing on liquidation costs through swing pricing. Investors will stay in the fund, bearing some of these costs, as long as the fund provides a better return than investors' outside option.

[7]Allen & Walther (2021) distinguish their definition of a floating NAV from the fixed NAV used by some money market funds. As we have seen, mutual funds operate somewhere in between, with an NAV that is fixed daily and fixed at a value that may differ from the fully floating value because of trading costs.

We may therefore interpret the Allen & Walther (2021) result in one of two ways. We can say that a mutual fund becomes run-proof if (*a*) the intraday NAV guarantee is eliminated or (*b*) the fund is able to swing its NAV so that redeeming investors bear their liquidation costs. Both interpretations are consistent with the Allen & Walther (2021) NAV definition, and both conclusions are consistent with our earlier discussions.

These comments on the timing of asset liquidation and NAV fixing also help position the work of Zeng (2017). His model features a repeated sequence of two-period stages, with early and late consumers within each stage. Zeng (2017) concludes that swing pricing cannot mitigate the risk of runs because, in his model, the fund's current NAV already reflects trading costs. A run in his model is precipitated by a fund rebuilding its cash buffer, rather than by investors' anticipation of costly liquidations to meet investor redemptions.

5. EMPIRICAL EVIDENCE

Does swing pricing work? As a step towards understanding the answer to this question, we examine empirical work on two more basic questions: How does swing pricing change investor behavior? How do funds that adopt swing pricing differ from funds that do not? Of particular interest is evidence that swing pricing discourages run-like behavior by investors, especially in funds holding less-liquid assets. We discuss insights into these questions provided by the empirical work of Jin et al. (2022), Lewrick & Schanz (2023),[8] Malik & Lindner (2017), and Deghi et al. (2022).

5.1. Data

Jin et al. (2022) have undertaken an extensive study using confidential data from the UK's Financial Conduct Authority on 224 corporate bond funds managed by 22 asset management companies in 2006–2016. The funds are primarily invested in UK assets. Their confidential data also allow the authors to track positions of individual investors within and across funds.

Jin et al. (2022) classify funds as having traditional or alternative pricing rules, with the alternative group forming roughly 80% of their sample. Alternative pricing includes swing pricing, but it also includes dual pricing, in which a fund maintains two prices for its shares, one for buyers and one for sellers. The findings by Jin et al. (2022) do not distinguish between swing pricing and dual pricing, but only 10% of funds in their alternative group use dual pricing.

Lewrick & Schanz (2023) base their analysis on a comparison of 1,233 US bond funds and 645 Luxembourg bond funds in the same style categories in 2012–2017. In this period, the Luxembourg funds were permitted to use swing pricing but the US funds were not. For part of their analysis, they form matched sets of funds from the two jurisdictions based on fund characteristics available to investors.

The comparisons by Malik & Lindner (2017) are based on six funds that used swing pricing in 2009–2016, in some cases matched with otherwise similar funds that did not use swing pricing. Given the limited data in the work by Malik & Lindner (2017), we put more emphasis on the other two studies. We also briefly discuss some of the findings by Deghi et al. (2022).

5.2. Does Swing Pricing Discourage Runs?

The studies cited contain many specifications and findings. We limit our discussion to some of the most important ones.

[8]An earlier version appeared as Lewrick & Schanz (2017a).

All four studies test for run-like behavior through interaction effects. A run can be seen as an increase in the flow sensitivity of investors associated with lower levels of asset liquidity and elevated market stress. The effectiveness of swing pricing may be measured as a further interaction with a dummy variable for its adoption.

Jin et al. (2022) run a panel regression of the form

$$Flow_{i,t} = \alpha_i + \beta_1 Alt_{i,t} + \beta_2 Stress_t + \beta_3 Alt_{i,t} \times Stress_t + \cdots, \qquad 19.$$

where $Flow_{i,t}$ is the flow into fund i in month t, $Alt_{i,t}$ is an indicator variable for whether fund i uses alternative pricing in month t, and $Stress_t$ is an indicator for market stress in month t. (For simplicity, we display only the most relevant portion of each study's specification, omitting controls, fixed effects, and error terms.) Jin et al. (2022) define stress periods through the level of the VIX. A negative β_2 indicates reduced inflows (or greater outflows) in times of stress, and a positive β_3 indicates an offsetting effect through alternative pricing.

