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Managing Overreaction During a Run

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Abstract

This paper studies whether suspensions intended to provide a time-out for agents to digest incoming information attenuate runs, under the assumption that agents overreact to news and need time to properly process it. To do so, I embed diagnostic expectations into a standard global game model of runs. I show that during bad times, when bad public news arrives and/or investment returns are low, such policy actually amplifies runs, even in cases where almost all investors are receiving negative news and temporarily overreacting to it. During good times, the opposite result arises.

JEL Classifications: D84, D91, G41.

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1 Introduction

Processing incoming news is a difficult task for humans and requires time. Recent work points out that even professional forecasters systematically overreact to incoming news, interpreting negative news as worse than they really are, and being overly optimistic after receiving positive news, but those distortions tend to vanish as time passes (Bordalo et al., 2019, Bordalo, Gennaioli and Shleifer, 2022). Those patterns can be explained by diagnostic expectations models of belief formation, as formalized in Bordalo et al. (2016). The tendency of agents to overreact to news can explain why commentators often label some distress events in financial markets—such as bank runs, asset market runs and runs on mutual funds—as the result of "irrational panics".[1]

This initial overreaction could help justify temporary suspensions that are prevalent in financial markets after large shocks, such as: tradings halts (also referred to as circuit breakers), which are used by virtually every stock exchange; suspension of flows in mutual funds, which were prevalent in Europe after the COVID-19 shock; or the freezing of crypto accounts, which were common after the run on Terra Luna.[2] Defendants of such suspensions often point out that agents need time to properly digest incoming news, as to avoid panicking and rushing to conclusions, and temporarily prohibiting agents from acting could help in that dimension.

Those behavioral arguments are well summarized by Kodres (2020) when discussing the historical context in which circuit breakers were implemented in the US: *"The circuit breaker idea was grounded in the notion that a time-out could allow participants to clear their heads and that a panic could be quelled."* This resonates the view of Nicholas Brady and Robert Glauber—two prominent participants of the Brady Comission, whose recommendations were largely responsible for the implementation of those mechanisms in the US—who claim that trading halts can *"give participants a time-out to take a deep breath, evaluate the situation and perhaps interrupt the sense of panic. With a brief time to think again, perhaps some sellers will withdraw to the sidelines and value buyers will enter the market"* (Brady and Glauber, 2020).

Despite the prevalence of suspensions intended to give financial markets participants

[1] This narrative differs from the one in which runs are viewed as the result of "rational panics", which usually refers to self-fullfiling crises that happen among fully rational investors in settings with multiple equilibria, such as those in the classic work of Diamond and Dybvig (1983).

[2] Of course, there are other considerations that are used to justify such suspensions, such as liquidity issues.

a time-out, mostly after negative shocks, there is a lack of formal treatments of the behavioral arguments often used to justify them. This paper provides such formal treatment, analyzing whether suspensions can attenuate runs in financial markets, under the assumption that agents' beliefs need time to revert toward rationality after the arrival of news. I start by embedding a diagnostic expectations model of belief formation—in which agents overreact to both good and bad news (Bordalo, Gennaioli and Shleifer, 2018)—into a global game similar to those used to study different types of runs, such as asset market runs (Morris and Shin, 2004), bank runs (Goldstein and Pauzner, 2005) and mutual fund runs (Chen, Goldstein and Jiang, 2010). Then, I use the model to investigate under which circumstances suspensions that temporarily prohibit agents from acting are optimal for an authority that wishes to minimize the size of a run, considering that agents can better process incoming information as time passes.

The main result of the paper is that during bad times, when bad public news arrives and/or expected investment returns are low, suspensions amplify runs, not attenuate them. This happens even in cases where most agents are receiving negative news and temporarily overreacting to it, and even though the only channel through which suspensions operate in the model is by curbing investors' overreaction to incoming news. Hence, what common wisdom claims to be a benefit of suspensions—allowing agents to better digest information after the arrival of bad public news—can actually be a cost in a context of runs. In fact, suspensions can only attenuate runs during good times, in which runs are already less severe.

The result is driven by an endogenous mismatch between the effect of suspensions on the *average* and *marginal* investor. During bad times, suspensions can indeed induce investors to make decisions under much more optimistic beliefs, on average. However, precisely when that happens, they tend to worsen the beliefs of the agents that happen to matter in equilibrium, the marginal investors (for reasons to be discussed).

I now further detail the model ingredients and the intuition behind the main results.

A model of runs with diagnostic investors. I start from the standard global game model of runs of Morris and Shin (2000). A continuum of investors have an investment of one dollar and must decide whether to cancel (run) or renew it. Canceling the investment imposes a negative externality on investors that stay: The payoff of renewing the investment is decreasing in the proportion of investors that run. The payoff of renewing also depends on ex ante expected asset returns, which are common knowledge, and on a fundamental shock that is not directly observed by agents.

Investors have a prior about the fundamental shock and receive two pieces of information: a private and a public signal. After observing both signals, investors do not update their beliefs according to Bayes Rule, but instead form their posterior using diagnostic expectations, as in Bordalo, Gennaioli and Shleifer (2018). Agents observing positive (combined) signals then become overly optimistic about the fundamental shock, while agents observing negative news become overly pessimistic. There is a parameter that measures how much agents overreact to information. If that parameter equals zero, agents are rational and the model is the same as in Morris and Shin (2000).

I first show under which conditions uniqueness of equilibrium is guaranteed. Diagnostic expectations play in favor of guaranteeing a unique equilibrium. If the equilibrium is unique under rational expectations, then it is unique under diagnostic expectations, but the converse does not hold: under some parameters, the equilibrium is not unique under rational expectations, but is so under diagnostic expectations. In equilibrium, agents receiving good (bad) news are not only overly optimistic (pessimistic) about the fundamental shock, but also about the decision of other investors.

Temporary suspensions. The model is then extended to include a subsequent stage where expectations revert back to rationality. Time is divided in three dates. At date 1, new information (public and private signals) arrive, and agents update their beliefs using the diagnostic model of belief formation. At date 2, sufficient time to process incoming information has passed, and agents' expectations become rational.[3] At date 3, agents' choices and fundamentals become common knowledge and payoffs realize.

In the absence of a suspension, a terminal where agents can send run/renew orders opens at the beginning of date 1 and closes at the end of date 2. Agents derive some extra utility from moving early (date 1) rather than late (date 2), which reflects information processing costs, attention frictions or different types of early mover advantages. Date 1 investors find it optimal (using their distorted beliefs) to run or renew right after the arrival news, even when their future (rational) self would choose something different. The equilibrium thus captures the idea of "irrational panics" as an equilibrium outcome: Agents receive some news, rush to conclusions and act on this information, even though their future selves may regret such choice.

[3]It is not critical that expectations fully revert back to rationality, only that the belief distortion is lower at date 2. See Section 6.3.

If an authority implements a suspension, investors are prohibited from making decisions at date 1, while they are still diagnostic. Hence, a suspension guarantees agents will decide when they have fully processed the incoming information. The authority observes the public signal, and wishes to minimize the expected number of agents that run. Deliberately, it is assumed that the only effect through which suspensions affect investors is by forcing them to *"take a deep breath"* before acting, mitigating their irrational overreactive behavior. Other potential costs/benefits of suspensions (e.g., liquidity considerations) are ignored, as to avoid confounders and to be transparent about whether the behavioral arguments often invoked as a benefit of such policies are justified.

I show that the arrival of bad news (low realizations of the public signal) tends to make a suspension amplify runs, and it is so precisely because such policy helps to curb overreaction. Suspensions amplify runs even in scenarios where most agents are receiving negative news and overreacting to it. Also, when ex-ante investment returns are low, suspensions also make runs more severe. Hence, suspensions are not desirable in bad times, and in fact can only prevent run behavior in good times (when the realization of public signals and/or ex-ante returns are high, and hence runs are less severe).

How can a suspension amplify runs following the arrival of bad news? After very bad public news arrives, it is likely that most investors have received negative news overall, after combining their private and public information. Hence, given that they overreact to negative news initially, imposing a suspension induces agents to be more optimistic at the time they decide, on *average*. However, I show that what matters is not how such policy affects average beliefs, but how it affects the beliefs of agents that are close to indifference in equilibrium, the marginal investors, which are the ones more prone to changing their decision. The identity of the marginal investors is an equilibrium object. Who are they when bad public news arrives?

Due to coordination motives, public signals play a critical role in the model, since they anchor investors' expectations about the behavior of other investors. After very bad public information arrives, investors become very prone to running, even if they receive good private information that offsets it. More precisely, for a given level of expected fundamentals, an investor is more prone to running if she observed a low public signal and a high private signal than if the converse holds. This is because the former is more pessimistic about what other investors think (higher-order beliefs). Hence, in such bad public news scenario, agents that are close to indifference between running or not are agents that overall received positive news, and a suspension makes them stop being overly optimistic at the time they decide, amplifying runs. Therefore, while such policy tends to improve average beliefs at the time decisions are taken, it worsens the beliefs of the (few) agents that matter.

A similar intuition explains why suspensions amplify runs when ex-ante returns are low, since in such cases investors have high incentives to run, and hence agents close to indifference are those observing positive news overall.

I also discuss how the quality of the arriving information interacts with the effects of suspensions. As long as coordination motives are sufficiently relevant—meaning that investors do not have a dominant action before observing their signals—the precision of the arriving information does affect the ex-ante probability of a suspension being optimal. In such case, for low ex-ante returns, more precise public information increases the probability of a suspension being desirable, and reduces it for high ex-ante returns. The opposite is true regarding the effect of the precision of private information.

Extensions. I show that the main results remain unchanged under three alternative modeling assumptions. First, I present the case where investors' payoffs are a discontinuous function of the proportion of agents that run and of the fundamental, as usual in games of regime change. Second, I relax a parametric assumption that guarantees equilibrium uniqueness, assuming that investors always play according to some extreme equilibrium whenever there is multiplicity. Third, I present the case where expectations only partially revert toward rationality.

Related literature. This paper is mainly related to two strands of literature. First, it relates to the global games literature studying bank runs, market runs and coordination games in general (for instance, Carlsson and Van Damme, 1993, Morris and Shin, 1998, Morris and Shin, 2004, Goldstein and Pauzner, 2005, Sakovics and Steiner, 2012). Second, it relates to the literature that formalizes and incorporates diagnostic expectations in different contexts (Gennaioli and Shleifer, 2010, Bordalo, Gennaioli and Shleifer, 2018, Bordalo et al., 2019, Bordalo et al., 2021, Bianchi, Ilut and Saijo, 2022, Maxted, 2023 to name a few). The novel contribution here is to embed diagnostic expectations into a standard model of runs, and use it to study suspensions.

More broadly, this paper is also related to the literature studying different types of suspensions in financial markets (examples include Gorton, 1985, Kodres and O'Brien, 1994, Hautsch and Horvath, 2019), contributing to the debate by theoretically analyzing the behavioral arguments often used to defend those policies during runs.

Layout. Section 2 incorporates diagnostic expectations into a model of runs. Section 3 presents the equilibrium. Section 4 augments the model to allow beliefs to revert to rationality after some time. Section 5 studies the effects of temporary suspensions. Section 6 discusses extensions of the main model. Section 7 concludes. All proofs are in Appendix A.

2 A Model of Runs with Diagnostic Investors

I start by modeling the decision of agents to run on some investment when they do not update their beliefs using Bayes rule, but instead have diagnostic expectations, as in Bordalo, Gennaioli and Shleifer (2018). In Section 4, I then propose a simple extension of this setting to capture the idea that agents' beliefs converge toward rational expectations as time passes, as commonly assumed and documented in the diagnostic expectations literature, which then allows me to study the role of temporary suspensions. The model presented in this section is the global game model of runs of Morris and Shin (2000), augmented with diagnostic expectations.

Investors and payoffs. A continuum of risk-neutral investors indexed by $i \in [0, 1]$ must decide whether to cancel or renew an investment. Canceling is labeled as action $a_i = 0$ and also referred to as the decision to "run". Renewing is labeled as $a_i = 1$. Investors that run recover the dollar amount invested initially, and hence their payoff is normalized to one. The payment received by investors that renew their investment depends positively on a fundamental shock (η) and negatively on the proportion of agents that run (ℓ). For tractability, I assume that the payoffs of investors that renew are linear, as in the rollover game of Morris and Shin (2000), and hence are given by

$$v(\eta, \ell) = z + \eta - \gamma \ell, \tag{1}$$

where $\gamma > 0$ and $z \in \mathbb{R}$.[4] Hence, investment returns are the sum of the ex-ante returns (z) and the fundamental shock (η), minus the externalities caused by those that run ($\gamma \ell$). When z is high (low), we say that the economy is facing good (bad) times from an ex-ante perspective.

[4]In Section 6.1, I show that the main results hold in a setting where $v(\eta, \ell)$ is a step function, as in games of regime change.

The key economic force captured by the proposed payoffs is that of strategic complementarities: An investor's incentive to run is increasing in the number of investors that run. Strategic complementarities form the basis of traditional models of runs. In the context of asset market runs (events in which many investors decide to suddenly sell an asset), strategic complementarities can arise due to traders' loss limits (Morris and Shin, 2004), relative performance concerns (Morris and Shin, 2016), balance sheet constraints and liquidity shocks (Eisenbach and Phelan, 2023) or due to sufficiently strict margin requirements (Bernardo and Welch, 2004). In the context of bank runs, strategic complementarities are a consequence of the costs early liquidation imposes on banks' assets (Morris and Shin, 2000, Goldstein and Pauzner, 2005). In the context of runs on mutual funds, it arises when the net asset value of a fund does not perfectly reflect the fire-sale penalties triggered by redemptions (Chen, Goldstein and Jiang, 2010). In the context of cryptocurrencies it can also be reinforced by transaction motives (Sockin and Xiong, 2022).

Information. The fundamental shock η (or fundamental, in short) is not observed and is drawn from a normal distribution with mean zero and variance $1/\tau_0$. Hence, agents share a common prior $\eta \sim N(0, 1/\tau_0)$. Each agent receives two pieces of news before deciding whether to run: the realization of a public signal y that is observed by everyone, and the realization of a private signal x_i. Each signal consists of the true fundamental plus some noise:

$$x_i = \eta + \varepsilon_i,$$

$$y = \eta + \omega,$$

where $\varepsilon_i \sim N(0, 1/\tau_x)$ and is iid across agents, $\omega \sim N\left(0, 1/\tau_y\right)$, and ε_i and ω are independent. The parameters τ_x, τ_y and τ_0 are referred to as the precision of the signals and the prior. Throughout the paper, I often use $\phi(\cdot)$ and $\Phi(\cdot)$ to denote the standard normal density and distribution functions, respectively.

Beliefs updating. The only relevant deviation I make from a standard model of runs is that agents in my setting do not update their beliefs about the fundamental η using Bayes Rule, but instead, have distorted beliefs. I follow Bordalo, Gennaioli and Shleifer (2018) and Bordalo et al. (2019) and assume that investors have diagnostic expectations.

Let agents' beliefs after observing signals x_i and y be represented by a pdf $f^{\theta}(\eta | x_i, y)$, and let $f(\eta | x_i, y)$ be the conditional pdf given by Bayes Rule. Following Bordalo, Gennaioli and Shleifer (2018), I assume that:

$$f^{\theta}\left(\eta \middle| x_i = \hat{x}, y = \hat{y}\right) = f\left(\eta \middle| x_i = \hat{x}, y = \hat{y}\right) \mathcal{R}\left(\eta, \hat{x}, \hat{y}\right)^{\theta} C, \tag{2}$$

where

$$\mathcal{R}\left(\eta, \hat{x}, \hat{y}\right) = \frac{f\left(\eta \middle| x_i = \hat{x}, y = \hat{y}\right)}{f\left(\eta | x_i = 0, y = 0\right)}$$

is called the representativeness index, $\theta \geq 0$ denotes the strength of probability distortions, and C is a constant that guarantees the distorted density $f^{\theta}(\cdot)$ integrates to one. Throughout the paper, I often use hats to indicate a specific realization of a random variable, as above.

One of the key ideas behind formula (2) is that agents have limited and selective memory, and that "representative types" come more easily to mind. To illustrate, suppose agents are evaluating the probability of bankruptcy of a firm in the next year. The firm discloses a financial report saying revenue fell relative to last year. To estimate how such report affects the probability of bankruptcy, investors try to recall whether other firms that reported a fall in revenue in the past went bankrupt in the subsequent year. However, due to *limited memory*, the disclosure of some reports is forgotten by investors when doing these mental calculations. Due to *selective memory,* investors are less likely to forget the disclosure of reports of firms that later went bankrupt, so the events in which a firm went bankrupt after disclosing a fall in revenue are oversampled in investors' minds. That is, investors can better recall situations that are more *representative* of bankruptcy. As a result, investors think the disclosure of such report increases the probability of bankruptcy more than it actually does, they overreact to negative news. If given more time to process the information, investors should be able to better recall the events they initially forgot, reducing the oversampling problem. A similar logic implies that investors have a tendency to overreact to positive news, for instance, overestimating the probability of a startup firm being the next Google after observing positive earnings reports. See Tversky and Kahneman (1983) and Bordalo, Gennaioli and Shleifer (2018) for further discussion of those concepts.

Equation (2) is standard in the literature, because it captures well those effects in a tractable manner. Whenever positive news arrives, say $y > 0$ and $x_i > 0$, the representative index $\mathcal{R}$ is above 1 for $\eta > 0$ and below one for $\eta < 0$. Hence, compared to a Bayesian agent, diagnostic agents put more weight on positive realizations of η and lower weight on negative realizations, overreacting to positive news. As positive signals are representative of positive realizations of η, agents overweight the association between positive values of the signals and positive values of the fundamental in their judgment, and the opposite is true for negative signals.

Strategies and equilibrium definition. Since agents are not rational in my setting, I cannot rely on standard definitions of equilibrium, such as Perfect Bayesian Equilibrium (PBE). To deviate as little as possible from the restrictions imposed by PBE, I propose an equilibrium definition that would be equivalent to PBE if agents updated their beliefs about the fundamental η using Bayes Rule and not the diagnostic rule (2).

A strategy for agent i is defined as a measurable function $g_i(x_i, y) \mapsto \{0, 1\}$, that is, it is a map from the observed signals x_i and y to actions $a_i \in \{0, 1\}$. A strategy profile is a collection $(g_i)_{i\in[0,1]}$. For a given realization of the fundamental η and fixing a strategy profile $(g_i)_{i\in[0,1]}$, investors can perfectly anticipate the proportion of investors that will run, which is given by

$$\tilde{\ell}(\eta) = \int_0^1 \int_{\mathcal{X}_i} \sqrt{\tau_x}\phi\left(\sqrt{\tau_x}(x - \eta)\right) dx\, di, \tag{3}$$

where $\mathcal{X}_i = \{x : g_i(x, y) = 0\}$ denotes the set of private signals for which an agent runs (which depends on the realization of y). However, agents do not update their beliefs about η according to Bayes Rule, but according to (2). Hence, their distorted expected payoff of renewing is given by

$$V^{\theta}(x_i, y) = \int_{-\infty}^{\infty} \left(z + \eta - \gamma\tilde{\ell}(\eta)\right) f^{\theta}(\eta | x_i, y)\, d\eta. \tag{4}$$

If $\theta = 0$ the expression above is simply agents' expected payoff of renewing the investment, after observing the signals and taking as given the strategies of others. With $\theta > 0$, agents have distorted beliefs about the fundamental, which also leads them to distort their beliefs about the proportion of other agents running. For instance, if the distortion leads agents to be too optimistic about η and agents renew only if they observe signals above a threshold, then diagnostic beliefs lead agents to overestimate the mass of agents renewing, as their optimistic belief about η implies they are too optimistic about others' signals.

Having defined how agents distort their beliefs when computing their expected payoffs, the definition of equilibrium follows naturally.

Definition 1. A strategy profile $g_i : (x_i, y) \mapsto \{0, 1\}$, for all $i \in [0, 1]$, is a Diagnostic Equilibrium if $g_i(x_i, y) = 1$ implies $V^\theta(x_i, y) \geq 1$ and $g_i(x_i, y) = 0$ implies $V^\theta(x_i, y) \leq 1$, taking as given other agents' strategies.

In other words, a Diagnostic Equilibrium is a Nash Equilibrium of the game where the payoff of renewing is given by $V^\theta(x_i, y)$ in (4). If $\theta = 0$, the definition above is then equivalent to that of a Perfect Bayesian Equilibrium in my setting.

A notation remark: In what follows, $\mathbb{E}^\theta[\eta|x_i, y]$ represents the expectation of η for an agent with beliefs given by (2), that is, $\mathbb{E}^\theta[\eta|x_i, y] = \int_{-\infty}^{\infty} \eta f^\theta(\eta|\, x_i, y)\, d\eta$. $\mathbb{E}[\eta|x_i, y]$ is reserved for the expectation of a rational agent: $\mathbb{E}[\eta|x_i, y] = \int_{-\infty}^{\infty} \eta f(\eta|\, x_i, y)\, d\eta$.

3 Equilibrium

Before computing the equilibrium, I characterize the distribution of investors' beliefs conditional on their signals:

Lemma 1. *After observing signals x_i and y, investors believe η is normally distributed with mean $\tilde{\mu}_1(x_i, y)$ and variance $1/\tilde{\tau}_1$, where*

$$\tilde{\mu}_1(x_i, y) = \frac{(1+\theta)\left(\tau_x x_i + \tau_y y\right)}{\tau_0 + \tau_x + \tau_y}, \tag{5}$$

$$\tilde{\tau}_1 = \tau_0 + \tau_x + \tau_y. \tag{6}$$

As usual, normality of the information structure is inherited by agents' diagnostic beliefs. Combined with the assumption of linear payoffs, this makes the analysis much more tractable. Note that a Bayesian agent ($\theta = 0$) updates upwards his expectation of the fundamental, $\tilde{\mu}_1(x_i, y)$, if and only if the weighted sum $\tau_x x_i + \tau_y y$ of the private and public signal is above zero. Diagnostic agents ($\theta > 0$) also do so, but they overreact: After observing good or bad combined signals they change their beliefs more.