Lewrick & Schanz (2023) run panel regressions of the form

$$\begin{aligned} Flow_{i,t} = {} & \alpha_i + \beta_1 R_{i,t-1} + \beta_2 BelowRF_{i,t-1} \\ & + \beta_3 R_{i,t-1} \times SP_i + \beta_4 BelowRF_{i,t-1} \times SP_i \\ & + \beta_5 R_{i,t-1} \times Stress_t + \beta_6 BelowRF_{i,t-1} \times Stress_t \\ & + \beta_7 R_{i,t-1} \times SP_i \times Stress_t + \beta_8 BelowRF_{i,t-1} \times SP_i \times Stress_t + \cdots, \end{aligned} \qquad 20.$$

where the $R_{i,\,t-1}$ are lagged returns, $BelowRF_{i,\,t-1}$ are lagged returns below the risk-free rate,[9] and SP_i is an indicator for the use of swing pricing. The stress period in the work by Lewrick & Schanz (2023) is the taper tantrum, which they date from May to early July in 2013.

For each fund, Malik & Lindner (2017) run a time series regression of the form

$$R_t = \alpha + \delta NegFlow_t \times (1 - Stress_t) + \varphi NegFlow_t \times Stress_t + \cdots, \qquad 21.$$

where $NegFlow_t$ is the fund's flow in month t if the flow is negative and zero otherwise. Malik & Lindner (2017) consider several ways of defining periods of stress (or illiquidity in their terminology). They take $\delta = \varphi$ as their condition for the absence of a first-mover advantage in the fund: If this condition holds, fund performance is no more vulnerable to outflows in times of stress than in other times. They compare values of $\varphi - \delta$ for funds with and without swing pricing. The interpretation of their results would perhaps be more natural with the roles of returns and flows reversed, as in the previous specifications.

We turn now to the main findings. Jin et al. (2022) find consistent evidence that β_2 is negative and β_3 is positive in Equation 19. In other words, outflows are elevated in times of stress, and this effect is mitigated by the use of alternative pricing. Moreover, they find that β_3 is very nearly equal to $-\beta_2$, suggesting that the offsetting effect is nearly perfect. This finding appears to be very robust, holding up with a variety of controls and fixed effects and extending to quantile regressions. We return to this offsetting effect in Section 6.1.

In estimating several versions of Equation 20, Lewrick & Schanz (2023) similarly find that β_2 is positive and β_4 is negative, indicating that elevated flow sensitivity to poor returns (β_2) is offset by the use of swing pricing (β_4). As in Jin et al. (2022), these coefficients have similar magnitudes, and in some specifications result in a nearly perfect offset.

[9] Some of their specifications use negative returns instead of returns below the risk-free rate.

However, this pattern does not extend to the interaction with their stress period, the taper tantrum. The coefficient β_8 in Equation 20 measures the mitigation of return-driven outflows in the stress period, and the estimates of β_8 in Lewrick & Schanz (2023) are not statistically significant. Lewrick & Schanz (2023) conclude that although outflows following poor returns are larger in US funds than in the swing pricing funds, the two groups of funds experienced similar responses to poor returns during the taper tantrum. They provide further support for this conclusion through a comparison of matched sets of US and Luxembourg funds.

Lewrick & Schanz (2017a) explain this finding through the structure of swing pricing commonly used in practice, which involves a fixed threshold for swinging the NAV and a fixed percentage by which the NAV is then swung. They argue that this results in an NAV adjustment that is too large at intermediate outflows (just above the threshold) and too small at very large outflows. Capponi, Glasserman & Weber (2020) make a similar point in comparing their theoretical swing factor with the type of adjustment made in practice.

In reconciling the conclusions of Jin et al. (2022) and Lewrick & Schanz (2023), it is worth noting that the VIX was not particularly elevated during the taper tantrum.[10] Malik & Lindner (2017) consider several definitions of stress periods. They generally find that their measure of first-mover advantage is reduced but not eliminated in funds using swing pricing.

The picture that emerges from these studies is that the use of swing pricing is associated with diminished outflows in response to negative returns and at least some types of market stress. Future work should shed further light on the strength of this effect in different market conditions and under different implementations of swing pricing.

Jin et al. (2022) provide further insight by tracking individual investors and funds over time. Their sample includes 34 funds that switched from traditional to alternative pricing (and none that made the opposite switch). They find that investors with positions in both traditional funds and funds that switched withdraw less during market stress from the funds that switched. They also find that a switch to alternative pricing has a greater impact on institutional investors than retail investors, as measured by the change in their withdrawals in stress periods. This pattern is broadly consistent with the discussion of Section 3.3, which takes institutional investors as a proxy for first movers.