Next proposition characterizes the equilibrium.

Proposition 1. *Suppose that the following condition holds:*

$$\gamma \frac{\tau_0 + \tau_y - \theta\tau_x}{1+\theta} \sqrt{\frac{\tau_0 + \tau_x + \tau_y}{\tau_x\left(\tau_0 + 2\tau_x + \tau_y\right)}} < \sqrt{2\pi}. \tag{7}$$

Then, the model has an essentially unique equilibrium, in which agents renew if $x_i > x^*$ and run if $x_i < x^*$, where x^* is the unique solution to

$$z + \tilde{\mu}_1 (x^*, y) - \gamma \Phi \left(\sqrt{\frac{\tilde{\tau}_1 \tau_x}{\tilde{\tau}_1 + \tau_x}} (x^* - \tilde{\mu}_1 (x^*, y)) \right) = 1. \tag{8}$$

Provided the equilibrium is unique, investors play a *cutoff strategy*: they renew if their signal is above a cutoff, and run if it is below it. I say that the equilibrium is "essentially" unique because there is still multiplicity when agents observe a signal $x_i = x^*$, in which case they are indifferent between both actions. The left-hand side of (7) is strictly decreasing in τ_x, and that condition is satisfied as τ_x becomes sufficiently large. Hence, as is usually the case in global games, if agents' private information is sufficiently precise, the equilibrium is unique. If $\theta = 0$ and $\gamma = 1$, condition (7) boils down to the same condition for uniqueness found in Morris and Shin (2000).

Interestingly, (7) also depends on the strength of diagnostic expectations, θ. One can verify that the left-hand side of (7) is strictly decreasing in θ, and hence diagnostic expectations play in favor of guaranteeing uniqueness. In fact, one can easily construct an example where the equilibrium is not unique with $\theta = 0$ but it is so for a sufficiently large θ. In what follows, to rule out multiplicity, I assume that (7) holds even if $\theta = 0$, that is,

$$\gamma \left(\tau_0 + \tau_y\right) \sqrt{\frac{\tau_0 + \tau_x + \tau_y}{\tau_x \left(\tau_0 + 2\tau_x + \tau_y\right)}} < \sqrt{2\pi}. \tag{A1}$$

This type of assumption is standard in global games and delivers tractability. Still, in Section 6.2, I show that the main results survive if (A1) is violated and one focuses on extreme equilibria.

4 Reversion to Rationality

I now extend the model of Section 2 to capture the idea that, following the arrival of news, investors' beliefs revert back to rational expectations as time passes. This is a common assumption in the diagnostic expectations literature and is consistent with data on expectations (Bordalo et al., 2019).

I divide time in three dates, 1, 2 and 3. Date 1 is interpreted as the date at which new information arrives: Investors start date 1 holding the same prior and receive signals x_i

and y about η as in Section 2, then updating their beliefs using the diagnostic rule (2). Date 2 is interpreted as the date at which investors' beliefs revert back to rationality after the arrival of news, and hence they hold beliefs about η that are consistent with Bayes Rule.[5] A terminal to send cancel/renew orders opens right after signals are received at date 1 and closes at the end of date 2. At date 3, agents' choices and fundamentals become common knowledge and payoffs realize. The timeline is summarized below.

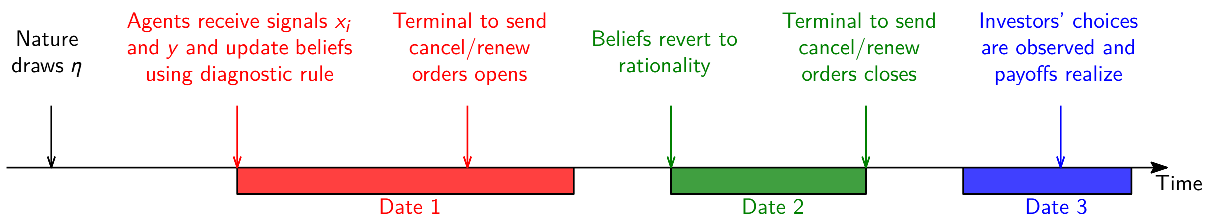

Figure 1: Timeline with reversion to rational expectations.

We can frame the problem of investors at date 1 as that of choosing between three actions: cancel (0), renew (1) or wait (W). If an investor at date 1 chooses to wait, then at date 2 the investor must finally decide whether she will run or renew. If an investor at date 1 chooses to run or renew, then there is no decision to be made at date 2.

A strategy for investor i at date 1 is defined as a map $g_{1,i}(x_i, y) \mapsto \{0, 1, W\}$. A strategy for investor i at date 2, after choosing W at date 1, is a map $g_{2,i}(x_i, y) \mapsto \{0, 1\}$. The proportion of agents that run at either of the two dates is still denoted by ℓ, and for a given η, it is still given by (3), but now with the set of private signals that lead investors to run given by $\mathcal{X}_i \equiv \left\{x : g_{1,i}(x, y) = 0\right\} \cup \left\{x : g_{2,i}(x, y) = 0 \text{ and } g_{1,i}(x, y) = W\right\}$, to capture that agents can run at dates 1 or 2.

I assume that investors that wait pay a cost $\delta > 0$, which captures early mover advantages. This cost can reflect an information processing cost, due to the fact that investors who have not made a decision at date 1 will remain processing the information they received. It could also reflect an attention friction: Investors who do not decide at date 1, right after the arrival of news, may forget to do so afterwards with some probability, which is costly.[6]

Beyond the utility cost of waiting, the final payment received by investors is the same:

[5]The assumption of full reversion to rationality is made only for expositional purposes. In Section 6.3, I show that the main results remain unchanged if expectations only partially revert toward rational expectations, that is, if agents still hold diagnostic beliefs at date 2, but with a reduced θ.

[6]This cost is not critical, but simplifies the exposition by breaking indifference in some cases. If $\delta = 0$ all the results regarding the optimality of suspensions still hold.

Investors that run get 1 and those who renew get $v(\eta, \ell)$ in (1). However, the way they compute their expected payoffs depends on the date at which they are deciding: At date 1, agents compute their expected payment of renewing using (4), while agents at date 2 compute it according to

$$V(x_i, y) = \int_{-\infty}^{\infty} \left(z + \eta - \gamma \tilde{\ell}(\eta) \right) f(\eta | x_i, y) \, d\eta. \tag{9}$$

Note that investors at date 1 play a game with their *future selves* at date 2, since they have a different payoff function. Hence, treating investor i playing at date 1 as one player, and investor i playing at date 2 after observing wait from its date-1 counterpart as a different player, we can define an equilibrium as a Nash Equilibrium of the game where: (i) date-1 players' payoffs are given by (4) if they play renew, 1 if they play run, and if they play wait, payoffs are given by (4) minus δ in case their date-2 self renews, and by $1-\delta$ if their date-2 self runs; (ii) date-2 players' payoffs, after observing wait, are given by (9) minus δ if they renew and $1-\delta$ if they run.[7] Alternatively, one could define the equilibrium as one where each date-1 player is naive and does not anticipate his date-2 self will have a different payoff, and all the results that follow would be unchanged.

The next proposition characterizes the equilibrium in this game.

Proposition 2. *In equilibrium, the cancel/renew decision is taken at date 1 and investors behave as in Proposition 1: They renew if $x_i > x^*$ and run if $x_i < x^*$, where x^* is given by (8).*

This result is straightforward. Date-1 investors can either make a decision today or delegate it to a future self that has a different utility from theirs, further incurring a cost δ. Hence, waiting at date 1 is strictly dominated under the beliefs of date-1 investors.

The model and the equilibrium presented here capture well the notion that agents can *irrationally panic* after the arrival of news, possibly taking actions that they would regret if they kept processing the incoming information—that is, choosing something at date 1 that goes against the will of their date-2 selves. For some parameters and realization of the signals, in equilibrium it happens that a date-1 agent runs when her date-2 self would renew. But it is also true that the opposite can happen for a different set of signals and parameters: a date-1 investor renews when her date-2 self would like to run. This is

[7] I could define it as a Subgame Perfect Equilibrium as well, given the sequential play of date-1 and date-2 selves, but it is equivalent to Nash Equilibrium in this setting.

because diagnostic agents overreact to both positive and negative news.

The discussion above suggests that a regulator may, in some circumstances, benefit from preventing agents from acting while they did not have enough time to fully come to their senses with respect to the incoming information. Next, I analyze under which circumstances temporarily suspending the receipt of new orders attenuates runs.

5 Temporary Suspensions

I now add an authority to the model of Section 4, who can prohibit agents from making decisions at date 1. In other words, the authority can suspend the terminal at date 1, thus forcing agents to decide only when their expectations have reverted back to rationality. That is, the authority can force investors to choose waiting at date 1. By now, it should not be surprising that such an authority can effectively decide whether agents' decisions will be governed by diagnostic or rational expectations. Figure 2 shows the timeline when a suspension is in place.

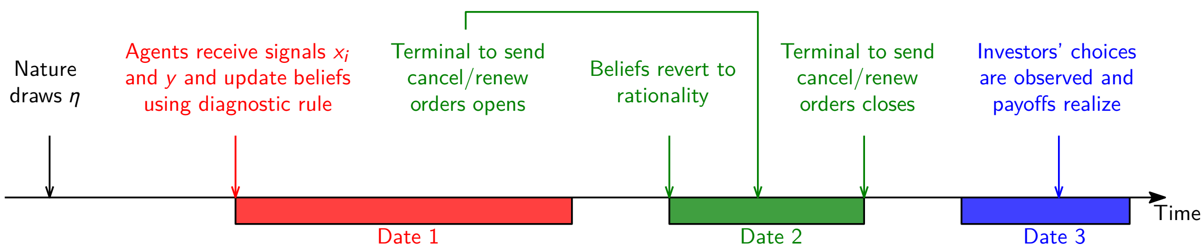

Figure 2: Timeline when a suspension is in place.

Such policy is akin to classical trading halts in stock markets, mutual fund suspensions observed during the COVID-19 crisis, or the recent temporary suspension of crypto platforms, which froze investors' accounts.

The authority has no information other than the prior and the public signal, and its objective is to minimize the expected number of agents that run. Since I want to discuss whether a suspension is optimal or not from the point of view of a rational authority, I assume the authority has rational expectations.[8] Formally, the authority loss is defined as

$$\mathcal{L} = \int_{-\infty}^{\infty} \tilde{\ell}(\eta) f(\eta|y)\, d\eta,$$

[8]However, the results that follow also hold if the authority holds diagnostic beliefs, and the proofs remain unchanged.

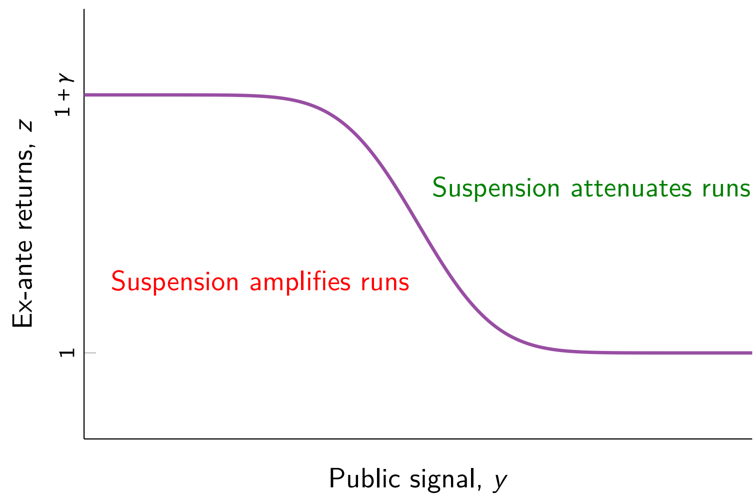

Figure 3: Regions where a suspension amplifies/attenuates runs.

where $f(\eta|y)$ is the conditional belief given by Bayes Rule, and the map $\tilde{\ell}(\eta)$ depends on the strategy profile played by investors, as defined in Section 4. The authority anticipates how a suspension affects the strategy profile played in equilibrium, and hence it anticipates that, in equilibrium, the map $\tilde{\ell}(\eta)$ is not the same with and without a suspension. The next Proposition shows under which conditions such a suspension attenuates runs, and Figure 3 summarizes it.

Proposition 3. *A suspension attenuates runs in good times and amplifies them in bad times: The authority implements a suspension if $z > z^*$, does not implement it if $z < z^*$, and is indifferent when $z = z^*$, where*

$$z^* = 1 + \gamma \Phi \left(-y\tau_y \sqrt{\frac{\tau_0 + \tau_x + \tau_y}{\left(\tau_0 + 2\tau_x + \tau_y\right)\tau_x}} \right). \tag{10}$$

Moreover, the authority is less prone to implementing a suspension after bad public news arrives: $\frac{\partial z^*}{\partial y} < 0$.

To build intuition, it is useful to inspect the effect of suspensions on agents' beliefs at the time they act, from the point of view of the authority. For a given realization of η, define $\Delta_i = \mathbb{E}\left[\eta | x_i, y\right] - \mathbb{E}^{\theta}\left[\eta | x_i, y\right]$ as the "change in beliefs" from date 1 to 2 for an agent observing signals x_i and y. This reflects how much a suspension improves (or worsens) agent i's expectations about the fundamental at the time she decides. Using

Lemma 1 and $x_i = \eta + \varepsilon_i$, we can write it as

$$\Delta_i = -\theta \left[\frac{\tau_x (\eta + \varepsilon_i) + \tau_y y}{\tau_0 + \tau_x + \tau_y} \right].$$

After observing the public signal, the authority believes that $\eta \sim N\left(\frac{\tau_y y}{\tau_0+\tau_y}, \frac{1}{\tau_0+\tau_y}\right)$. Hence the expected change in beliefs from the authority's standpoint is

$$\mathbb{E}\left[\Delta_i \mid y\right] = -\frac{\theta\tau_y}{\tau_0 + \tau_y} y. \tag{11}$$

After some algebra, we can also compute the probability the authority assigns to an agent improving its belief:

$$\Pr\left(\Delta_i > 0 \mid y\right) = \Phi\left(-y\tau_y \sqrt{\frac{\tau_0 + \tau_x + \tau_y}{\tau_x\left(\tau_0 + \tau_y\right)}}\right). \tag{12}$$

Equation (11) tells us that after negative news arrives ($y < 0$), the authority expects agents to be more optimistic at date 2 than at date 1 on average ($\mathbb{E}\left[\Delta_i \mid y\right] > 0$). Equation (12) implies that if public news are sufficiently bad, it is expected that almost all agents will improve their beliefs about the fundamental at date 2 ($\lim_{y\to-\infty} \Pr\left(\Delta_i > 0 \mid y\right) = 1$). Those results are in a way expected. When unfavorable public news arrives, it is likely that most agents have received negative news when combining their private and public signals. Since agents overreact to negative news, expectations are more pessimistic, on average, under diagnostic expectations. This suggests that a suspension could be beneficial, since it makes agents more optimistic on average at the time they decide whether to run, and is in line with the arguments presented in the introduction to justify suspensions in financial markets.

However, the argument so far misses two important points: (i) What matters is not how such policies affect average beliefs or the beliefs of most agents, but how it affects the behavior of the agents more likely to change their decisions; (ii) In equilibrium, as public news worsens, the agents more likely to change their decisions become agents that received better news when combining their public and private signals.

Point (i) implies that agents that are close to indifference in equilibrium under diagnostic expectations are those that the authority should pay attention to. That is, agents that observed a private signal x_i close to the equilibrium cutoff without a suspension x^*

may change their decision when they stop overreacting; agents that are far from the cutoff are very decided, and unlikely to change their minds. I refer to the investor observing $x_i = x^*$as the marginal investor, or more broadly, to those observing x_i close to x^*as the marginal investors, where x^* is the equilibrium cutoff without a suspension.

Point (ii) says that, as public news worsens, the identity of marginal investors also changes in equilibrium, becoming agents that received better news when combining their public and private signals: The distorted expectation of the marginal investor without a suspension, $\mathbb{E}^\theta\left[\eta|x^*, y\right]$, is a decreasing function of y.[9] When agents anticipate that others observed worse news, they are relatively more prone to running, even holding constant their expectations about the fundamental. The reason is that they become more pessimistic about the proportion of agents that renew, as they know others observed a bad public signal. For instance, if the public and private signals are equally precise, an agent observing $x_i = 1$ and $y = -1$ is more prone to running than an agent observing $x_i = -1$ and $y = 1$. Both hold the same belief about the fundamental, but the former is more pessimistic about what others think about the fundamental (higher-order beliefs). Hence, as long as agents are not ex-ante very prone to renewing ($z > 1 + \gamma$), sufficiently bad news makes the few agents that receive positive news overall the marginal ones. Point (ii) can be seen as a natural generalization of the so-called publicity multiplier of Morris and Shin (2003) for a setting with diagnostic agents.

Taken together, points (i) and (ii) imply that, after very bad public news arrives, it is likely that the agents that matter for the authority are the few that received positive news. A suspension, precisely because it curbs overreaction, will then worsen the beliefs of those key agents at the time they decide, further increasing the size of the run, even if almost all agents are receiving negative news and overreacting to it.

In short, the argument relies on the fact that suspensions tend to have a very different effect on the average investor (which is an exogenous object) and the marginal investor (which is determined in equilibrium), and particularly so for low and high realizations of the public signal. This is graphically shown with an example in Figure 4, which depicts

[9] Using (5) and (8) we can write:

$$z + \tilde{\mu}_1^* - \gamma\Phi\left(\sqrt{\frac{\tilde{\tau}_1\tau_x}{\tilde{\tau}_1 + \tau_x}}\left(\frac{\left(\tau_0 + \tau_y - \theta\tau_x\right)\tilde{\mu}_1^*}{\tau_x\left(1+\theta\right)} - \frac{\tau_y}{\tau_x}y\right)\right) = 1,$$

where $\tilde{\mu}_1^* = \mathbb{E}^\theta\left[\eta|x^*, y\right]$. Taking derivatives, one can see that the right-hand side of the equation above is strictly increasing in $\tilde{\mu}_1^*$ and y, implying the claim made in the text.

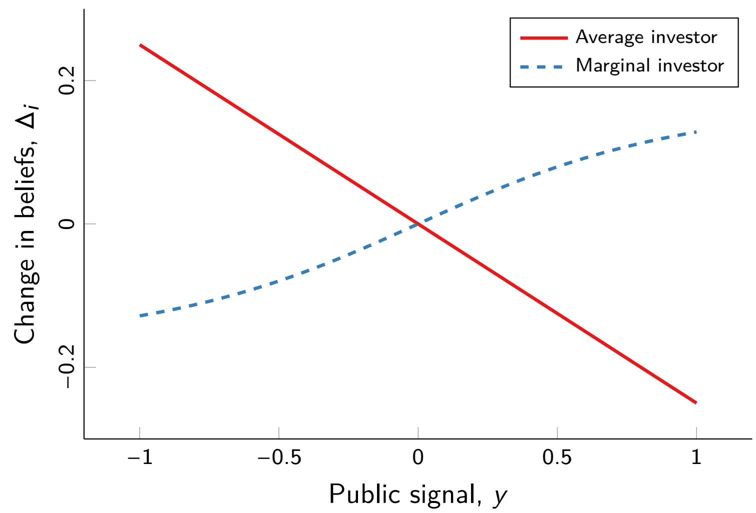

Figure 4: Change in beliefs from date 1 to 2 for average and marginal investor.

Notes. "Average investor" refers to an investor j observing a private signal $x_j = \mathbb{E}\left[x_i | y\right]$, which implies $\Delta_j = \mathbb{E}\left[\Delta_i | y\right]$. "Marginal investor" refers to an investor k observing $x_k = x^*$, where x^* is the equilibrium cutoff without a suspension, and hence $\Delta_k = \mathbb{E}\left[\eta | x^*, y\right] - \mathbb{E}^{\theta}\left[\eta | x^*, y\right]$. The following parameters were used: $\tau_0 = \tau_x = \tau_y = \gamma = 1$, $z = 3/2$, $\theta = 1/2$.

how the beliefs of the average and marginal investor change as agents stop overreacting, for different observations of the public signal.

Proposition 3 also shows that, for a given realization of the public signal, lower ex-ante investment returns make the authority less prone to suspending. This comes from the fact that, when the investment is ex-ante very unprofitable, agents are very inclined to run, and hence the marginal investor will be an agent that observed positive news overall.

The results discussed here also explain why a suspension attenuates runs when ex-ante returns are high and/or public news is good: In such cases, the marginal investor is someone observing negative news, for the reasons already discussed. Of course, if suspensions implied other costs (for reasons outside my model), the authority would not find them optimal in good scenarios where most agents would not run regardless of the policy (high z and/or y).

Finally, note that when z is above $1 + \gamma$, there is no realization of y able to dissuade the authority from implementing a suspension. Similarly, for $z < 1$, the authority always prefers not to implement it.[10] Those are the cases in which investors have a dominant choice before receiving their signals, and hence coordination motives are less strong. In

[10] This follows from $\lim_{y\to\infty} z^* = 1$ and $\lim_{y\to-\infty} z^* = 1 + \gamma$.

such cases, changes in y still affect the beliefs of the marginal investor in the direction emphasized above, but it is never enough to revert the authority's decision.

5.1 Information Quality and Supensions

I now further explore some comparative statics on the information structure. The analysis so far assumes policymakers can alter investors' beliefs simply by forcing them to take some time to absorb incoming information, but take the information received by agents as given. Another common policy used by policymakers to affect beliefs in a context of runs is information disclosure, which aims at directly affecting the type and quality of information received by investors (Iachan and Nenov, 2015, Ahnert and Kakhbod, 2017). If the quality of the information arriving improves, is it more likely that a suspension is desirable? As shown below, the answer depends on the type of information improving (private vs public) and on how vulnerable to runs the economy is from an ex-ante perspective (ex-ante investment returns).