Deghi et al. (2022) take a different perspective from the other studies by measuring the impact of swing pricing on asset price volatility. If swing pricing enhances financial stability, the benefits should show up in asset prices, and Deghi et al. (2022) use price volatility as a proxy for market fragility. They find that assets that are held in greater proportions by funds in Luxembourg and the United Kingdom (where swing pricing is often used) experience lower price volatility than assets held in greater proportions by funds in the United States (where swing pricing has not yet been used). Moreover, they find that this effect is greater for assets held by more vulnerable funds, meaning funds that hold a higher proportion of illiquid assets. However, they also find that the effect is not sufficiently large to offset the increased asset price volatility associated with increased ownership by vulnerable funds, which they attribute to funds using insufficiently large swing adjustments. Their analysis is based on a large sample of funds observed between 2013 and 2022.

5.3. How Are Swing Funds Different?

Jin et al. (2022) and Lewrick & Schanz (2017a) find that funds in their swing groups [alternative pricing funds in Jin et al. (2022) and Luxembourg funds in Lewrick & Schanz (2017a)] hold less

[10]The VIX averaged approximately 15 in May–June 2013 and peaked at 20.5. The stress threshold in Jin et al. (2022) is the 75th percentile of the level of the VIX over their sample period, which is 23, so the period highlighted by Lewrick & Schanz (2023) would not register as a stress period in Jin et al. (2022).

cash, supporting the idea that cash buffers and swing pricing are substitutes as liquidity management tools. Jin et al. (2022) find that funds that use alternative pricing hold less liquid portfolios, as measured by the bid-ask spreads of the portfolio's assets.

The two studies suggest that swing pricing is associated with better fund performance. Lewrick & Schanz (2023) find that swing pricing funds enjoyed higher market-adjusted returns during the taper tantrum than matched sets of US funds. Jin et al. (2022) find that outflows from traditional pricing funds are associated with lower future fund performance, while the same level of outflows from alternative pricing funds are not. Using their data on individual investors, Jin et al. (2022) report that investors in alternative pricing funds appear to have longer investment horizons, which may also contribute to higher returns. In a case study of one fund over a 1-year period, Malik & Lindner (2017) suggest that swing pricing may have increased the fund's return by 3.5 percentage points.

6. DIRECTIONS FOR FUTURE RESEARCH

6.1. What Is the Right Objective for Swing Pricing?

We noted in Section 5.2 that, in estimating Equation 19, Jin et al. (2022) find that β_2 and β_3 have opposite signs and nearly equal magnitudes; similar statements hold for the estimates of β_2 and β_4 in Equation 20, reported by Lewrick & Schanz (2023). In both cases, the use of swing pricing appears to have a perfectly offsetting effect on withdrawals, which may be taken as evidence of success. But is it? How much outflow should be suppressed?

We posited in Section 3.4 that the goal of swing pricing should not be to eliminate all liquidation costs but rather to eliminate any additional costs created by the structure of the mutual fund contract—specifically, the same-day NAV guarantee. This makes the relevant benchmark the level of sales and liquidation costs investors would incur if they held the assets directly, rather than through a mutual fund. First movers sell more than they would otherwise because of the fund structure, and swing pricing should target this incentive, not all withdrawals due to market stress.

If we adopt the perspective of a Diamond & Dybvig (1983) model, we reach a parallel conclusion. Following a liquidity shock, the early consumers have a legitimate need to redeem shares, and the mutual fund exists in part to manage the risk of this shock. A run occurs when otherwise patient investors redeem shares early. Theory therefore suggests that swing pricing should discourage these excess early redemptions and not all early redemptions.

From either perspective, a perfect offset may be evidence of overly aggressive NAV adjustments, at least at moderate levels of outflows, rather than carefully calibrated swing pricing. It is less clear what level of offset would be ideal empirically if the goal is to match the direct-ownership benchmark.[11]

6.2. Liquidity Shock or Market Shock?

The answer to the previous question depends in part on whether one views the stress that leads to elevated redemptions as a liquidity shock or a market shock. The empirical literature documenting return-flow relations is better aligned with a market shock perspective, and this is the motivation for the reduced-form model of Section 3. The theoretical literature discussed in Section 4 is based

[11] Our focus has been on the financial stability objective of swing pricing. But swing pricing can also serve an investor protection function by more equitably allocating costs among a fund's investors. This function could lead to different considerations in formulating the right objective.

on a liquidity shock. The types of outflows that swing pricing seeks to dampen are related but not identical in the two settings, and the way investors respond to incentives may also differ.