For $z \in (1, 1+\gamma)$, let y^* be the realization of the public signal that makes the authority indifferent between suspending or not. Using Proposition 3, it is given by

$$y^* = -\Phi^{-1}\left(\frac{z-1}{\gamma}\right)\frac{1}{\tau_y}\sqrt{\frac{(\tau_0 + 2\tau_x + \tau_y)\,\tau_x}{\tau_0 + \tau_x + \tau_y}}. \tag{13}$$

The ex-ante probability of a suspension being desirable for $z \in (1, 1+\gamma)$ is then

$$\Pr(y > y^*) = \int_{-\infty}^{\infty} \left[1 - \Phi\left(\sqrt{\tau_y}\,(y^* - \eta)\right)\right] \sqrt{\tau_0}\phi\left(\sqrt{\tau_0}\eta\right) d\eta.$$

For $z \notin (1, 1+\gamma)$ this probability is either zero or one (see Figure 3). The next proposition shows how $\Pr(y > y^*)$ is affected by the quality of the information that arrives in the complementary case.

Proposition 4. *Consider $z \in (1, 1+\gamma)$. Then,*

1. *If $z < 1 + \gamma/2$, $\frac{d\Pr(y>y^*)}{d\tau_y} > 0$ and $\frac{d\Pr(y>y^*)}{d\tau_x} < 0$;*
2. *If $z > 1 + \gamma/2$, $\frac{d\Pr(y>y^*)}{d\tau_y} < 0$ and $\frac{d\Pr(y>y^*)}{d\tau_x} > 0$.*

That is, if ex-ante returns are high, suspensions are more likely to be desirable when investors receive private information of high quality and public information of low quality—

provided coordination motives are strong and agents do not have a dominant action ex ante ($1 < z < 1 + \gamma$). When ex-ante returns are low, the opposite result arises.

To gather intuition, it is useful to first inspect an extreme case. Suppose $\tau_y = 0$, so that the public signal is ignored by agents, and $z \in (1, 1 + \gamma/2)$. An investor observing $x_i = \mathbb{E}[\eta] = 0$ (neutral news) has beliefs that are not distorted. For her to renew, it must then be that $\mathbb{E}[\ell | x_i = 0] > \frac{1-z}{\gamma} > 0.5$ (since $z < 1 + \gamma/2$). However, she believes that half of the agents observed a signal above her. Therefore, the marginal investor must be someone observing positive news ($x_i > 0$). A suspension is then not optimal with probability one, as the realization of the public signal has not effect on the equilibrium behavior of investors and the identity of the marginal investor.

Now suppose τ_y increases, and hence investors no longer ignore the public signal in their decisions. Now, if a sufficiently high public signal realizes, investors become very optimistic about the action of others, and even an investor that observes a quite negative private signal and updates her belief downward may be now be willing to renew simply because it is more optimistic about what others think about the fundamental. The marginal investor then becomes an investor that observed negative news overall with positive probability, in which case a suspension attenuates runs. A similar reasoning helps understand why $\Pr(y > y^*)$ decreases with τ_y for $z > 1 + \gamma/2$.

An increase in the precision of the private signal make agents put less weight on the public signal, and hence an increase in τ_x has an effect similar to a reduction in τ_y, which explains why $\frac{d \Pr(y > y^*)}{d\tau_y}$ and $\frac{d \Pr(y > y^*)}{d\tau_x}$ have opposite signs.

6 Extensions

I now show that the main results of the paper are similar under a few alternative modelling assumptions.

6.1 A Model of Regime Change with Diagnostic Investors

Consider a model with the same assumptions as the model of Section 2, except for the fact that now the payoff of renewing is given by

$$v(\eta, \ell) = \begin{cases} z & \text{if } \gamma\ell \leq \eta, \\ \alpha z & \text{if } \gamma\ell > \eta, \end{cases} \tag{14}$$

where $z > 1$, $\alpha z < 1$ and $\gamma > 0$. Similar payoffs arise in games of regime change (e.g., Angeletos, Hellwig and Pavan, 2007, Sakovics and Steiner, 2012, Iachan and Nenov, 2015). For convenience, when $\gamma \ell \leq \eta$ I say that investment succeeded, and when $\gamma \ell > \eta$ I say that it failed.

The next proposition is the analogous of Proposition 1.

Proposition 5. *Suppose that the following condition holds:*

$$\gamma \frac{\tau_0 + \tau_y - \theta \tau_x}{(1+\theta)\sqrt{\tau_x}} < \sqrt{2\pi}. \tag{15}$$

Then, the model has an essentially unique equilibrium, in which agents renew if $x_i > x^*$, run if $x_i < x^*$, and the investment fails iff $\eta < \eta^*$, where x^* and η^* are the unique solution to

$$\gamma \Phi\left(\sqrt{\tau_x}\left(x^* - \eta^*\right)\right) = \eta^*, \tag{16}$$

$$z - (1-\alpha) z \Phi\left(\sqrt{\tau_0 + \tau_x + \tau_y}\left(\eta^* - \frac{(1+\theta)\left(\tau_x x^* + \tau_y y\right)}{\tau_0 + \tau_x + \tau_y}\right)\right) = 1. \tag{17}$$

Note that the left-hand side of (15) is strictly decreasing in θ. Hence, to guarantee the equilibrium is unique for every $\theta \geq 0$, I impose the following assumption throughout this subsection:

$$\gamma \frac{\tau_0 + \tau_y}{\sqrt{\tau_x}} < \sqrt{2\pi}. \tag{A2}$$

This assumption then plays the same role as assumption (A1) in the main model.

6.1.1 Suspensions

Now consider the model used in Sections 4 and 5, but with the payoffs of investing replaced by (14). Given the payoff structure, the authority might only care about the size of a run up to the point that it affects whether the investment fails or succeeds. Hence, it makes sense to generalize the payoff of the authority, so now I assume that it minimizes

$$\mathcal{L} = \int_{-\infty}^{\infty} \beta\left(\tilde{\ell}(\eta), \eta\right) f(\eta|y)\, d\eta,$$

where $\beta(\ell, \eta)$ is a (weakly) increasing function. I also assume that $\beta(\ell, \eta)$ is not always constant on ℓ: for every η, there exists ℓ_1 and ℓ_2, with $\ell_2 > \ell_1$, such that $\beta(\ell_2, \eta) > \beta(\ell_1, \eta)$. For instance, if $\beta(\ell, \eta) = \ell$, we have the same objective as in Section 5. If, however, $\beta(\ell, \eta) = -z$ for $\ell \leq \eta/\gamma$, and $\beta(\ell, \eta) = -\alpha z$ for $\ell > \eta/\gamma$, then the authority objective is equivalent to maximizing expected investment returns.

The next result is the analogous of Proposition 3.

Proposition 6. *The authority implements a suspension if $z > z^*$, does not implement it if $z < z^*$, and is indifferent when $z = z^*$, where*

$$z^* = 1 + (1-\alpha) z \Phi\left(\tilde{\eta}\sqrt{\tau_0 + \tau_x + \tau_y}\right), \tag{18}$$

and $\tilde{\eta}$ solves $\gamma\Phi\left(-\sqrt{\tau_x}\left(\frac{\tau_y}{\tau_x}y + \tilde{\eta}\right)\right) = \tilde{\eta}$. Moreover, $\frac{dz^*}{dy} < 0$.

6.2 Equilibrium Multiplicity

In this section, I consider the same model presented in Sections 4 and 5, except for the fact that here I do not assume that condition (A1) necessarily holds. Hence, there may be multiple equilibria. To compute how policies affect equilibrium outcomes, one now needs an equilibrium selection criterion, which I discuss below.

As defined before, for a given public signal y, I say that x^* is a cutoff strategy if investors renew if $x_i > x^*$ and run if $x_i < x^*$, and that x^* is a symmetric cutoff equilibrium if all investors playing the cutoff strategy x^* is an equilibrium. Given that investor's payoffs of renewing are strictly increasing in their own private signal, an investor that believes others will follow a cutoff strategy will best-respond by playing a cutoff strategy (see the proof of Proposition 1 for details).

Let then $BR(\tilde{x})$ be the optimal cutoff strategy of an investor that believes all others are playing according to a cutoff strategy $\tilde{x}$ (BR stands for best-response). I say that x^* is a *stable* cutoff equilibrium if $BR(x^*) = x^*$ and $BR'(x^*) < 1$. The latter condition is necessary and sufficient for the best-response dynamics to locally converge to the fixed point x^*. Writing the payoff of renewing as in (19) in Appendix A, one can easily verify that a stable cutoff equilibrium always exists in the model of Section 2, even if (A1) is violated.

In what follows, the largest and smallest stable cutoff equilibrium denotes the symmetric cutoff equilibrium with the largest and smallest cutoff x^*, respectively, among all symmetric cutoff equilibria. I then define two selection criteria:

S1: Investors always play according to the largest stable cutoff equilibrium;

S2: Investors always play according to the smallest stable cutoff equilibrium.

The next proposition generalizes the results in Proposition 3.

Proposition 7. *Suppose that either S1 or S2 holds. Then, there is a* z^{**} *such that the authority implements a suspension if* $z > z^{**}$ *and does not implement it if* $z < z^{**}$*. Moreover,* z^{**} *is a decreasing and non-constant function of the public signal* y*.*

Note that it cannot be guaranteed that z^{**} is *strictly* decreasing in y, but the main insights remain.

6.3 Partial Reversion to Rationality

Now consider the same model of Sections 4 and 5, except for the following deviation: At date 1 agents hold beliefs given by (2) with $\theta = \theta_1 > 0$, and at date 2 they hold beliefs given by (2) with $\theta = \theta_2 \in (0, \theta_1)$. That is, now investors still hold diagnostic beliefs at date 2, but beliefs distortions are smaller than at date 1. The next proposition shows the main result of the paper remains unchanged.

Proposition 8. *The results in Proposition 3 continue to hold in the model where beliefs only partially revert toward rationality.*

7 Final Remarks

This paper proposes a global game model of runs with diagnostic investors, and uses it to formally analyze the behavioral arguments often used to defend suspensions in a context of runs. The key novel normative insight is that an often emphasized potential benefit of suspensions during bad times—namely forcing investors to act only after overreaction to incoming information fades—can actually be a cost in a setting with strategic complementarities.

On the methodological side, the paper shows how to combine standard models of coordination failures (global games) with models of belief formation that depart from rationality (diagnostic expectations). Hence, the proposed model could serve as a starting point to study other problems where coordination and overreaction are important.

I conclude with some remarks on the scope of my contribution. There are certainly other costs/benefits of suspensions driven by channels not present in my model. It is beyond the scope of this paper to conduct a full cost-benefit analysis of suspensions. Instead, the goal here is to characterize under which circumstances the effects of suspensions that operate through curbing overreaction to news—a channel frequently invoked by defendants of those policies—attenuate or amplify runs.

A Proofs

A.1 Proof of Lemma 1

Standard Bayesian updating implies that η conditional on observing a private signal x_i and a public signal y is normally distributed with mean $\frac{\tau_x x_i+\tau_y y}{\tau_0+\tau_x+\tau_y}$ and variance $\left(\tau_0+\tau_x+\tau_y\right)^{-1}$. Hence:

$$f\left(\eta\right| x_i=\hat{x}, y=\hat{y}) = \sqrt{\frac{\tau_0+\tau_x+\tau_y}{2\pi}} \exp\left\{-\frac{\tau_0+\tau_x+\tau_y}{2}\left(\eta-\frac{\tau_x\hat{x}+\tau_y\hat{y}}{\tau_0+\tau_x+\tau_y}\right)^2\right\}.$$

Using (2) we get:

$$f^{\theta}\left(\eta\right| x_i=\hat{x}, y=\hat{y}) = \sqrt{\frac{\tau_0+\tau_x+\tau_y}{2\pi}} \exp\left\{-\frac{\tau_0+\tau_x+\tau_y}{2}\left(\eta-\frac{\tau_x\hat{x}+\tau_y\hat{y}}{\tau_0+\tau_x+\tau_y}\right)^2\right\} \cdot\left[\frac{\exp\left\{-\frac{\tau_0+\tau_x+\tau_y}{2}\left(\eta-\frac{\tau_x\hat{x}+\tau_y\hat{y}}{\tau_0+\tau_x+\tau_y}\right)^2\right\}}{\exp\left\{-\frac{\tau_0+\tau_x+\tau_y}{2}\eta^2\right\}}\right]^{\theta} C.$$

Letting $C = \exp\left\{-\frac{1}{2}\frac{\theta(1+\theta)\left(\tau_x\hat{x}+\tau_y\hat{y}\right)^2}{\tau_0+\tau_x+\tau_y}\right\}$ and simplifying above, we get the density of a normal distribution with mean $\tilde{\mu}_1\left(x_i, y\right)$ and variance $1/\tilde{\tau}_1$. □

A.2 Proof of Proposition 1

Fix a realization of the public signal y. I say that x^* is a cutoff strategy if investors renew if $x_i > x^*$ and run if $x_i < x^*$, and that x^* is a symmetric cutoff equilibrium if all investors playing the cutoff strategy x^* is an equilibrium. Suppose all agents play according to a cutoff strategy x^*. In such case, for a given η, ℓ is equal to

$$\tilde{\ell}(\eta) = \Phi\left(\sqrt{\tau_x}\,(x^* - \eta)\right).$$

Denote by $h(x, x^*)$ the distorted expected payoff of renewing of an agent that observes a private signal x and believes others are playing a cutoff strategy x^*. Using Lemma 1, we can write it as:

$$h(x, x^*) = z + \tilde{\mu}_1(x, y) - \gamma \int_{-\infty}^{\infty} \Phi\left(\sqrt{\tau_x}\,(x^* - \eta)\right) \sqrt{\tilde{\tau}_1}\phi\left(\sqrt{\tilde{\tau}_1}\,(\eta - \tilde{\mu}_1(x, y))\right) d\eta.$$

Now let $k = \sqrt{\tilde{\tau}_1}\,(\eta - \tilde{\mu}_1(x))$ and apply a change of variables to the integral above:

$$h(x, x^*) = z + \tilde{\mu}_1(x, y) - \gamma \int_{-\infty}^{\infty} \Phi\left(\sqrt{\tau_x}\,(x^* - \tilde{\mu}_1(x, y)) - \sqrt{\frac{\tau_x}{\tilde{\tau}_1}}k\right) \phi(k)\, dk.$$

Using the known fact that for any constants a and b, $\int_{-\infty}^{\infty} \Phi(a + bk)\phi(k)dk = \Phi\left(\frac{a}{\sqrt{1+b^2}}\right)$:

$$h(x, x^*) = z + \tilde{\mu}_1(x, y) - \gamma\Phi\left(\sqrt{\frac{\tilde{\tau}_1\tau_x}{\tilde{\tau}_1 + \tau_x}}\,(x^* - \tilde{\mu}_1(x, y))\right). \quad (19)$$

One can easily verify that $h(x, x^*)$ is strictly increasing in x. Hence, the optimal response of an agent that believes others will play a cutoff strategy is to play a cutoff strategy x^{**} satisfying $h(x^{**}, x^*) = 1$. Hence, a necessary and sufficient condition for x^* to be an equilibrium is $h(x^*, x^*) = 1$, that is, (8) must hold. A cutoff equilibrium exists, since $\lim_{x^* \to \infty} h(x^*, x^*) = \infty$ and $\lim_{x^* \to -\infty} h(x^*, x^*) = -\infty$. A sufficient condition for (8) to have an unique solution is that its RHS is strictly increasing in x^*. Differentiating the RHS of (8), one gets the following sufficient condition for equilibrium uniqueness in symmetric cutoff strategies:

$$\frac{\partial\tilde{\mu}_1(x^*, y)}{\partial x_i} - \gamma\phi\left(\sqrt{\frac{\tilde{\tau}_1\tau_x}{\tilde{\tau}_1 + \tau_x}}\,(x^* - \tilde{\mu}_1(x^*, y))\right)\sqrt{\frac{\tilde{\tau}_1\tau_x}{\tilde{\tau}_1 + \tau_x}}\left(1 - \frac{\partial\tilde{\mu}_1(x^*, y)}{\partial x_i}\right) > 0, \quad \forall x^* \in \mathbb{R}. \quad (20)$$

Replacing (6) and $\frac{\partial \tilde{\mu}_1(x^*,y)}{\partial x_i} = \frac{(1+\theta)\tau_x}{\tau_0+\tau_x+\tau_y}$ in (20) and using that the maximum of the standard normal density is $1/\sqrt{2\pi}$, it suffices to check whether

$$\frac{(1+\theta)\,\tau_x}{\tau_0+\tau_x+\tau_y} - \frac{\gamma}{\sqrt{2\pi}}\sqrt{\frac{\left(\tau_0+\tau_x+\tau_y\right)\tau_x}{\tau_0+2\tau_x+\tau_y}}\left(1-\frac{(1+\theta)\,\tau_x}{\tau_0+\tau_x+\tau_y}\right) > 0,$$

which simplifies to (7).

It remains to show that all equilibria are symmetric cutoff equilibria. For a given y, my equilibrium definition is equivalent to Nash Equilibrium in the game where the payoff of renewal is given by (4) and strategies are maps $d : x_i \mapsto \{0,1\}$. I now show that there is an essentially unique strategy profile surviving iterated elimination of strictly dominated strategies (IESDS hereafter), which then implies that all Nash Equilibria are symmetric cutoff equilibria. What follows extends the uniqueness arguments in Morris and Shin (2000) to my setting with diagnostic investors.

Suppose all investors $j \neq i$ follow the strategy of running regardless of the observed signal x_j. Then, investor i strictly prefers to renew when she observes $x_i > \zeta_1$ and strictly prefers to run if $x_i < \zeta_1$, where ζ_1 satisfies $\lim_{x^*\to\infty} h\left(\zeta_1, x^*\right) = z + \tilde{\mu}_1\left(\zeta_1\right) - \gamma = 1$, since $h\left(\cdot\right)$ is strictly increasing in its first argument. Given that payoffs (4) are strictly decreasing in $\tilde{\ell}\left(\eta\right)$, any strategy prescribing running when observing $x_i > \zeta_1$ is a strictly dominated strategy. Now consider the game where we remove strategies that satisfy $d\left(x_i\right) = 0$ for some $x_i > \zeta_1$ from investors' strategy space. Suppose, all investors $j \neq i$ play the cutoff strategy ζ_1. Again, investor i strictly prefers to run (renew) if $x_i < \zeta_2$ ($x_i > \zeta_2$), where ζ_2 satisfies $h\left(\zeta_2, \zeta_1\right) = 1$. Using the same arguments as before, this implies that running after $x_i > \zeta_2$ is part of a strictly dominated strategy in this modified game. Moreover, $\zeta_2 < \zeta_1$, since $h\left(\cdot\right)$ is strictly increasing in the first argument and strictly decreasing in the second. Continuing to eliminate strictly dominated strategies, one constructs a strictly decreasing sequence ζ_n. Such sequence has a lower bound, since whenever x_i is below the x that solves $z + \tilde{\mu}_1\left(x, y\right) = 1$, investors strictly prefer to run regardless of what others do. Therefore, it converges to some ζ_∞ so that any strategy that prescribes running for some $x_i > \zeta_\infty$ does not survive IESDS. Moreover, since $h\left(\zeta_{k+1}, \zeta_k\right) = 1$, for all $k \geq 1$, we have that $h\left(\zeta_\infty, \zeta_\infty\right) = 1$.

Starting with the assumption that all players $j \neq i$ follow the strategy of always renewing, regardless of their signal, and following steps analogous to those in the previous paragraph, one obtains a strictly increasing sequence ξ_n that converges to some ξ_∞

such that: (i) strategies that prescribe renewing for $x_i < \xi_\infty$ do not survive IESDS; (ii) $h(\xi_\infty, \xi_\infty) = 1$. However, given (7), there is an unique x^* satisfying $h(x^*, x^*) = 1$ and hence $\xi_\infty = \zeta_\infty$. Therefore, any strategy that survives IESDS is a cutoff strategy, with cutoff given by the unique solution to $h(x^*, x^*) = 1$. □

A.3 Proof of Proposition 2

Fixing any strategy profile of date-1 and date-2 investors, any investor at date 1 strictly prefers to decide between renewing and running himself than waiting, since waiting is equivalent to delegating the decision to his date-2 self, which at best will lead to its preferred option between actions 0 and 1 but will imply a cost δ. That is, waiting after some signals is a strictly dominated strategy for date-1 investors. Hence, we can eliminate those strategies from the strategy space. The game becomes identical to that of Section 2 from the point of view of date-1 investors, and hence in equilibrium they play according to the cutoff strategy x^* of Proposition 1. □

A.4 Proof of Proposition 3

For notational convenience, define

$$q(x^*, \theta, z) = z + \frac{(1+\theta)\left(\tau_x x^* + \tau_y y\right)}{\tau_0 + \tau_x + \tau_y} - \gamma \Phi\left(\sqrt{\frac{\left(\tau_0 + \tau_x + \tau_y\right)\tau_x}{\tau_0 + 2\tau_x + \tau_y}}\left(x^* - \frac{(1+\theta)\left(\tau_x x^* + \tau_y y\right)}{\tau_0 + \tau_x + \tau_y}\right)\right), \quad (21)$$

which is the LHS of (8) after replacing $\tilde{\mu}_1(x^*, y)$ and $\tilde{\tau}_1$. Condition (A1) implies that $q(x^*, \theta, z)$ is strictly increasing in x^*. Note that, with a suspension, investors play as in Proposition 1 assuming $\theta = 0$. Let $x^*_{eq}(\theta)$ be the equilibrium cutoff of Proposition 1 for a given θ. Denote by x^*_R and x^*_D the equilibrium cutoffs with and without a suspension, respectively. By Proposition 1, we have $q\left(x^*_{eq}(\theta), \theta, z\right) = 1$ for all $\theta \geq 0$, and, using