The well-documented return-flow relation may result from investors updating their beliefs about the riskiness of an investment and rebalancing their portfolios accordingly. In contrast, a liquidity shock to investors is exogenous to the mutual fund's assets. It would therefore be interesting to compare the effect of swing pricing in funds held in retirement accounts and unrestricted accounts. Investors subject to a liquidity shock would presumably redeem more shares from their unrestricted accounts; following a market shock, an investor may change allocations in both accounts.

6.3. What Is the Optimal Design of Swing Pricing?

The most widely used form of swing pricing is a partial swing defined by a threshold and a constant swing factor. As discussed in Section 5.2, Capponi, Glasserman & Weber (2020) and Lewrick & Schanz (2017a) challenge this structure, arguing that it may result in too large an adjustment for intermediate flows and too small an adjustment for large flows. The models of Sections 3 and 4 provide characterizations of appropriate swing adjustments, but more work is needed to translate these theoretical insights to specific policies for funds to adopt. Anadu et al. (2022) suggest that price differences between mutual funds and ETFs could be used to calibrate swing adjustments.

6.4. How Should Swing Pricing Be Tailored for Money Market Funds?

The original SEC rule allowing mutual funds to use swing pricing excluded money market funds; a more recent SEC proposal (SEC 2021) would require institutional prime and tax-exempt money market funds to adopt swing pricing. The change in perspective appears to be driven by the experience of the COVID-19 shock of March 2020. Earlier reforms had called for money market funds to apply redemption fees and gates to prevent runs, but investors apparently ran to get ahead of these fees and gates.

Money market funds hold short-dated securities such as US Treasury bills, commercial paper, and certificates of deposit. Some of these securities are primarily held to maturity and do not trade regularly in a secondary market, which presents a challenge to estimating market impact for swing pricing. Many money market funds offer same-day settlement to redeeming investors, which could limit the funds' ability to spread asset sales over multiple days. Institutional cash managers with large balances are highly motivated to monitor small differences in fund performance and reallocate cash quickly, potentially producing a high level of flow sensitivity to performance.

McCabe et al. (2012) propose an alternative measure they call a minimum balance at risk (MBR) to reduce incentives to run from a distressed money market fund. They define the MBR as a small fraction (between 3% and 5%) of each shareholder's balance that can be redeemed only with a delay of 30 days. In the event that a fund suffers losses, the MBRs of investors who have recently redeemed their shares would absorb costs first. These investors would thus internalize the costs of their redemptions, which in turn reduces losses imposed on investors who are slower to run and remain invested in a distressed fund. Further research is needed to guide the design of rules to mitigate money market funds' vulnerability to runs and to shed light on the pros and cons of swing pricing for this class of funds.

6.5. How Well Do Funds Swing?

To the extent that swing pricing seeks to make redeeming investors bear their own liquidation costs, a swing adjustment carries an implicit estimate of what those costs might be. How accurately are mutual funds that use swing pricing estimating those costs? This is a difficult question to answer because the use of swing pricing changes the costs one would want to measure.

A closely related question is whether swing pricing increases share price volatility. Critics of swing pricing often contend that NAV adjustments increase price volatility; however, if properly calibrated, these NAV adjustments may preempt larger price changes that would otherwise occur later. Lewrick & Schanz (2017a) discuss conditions under which swing pricing increases what they call accounting volatility, and they find higher levels of this measure among Luxembourg funds than US funds during the taper tantrum. Malik & Lindner (2017) find simulation-based evidence of increased volatility.

6.6. What Information Should Be Disclosed?

Questions about disclosure apply both to a fund's policies regarding swing pricing and to its application of swing pricing after the fact. Mutual funds are required to disclose their use of swing pricing in a prospectus or similar document. In Europe, funds that use partial swing pricing commonly disclose a fixed swing factor (e.g., 2%) while keeping their swing threshold confidential for fear that it may be gamed. Funds do not ordinarily report on which days they applied swing pricing (or by how much); in their financial statements, they do note that swing pricing (or a dilution adjustment) was applied at some point during the reporting period. Dual pricing provides greater transparency but is much less widely used.