Proposition 2, $x_R^* = x_{eq}^*(0)$ and $x_D^* = x_{eq}^*(\theta)$. Taking derivatives of $q(\cdot)$ with respect to θ:

$$\frac{\partial q(x^*,\theta,z)}{\partial\theta} = \left(\tau_x x^* + \tau_y y\right) \cdot \frac{\gamma\phi\left(\sqrt{\frac{(\tau_0+\tau_x+\tau_y)\tau_x}{\tau_0+2\tau_x+\tau_y}}\left(x^* - \frac{(1+\theta)\left(\tau_x x^*+\tau_y y\right)}{\tau_0+\tau_x+\tau_y}\right)\right)\sqrt{\frac{(\tau_0+\tau_x+\tau_y)\tau_x}{\tau_0+2\tau_x+\tau_y}} + 1}{\tau_0+\tau_x+\tau_y}, \quad (22)$$

and hence $\operatorname{sgn}\left(\frac{\partial q}{\partial\theta}\right) = \operatorname{sgn}\left(\tau_x x^* + \tau_y y\right)$. Suppose $\tau_x x_{eq}^*(0) + \tau_y y > 0$. Then, $\forall x^* \geq x_{eq}^*(0)$ and $\forall\theta \geq 0$, $\frac{\partial q(x^*,\theta,z)}{\partial\theta} > 0$. Hence, since $\frac{\partial q(x^*,\theta,z)}{\partial x^*} > 0$, $\forall x^*$ and $\forall\theta \geq 0$ (by (A1)), $x_{eq}^*(\theta) < x_{eq}^*(0)$, $\forall\theta > 0$, which implies that $x_D^* < x_R^*$. Similarly, if $\tau_x x_{eq}^*(0) + \tau_y y < 0$, then $\forall x^* \leq x_{eq}^*(0)$ and $\forall\theta \geq 0$, $\frac{\partial q(x^*,\theta,z)}{\partial\theta} < 0$. Hence, in that case, $x_{eq}^*(\theta) > x_{eq}^*(0)$, $\forall\theta > 0$, implying $x_D^* > x_R^*$. Suppose now $\tau_x x_{eq}^*(0) + \tau_y y = 0$. Then $q\left(x_{eq}^*(0), \theta, z\right)$ does not depend on θ, and hence $x_{eq}^*(\theta) = x_{eq}^*(0)$, $\forall\theta \geq 0$, and so $x_R^* = x_D^*$. Hence, a suspension increases (decreases) the equilibrium cutoff iff $x_R^* = x_{eq}^*(0)$ is above (below) $-\frac{\tau_y}{\tau_x}y$. For any given η, the mass of agents running is a strictly increasing function of the cutoff strategy followed by investors. Higher values of z imply lower values of x_R^*, since $\frac{\partial q}{\partial z} > 0$ and $\frac{\partial q}{\partial x^*} > 0$. Therefore, z^* is characterized by the value of z such that $x_R^* = -\frac{\tau_y}{\tau_x}y$:

$$q\left(-\frac{\tau_y}{\tau_x}y, 0, z^*\right) = z^* - \gamma\Phi\left(-y\tau_y\sqrt{\frac{\tau_0+\tau_x+\tau_y}{\left(\tau_0+2\tau_x+\tau_y\right)\tau_x}}\right) = 1, \quad (23)$$

yielding (10). The last statement follows directly from (10). □

A.5 Proof of Proposition 4

Given the symmetry properties the normal distribution, we can rewrite $\Pr(y > y^*)$ as

$$\Pr(y > y^*) = \int_{-\infty}^{\infty}\Phi\left(\sqrt{\tau_y}(\eta - y^*)\right)\sqrt{\tau_0}\phi\left(\sqrt{\tau_0}\eta\right)d\eta. \quad (24)$$

Therefore,

$$\frac{d\Pr(y > y^*)}{d\tau_y} = \int_{-\infty}^{\infty}\left(\frac{\eta - y^*}{2\tau_y} - \frac{dy^*}{d\tau_y}\right)\sqrt{\tau_y}\phi\left(\sqrt{\tau_y}(\eta - y^*)\right)\sqrt{\tau_0}\phi\left(\sqrt{\tau_0}\eta\right)d\eta,$$

where, by differentiating (13),

$$\frac{dy^*}{d\tau_y} = \frac{\left[\tau_y^2 + \left(2\tau_0 + \frac{7\tau_x}{2}\right)\tau_y + (\tau_0 + 2\tau_x)(\tau_0 + \tau_x)\right]\sqrt{\tau_x}\Phi^{-1}\left(\frac{z-1}{\gamma}\right)}{\sqrt{\tau_0 + 2\tau_x + \tau_y}\left(\tau_0 + \tau_x + \tau_y\right)^{3/2}\tau_y^2}. \tag{25}$$

After some algebra, one can conclude that for some scaling constant $\Sigma > 0$, $\Sigma\sqrt{\tau_y}\phi\left(\sqrt{\tau_y}(\eta - y^*)\right)\sqrt{\tau_0}\phi\left(\sqrt{\tau_0}\eta\right)$ is the density of a normal random variable with mean $\frac{\tau_y y^*}{\tau_0+\tau_y}$. Hence,

$$\frac{d\Pr(y > y^*)}{d\tau_y} = \frac{1}{\Sigma}\left[\frac{y^*}{2\left(\tau_0 + \tau_y\right)} - \frac{y^*}{2\tau_y} - \frac{dy^*}{d\tau_y}\right].$$

Replacing y^* and $\frac{dy^*}{d\tau_y}$ using (13) and (25) and simplifying, we get

$$\begin{aligned}\frac{d\Pr(y > y^*)}{d\tau_y} = -\frac{1}{\Sigma}&\frac{\Phi^{-1}\left(\frac{z-1}{\gamma}\right)\tau_x}{2\tau_y^2\left(\tau_0 + \tau_x + \tau_y\right)^{3/2}\left(\tau_0 + \tau_y\right)\sqrt{\left(\tau_0 + 2\tau_x + \tau_y\right)\tau_x}} \\ &\cdot\left[\left(2\tau_0 + 4\tau_y\right)\tau_x^2 + 3\left(\tau_0 + \frac{7}{3}\tau_y\right)\left(\tau_0 + \tau_y\right)\tau_x + \left(\tau_0 + 2\tau_y\right)\left(\tau_0 + \tau_y\right)^2\right].\end{aligned}$$

Therefore, if $z > 1 + \gamma/2$, $\Phi^{-1}\left(\frac{z-1}{\gamma}\right) > 0$ and $\frac{d\Pr(y>y^*)}{d\tau_y} < 0$. If $z < 1 + \gamma/2$, then $\Phi^{-1}\left(\frac{z-1}{\gamma}\right) < 0$ and $\frac{d\Pr(y>y^*)}{d\tau_y} > 0$.

Now differentiate (24) with respect to τ_x:

$$\frac{d\Pr(y > y^*)}{d\tau_x} = -\int_{-\infty}^{\infty}\frac{dy^*}{d\tau_x}\sqrt{\tau_y}\phi\left(\sqrt{\tau_y}(\eta - y^*)\right)\sqrt{\tau_0}\phi\left(\sqrt{\tau_0}\eta\right)d\eta.$$

Differentiating (13) we get

$$\frac{dy^*}{d\tau_x} = -\frac{\left[2\tau_x^2 + 4\left(\tau_0 + \tau_y\right)\tau_x + \left(\tau_0 + \tau_y\right)^2\right]\Phi^{-1}\left(\frac{z-1}{\gamma}\right)}{2\tau_y\left(\tau_0 + \tau_x + \tau_y\right)^{3/2}\sqrt{\left(\tau_0 + 2\tau_x + \tau_y\right)\tau_x}}.$$

Therefore, $\frac{d\Pr(y>y^*)}{d\tau_x} > 0$ if $z > 1 + \gamma/2$, and $\frac{d\Pr(y>y^*)}{d\tau_x} < 0$ if $z < 1 + \gamma/2$. □

A.6 Proof of Proposition 5

Fix a realization of the public signal y and suppose all investors play according to some cutoff strategy x^*, as defined in the proof of Proposition 1. Then, the investment fail iff $\eta < \eta^*$, where η^* is given by the unique solution to (16). In what follows I write η^* as $\eta^*(x^*)$ to emphasize that (16) implicitly defines η^* as a function of x^*. Using the implicit function theorem:

$$\frac{d\eta^*}{dx^*} = \frac{\gamma\sqrt{\tau_x}\phi\left(\sqrt{\tau_x}\left(x^* - \eta^*\left(x^*\right)\right)\right)}{\gamma\sqrt{\tau_x}\phi\left(\sqrt{\tau_x}\left(x^* - \eta^*\left(x^*\right)\right)\right) + 1} > 0.$$

Denote by $H(x, x^*)$ the distorted expected payoff of renewing of an agent that observes a private signal x and believes others are playing a cutoff strategy x^*. Using Lemma 1:

$$H(x, x^*) = z - (1-\alpha) z\Phi\left(\sqrt{\tau_0 + \tau_x + \tau_y}\left(\eta^*(x^*) - \frac{(1+\theta)\left(\tau_x x + \tau_y y\right)}{\tau_0 + \tau_x + \tau_y}\right)\right).$$

Since $H(x, x^*)$ is strictly increasing in x, x^* is a cutoff equilibrium iff $H(x^*, x^*) = 1$. Using (16), note that $\lim_{x^* \to \infty} \eta^*(x^*) = \gamma$ and $\lim_{x^* \to -\infty} \eta^*(x^*) = 0$. An equilibrium then exists, since $\lim_{x^* \to \infty} H(x^*, x^*) = z > 1$ and $\lim_{x^* \to -\infty} H(x^*, x^*) = \alpha z < 1$. In the proof of Proposition 1, the argument used to show that a cutoff satisfying $h(x^*, x^*) = 1$ was the essentially unique equilibrium relied only on two properties of the function $h(x, x^*)$, namely that: (i) $h(x, x^*)$ was strictly increasing in x; (ii) $r(x^*) \equiv h(x^*, x^*)$ was strictly increasing in x^*. If $H(x, x^*)$ and $R(x^*) \equiv H(x^*, x^*)$ satisfy (i) and (ii), respectively, then the same arguments used in the proof of Proposition 1 imply the desired result, after replacing $h(\cdot)$ by $H(\cdot)$ in that proof. That $H(x, x^*)$ is strictly increasing in x is straightforward. To show the second property, first I differentiate $R(x^*)$:

$$\frac{dR}{dx^*} = (1-\alpha) z\phi\left(\sqrt{\tau_0 + \tau_x + \tau_y}\left(\eta^*(x^*) - \frac{(1+\theta)\left(\tau_x x + \tau_y y\right)}{\tau_0 + \tau_x + \tau_y}\right)\right) \cdot \sqrt{\tau_0 + \tau_x + \tau_y}\left[\frac{(1+\theta)\tau_x}{\tau_0 + \tau_x + \tau_y} - \frac{d\eta^*}{dx^*}\right].$$