The consequences of this lack of transparency merit further study. Theoretical models generally assume that investors understand the choices they face, and opacity may interfere with the design and implementation of incentives. Our inclination is to favor transparency, but the industry's concern that transparency could be exploited cannot be entirely dismissed without further analysis. The indirect evidence available, based on the tracking of investors by Jin et al. (2022), suggests that investors in alternative pricing funds do have some understanding of how alternative pricing differs from traditional pricing, even with only limited information on how funds apply swing pricing.

6.7. What Is the Right Combination of Liquidity Management Tools?

Mutual funds have several tools available for liquidity management, including cash buffers, portfolio composition, redemption fees, redemption gates, fund loads, dual pricing, and swing pricing. We noted in Section 5.3 that Jin et al. (2022) and Lewrick & Schanz (2017a) document some substitution among these tools, with funds that use swing pricing holding less cash and more illiquid assets. Investors are generally averse to fees and gates. Higher cash buffers may lower returns, and their potential benefits may not be visible to investors. Swing pricing has the advantage of taking effect only when needed. What is the right trade-off between swing pricing and cash?

6.8. What Is the Equilibrium Mix of Fund Types?

Should we expect all funds to voluntarily adopt swing pricing or some other liquidity management tool? Or is diversity in fund types the natural equilibrium outcome? And what are the financial stability implications of the mix of tools used?

Jin et al. (2022) exploit changes in funds' pricing policies to measure how one fund's adoption of alternative pricing affects other funds. They report that the marginal benefit of adopting alternative pricing decreases as the number of funds using alternative pricing increases. This finding suggests that the coexistence of both types of funds may be the natural equilibrium outcome. Their sample includes just 34 funds that switched from traditional to alternative pricing, but the result is nevertheless intriguing.

Capponi, Glasserman & Weber (2020) examine a closely related interaction from a theoretical perspective. They consider how the magnitude of the required swing adjustment—required to remove the first-mover advantage—for one fund changes with the adoption and magnitude of the adjustment by another fund. They show that the required adjustment is smallest when both funds adopt swing pricing.

Jin et al. (2022) also report differences between institutional and retail investors and funds. They find that alternative pricing has a stronger effect on retail funds because their investor base is less concentrated; however, they also find that institutional investors respond more strongly to alternative pricing, particularly in predominantly retail funds. Capponi, Glasserman & Weber (2022) show theoretically that spillover losses are smaller when first movers are more evenly dispersed across funds. To the extent that institutional investors serve as a proxy for first movers, this result suggests that swing pricing should have the greatest system-wide benefit when institutional investors are unevenly dispersed among retail investors.

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LITERATURE CITED

Agarwal V, Ren H, Shen K, Zhao H. 2023. Redemption in kind and mutual fund liquidity management. *Rev. Financ. Stud.* 36(6):2274–318

ALFI (Assoc. Luxembourg Fund Ind.). 2022. *Swing pricing: update 2022*. Rep., ALFI, Luxembourg

Allen F, Walther A. 2021. Financial architecture and financial stability. *Annu. Rev. Financ. Econ.* 13:129–51

Anadu K, Levin J, Liu V, Tanner N, Malfroy-Camine A, Baker S. 2022. *Swing pricing calibration: a simple thought exercise using ETF pricing dynamics to infer swing factors for mutual funds*. SSRN Work. Pap. 4014689

Bank of England. 2021. *Liquidity management in UK open-ended funds*. Rep., Bank of England, London

BlackRock. 2021. *Swing pricing—raising the bar*. Policy Spotlight, Sept. **https://www.blackrock.com/corporate/literature/whitepaper/spotlight-swing-pricing-raising-the-bar-september-2021.pdf**

Capponi A, Glasserman P, Weber M. 2020. Swing pricing for mutual funds: breaking the feedback loop between fire sales and fund redemptions. *Manag. Sci.* 66(8):3581–602

Capponi A, Glasserman P, Weber M. 2022. *Stress testing spillover risk in mutual funds*. SSRN Work. Pap. 4270464

Chen Q, Goldstein I, Jiang W. 2010. Payoff complementarities and financial fragility: evidence from mutual fund outflows. *J. Financ. Econ.* 97(2):239–62

Chernenko S, Sunderam A. 2016. *Liquidity transformation in asset management: evidence from the cash holdings of mutual funds*. NBER Work. Pap. 22391

Choi J, Hoseinzade S, Shin SS, Tehranian H. 2020. Corporate bond mutual funds and asset fire sales. *J. Financ. Econ.* 138(2):432–57

Cipriani M, La Spada G. 2020. *Sophisticated and unsophisticated runs*. Staff Rep. 956, Fed. Reserve Bank, New York, NY

Claessens S, Lewrick U. 2021. Open-ended bond funds: systemic risks and policy implications. *BIS Q. Rev.* Dec.:37–51

Deghi A, Gan ZK, Guérin P, Helmke AT, Iyer T, et al. 2022. Asset price fragility in times of stress: the role of open-end investment funds. In *Global Financial Stability Report*, pp. 65–89. Washington, DC: Int. Monet. Fund

Diamond DW, Dybvig PH. 1983. Bank runs, deposit insurance, and liquidity. *J. Political Econ.* 91(3):401–19
ESMA (Eur. Secur. Mark. Author.). 2020. *Recommendation of the European Systemic Risk Board (ESRB) on liquidity risk in investment funds.* Rep., ESMA, Paris
Goldstein I, Jiang H, Ng DT. 2017. Investor flows and fragility in corporate bond funds. *J. Financ. Econ.* 126(3):592–613
Invest. Co. Inst. 2017. *Evaluating swing pricing: operational considerations. Addendum.* Invest. Co. Inst., Washington, DC
Jiang H, Li Y, Sun Z, Wang A. 2022. Does mutual fund illiquidity introduce fragility into asset prices? Evidence from the corporate bond market. *J. Financ. Econ.* 143(1):277–302
Jin D, Kacperczyk M, Kahraman B, Suntheim F. 2022. Swing pricing and fragility in open-end mutual funds. *Rev. Financ. Stud.* 35(1):1–50
Lewrick U, Schanz JF. 2017a. *Is the price right? Swing pricing and investor redemptions.* Work. Pap. 664, Bank Int. Settl., Basel, Switz.
Lewrick U, Schanz JF. 2017b. *Liquidity risk in markets with trading frictions: What can swing pricing achieve?* Work. Pap. 663, Bank Int. Settl., Basel, Switz.
Lewrick U, Schanz JF. 2023. Towards a macroprudential framework for investment funds: swing pricing and investor redemptions. *Int. J. Cent. Bank*. 19(3):229–67
Lewrick U, Schanz JF, Carpantier JF, Rasqué S. 2022. *An assessment of investment funds' liquidity management tools.* Work. Pap., Comm. Surveill. Sect. Financ., Luxembourg
Li Y, O'Hara M, Zhou X. 2022. *Mutual fund fragility, dealer liquidity provisions, and the pricing of municipal bonds*. SSRN Work. Pap. 3728943
Ma Y, Xiao K, Zeng Y. 2022. Mutual fund liquidity transformation and reverse flight to liquidity. *Rev. Financ. Stud.* 35(10):4674–711
Malik S, Lindner P. 2017. *On swing pricing and systemic risk mitigation.* Work. Pap. 17/159, Int. Monet. Fund, Washington, DC
McCabe P, Cipriani M, Holscher M, Martin A. 2012. *The minimum balance at risk: a proposal to mitigate the systemic risks posed by money market funds*. Staff Rep. 564, Fed. Reserve Bank, New York, NY
Morris S, Shim I, Shin HS. 2017. Redemption risk and cash hoarding by asset managers. *J. Monet. Econ.* 89:71–87
Schmidt L, Timmermann A, Wermers R. 2016. Runs on money market mutual funds. *Am. Econ. Rev.* 106(9):2625–57
SEC (Secur. Exch. Comm.). 2016. *Investment company swing pricing*. Final Rule, Release Number IC-32316, US Sec. Exch. Comm., Washington, DC
SEC (Secur. Exch. Comm.). 2021. *Money market fund reforms.* Proposed Rule, Release Number IC-34441, US Sec. Exch. Comm., Washington, DC
SEC (Secur. Exch. Comm.). 2022. *Open-end fund liquidity risk management programs and swing pricing*. Proposed Rule, Release Number IC-34746, US Sec. Exch. Comm., Washington, DC
Shek J, Shim I, Shin HS. 2018. Investor redemptions and fund manager sales of emerging market bonds: How are they related? *Rev. Finance* 22(1):207–41
Zeng Y. 2017. *A dynamic theory of mutual fund runs and liquidity management*. SSRN Work. Pap. 2907718