Since $\phi(k) \leq 1/\sqrt{2\pi}$, we have that $\frac{d\eta^*}{dx^*} \leq \frac{\gamma\sqrt{\tau_x}}{\gamma\sqrt{\tau_x}+\sqrt{2\pi}}$. Hence, a sufficient condition for $\frac{dR}{dx^*} > 0$, for all x^*, is

$$\frac{(1+\theta)\,\tau_x}{\tau_0+\tau_x+\tau_y} > \frac{\gamma\sqrt{\tau_x}}{\gamma\sqrt{\tau_x}+\sqrt{2\pi}},$$

which after rearranging yields condition (15). □

A.7 Proof of Proposition 6

Define $Q(x^*, \theta, z)$ as

$$Q(x^*, \theta, z) = z - (1-\alpha)\, z\Phi\left(\sqrt{\tau_0+\tau_x+\tau_y}\left(k(x^*) - \frac{(1+\theta)\left(\tau_x x^* + \tau_y y\right)}{\tau_0+\tau_x+\tau_y}\right)\right),$$

where $k(x^*)$ denotes the η^* that solves (16) for a given x^*. Replacing the reference to (8) in Proposition 2 by (16) and (17), one can see that the result and its proof also apply to the model of this section. Hence, letting x_R^* and x_D^* denote the equilibrium cutoff with and without a suspension, respectively, by Proposition 5, we have that $Q\left(x_R^*, 0, z\right) = 1$ and $Q\left(x_D^*, \theta, z\right) = 1$. Taking derivatives of $Q(\cdot)$ with respect to θ:

$$\frac{\partial Q}{\partial \theta} = \left(\tau_x x^* + \tau_y y\right)\frac{(1-\alpha)\, z}{\sqrt{\tau_0+\tau_x+\tau_y}}\phi\left(\sqrt{\tau_0+\tau_x+\tau_y}\left(k(x^*) - \frac{(1+\theta)\left(\tau_x x^* + \tau_y y\right)}{\tau_0+\tau_x+\tau_y}\right)\right),$$

and hence $\mathrm{sgn}\left(\frac{\partial Q}{\partial \theta}\right) = \mathrm{sgn}\left(\tau_x x^* + \tau_y y\right)$. Moreover, note that $Q\left(-\frac{\tau_y}{\tau_x}y, \theta, z\right) = 1$ for some $\theta \geq 0$ implies $Q\left(-\frac{\tau_y}{\tau_x}y, \theta, z\right) = 1$ for all $\theta \geq 0$. Given those properties of $Q(\cdot)$, one can then repeat the same arguments in the proof of Proposition 2, replacing $q(\cdot)$ by $Q(\cdot)$, to show that z^* is now given by

$$Q\left(-\frac{\tau_y}{\tau_x}y, 0, z^*\right) = z^* - (1-\alpha)\, z\Phi\left(k\left(-\frac{\tau_y}{\tau_x}y\right)\sqrt{\tau_0+\tau_x+\tau_y}\right) = 1.$$

Letting $\tilde{\eta} = k\left(-\frac{\tau_y}{\tau_x}y\right)$, we get (18). Moreover,

$$\frac{dz^*}{dy} = (1-\alpha)\, z\phi\left(\tilde{\eta}\sqrt{\tau_0+\tau_x+\tau_y}\right)\sqrt{\tau_0+\tau_x+\tau_y}\frac{d\tilde{\eta}}{dy}.$$

Applying the implicit function theorem to $\gamma\Phi\left(-\sqrt{\tau_x}\left(\frac{\tau_y}{\tau_x}y+\tilde{\eta}\right)\right)=\tilde{\eta}$, we get $\frac{d\tilde{\eta}}{dy}<0$, which then proves the last statement. □

A.8 Proof of Proposition 7

The notation in this proof follows the notation used in the proofs of Propositions 1 and 3. I start by representing the stability requirement differently. Using (19) and Lemma 1, we can find $BR(\tilde{x})$ by solving

$$z+\frac{(1+\theta)\left(\tau_x BR(\tilde{x})+\tau_y y\right)}{\tilde{\tau}_1}-\gamma\Phi\left(\sqrt{\frac{\tilde{\tau}_1\tau_x}{\tilde{\tau}_1+\tau_x}}\left(\tilde{x}-\frac{(1+\theta)\left(\tau_x BR(\tilde{x})+\tau_y y\right)}{\tilde{\tau}_1}\right)\right)=1.$$

By the implicit function theorem we have

$$BR'(\tilde{x})=\frac{\gamma\phi\left(\sqrt{\frac{\tilde{\tau}_1\tau_x}{\tilde{\tau}_1+\tau_x}}\left(\tilde{x}-\frac{(1+\theta)\left(\tau_x BR(\tilde{x})+\tau_y y\right)}{\tilde{\tau}_1}\right)\right)\sqrt{\frac{\tilde{\tau}_1\tau_x}{\tilde{\tau}_1+\tau_x}}}{\frac{(1+\theta)\tau_x}{\tilde{\tau}_1}\left[1+\gamma\phi\left(\sqrt{\frac{\tilde{\tau}_1\tau_x}{\tilde{\tau}_1+\tau_x}}\left(\tilde{x}-\frac{(1+\theta)\left(\tau_x BR(\tilde{x})+\tau_y y\right)}{\tilde{\tau}_1}\right)\right)\sqrt{\frac{\tilde{\tau}_1\tau_x}{\tilde{\tau}_1+\tau_x}}\right]}.$$

Using (21), one can verify that $BR'(\tilde{x})<1 \iff \frac{\partial q(\tilde{x},\theta,z)}{\partial x^*}>0$.

Proposition 2 and its proof still apply once one additionally specifies that x^* is the largest (if S1 holds) or the smallest (if S2 holds) solution to (8) that satisfies $\frac{\partial q(x^*,\theta,z)}{\partial x^*}>0$ in its statement. Moreover, with a suspension, investors play according to the largest (if S1 holds) or smallest (if S2 holds) cutoff x^* that satisfies $\frac{\partial q(x^*,\theta,z)}{\partial x^*}>0$ and (8) evaluated at $\theta=0$.

In the remaining of the proof I assume S1 holds, since the proof under S2 follows analogous steps. Let $x^*_{S1}(\theta,z)$ denote the largest x^* satisfying $\frac{\partial q(x^*,\theta,z)}{\partial x^*}>0$ and $q(x^*,\theta,z)=1$, for an arbitrary $\theta\geq 0$. Hence, given a parameter $\theta>0$, $x^*_{S1}(0,z)$ and $x^*_{S1}(\theta,z)$ represent the selected equilibrium cutoff with and without a suspension, respectively. Moreover, if $x^*_{S1}(0,z)<x^*_{S1}(\theta,z)$, then a suspension is optimal for the authority; if $x^*_{S1}(0,z)>x^*_{S1}(\theta,z)$, then a suspension is not optimal.

Using (22), note that if $\tau_x x^*+\tau_y y>0$, then $\frac{\partial q\left(x^\dagger,\theta,z\right)}{\partial\theta}>0$, $\forall x^\dagger\geq x^*$ and $\forall\theta\geq 0$. Suppose that $\tau_x x^*_{S1}(0,z)+\tau_y y>0$. Then, $\forall x^\dagger\geq x^*_{S1}(0,z)$ and $\forall\theta\geq 0$, $\frac{\partial q\left(x^\dagger,\theta,z\right)}{\partial\theta}>0$ and $q\left(x^\dagger,0,z\right)\geq 1$ (otherwise $x^*_{S1}(0,z)$ would not be the largest equilibrium with $\theta=0$, given $\lim_{x^*\to\infty}q(x^*,0,z)=\infty$). This implies $q\left(x^\dagger,\theta,z\right)>1$, $\forall x^\dagger\geq x^*_{S1}(0,z)$ and $\forall\theta>0$. Hence, $x^*_{S1}(0,z)>x^*_{S1}(\theta,z)$, $\forall\theta>0$, and a suspension is not optimal. Now suppose that $\tau_x x_{S1}^*(0,z) + \tau_y y < 0$. An analogous reasoning shows that a suspension is optimal, since $x_{S1}^*(0,z) < x_{S1}^*(\theta,z)$. Since $\frac{\partial q(x_{S1}^*(\theta,z),\theta,z)}{\partial x^*} > 0$, $\frac{\partial q(x^*,\theta,z)}{\partial z} > 0$, $\forall x^*$, and $q(x^\dagger,\theta,z) \geq 1$, $\forall x^\dagger \geq x_{S1}^*(\theta,z)$, an increase in z decreases the equilibrium cut-off, and so $x_{S1}^*(\theta,z)$ is strictly decreasing, but possibly discontinuous, in z. Moreover, $\lim_{z\to\infty} x_{S1}^*(\theta,z) = -\infty$ and $\lim_{z\to-\infty} x_{S1}^*(\theta,z) = \infty$. Hence, z^{**} is uniquely determined by the condition: $x_{S1}^*(0, z^{**} - \epsilon) > -\frac{\tau_y}{\tau_x} y$ and $x_{S1}^*(0, z^{**} + \epsilon) < -\frac{\tau_y}{\tau_x} y$, for all $\epsilon > 0$.

I now show that z^{**} is weakly decreasing in y. For a given y, define the following increasing transformation of x^*: $\mu_1^* = \mu_1(x^*, y)$. We can then write $q(x^*,0,z)$ in terms of μ_1^*:

$$q(x^*,0,z) = \check{q}(\mu_1^*, z, y) = z + \mu_1^* - \gamma\Phi\left(\sqrt{\frac{(\tau_0+\tau_x+\tau_y)\tau_x}{\tau_0+2\tau_x+\tau_y}}\left(\frac{(\tau_0+\tau_y)\mu_1^* - \tau_y y}{\tau_x}\right)\right). \tag{26}$$

For a given z and y, let $w_{S1}(z,y) = \mu_1(x_{S1}^*(0,z), y)$. Hence, $w_{S1}(z,y)$ is the largest μ_1^* that satisfies $\check{q}(\mu_1^*, z, y) = 1$ and $\frac{\partial \check{q}(\mu_1^*,z,y)}{\partial \mu_1^*} > 0$ (since $\frac{\partial q(x^*,0,z)}{\partial x^*} > 0 \iff \frac{\partial \check{q}(\mu_1^*,z,y)}{\partial \mu_1^*} > 0$). Also, $w_{S1}(z,y)$ is strictly decreasing in z, since $x_{S1}^*(0,z)$ is strictly decreasing in z. We can also define z^{**} as the unique value of z that satisfies: $w_{S1}(z-\epsilon, y) > 0$ and $w_{S1}(z+\epsilon, y) < 0$, for all $\epsilon > 0$ (hereafter condition D1). Consider an increase in y from y_1 to $y_2 > y_1$, and denote by z_1^{**} and z_2^{**} the values of z^{**} associated to y_1 and y_2, respectively. Note that $\check{q}(\mu_1^*, z, y)$ is strictly increasing in y. Moreover, $\check{q}(\mu_1^*, z, y_1) \geq 1$, $\forall \mu_1^* \geq w_{S1}(z, y_1)$ (otherwise $w_{S1}(z,y_1)$ would not be the largest μ_1^* satisfying $\check{q}(\mu_1^*, z, y_1) = 1$ and $\frac{\partial \check{q}(\mu_1^*,z,y_1)}{\partial \mu_1^*} > 0$, since $\lim_{\mu_1^*\to\infty} \check{q}(\mu_1^*, z, y) = \infty$). Hence, $w_{S1}(z, y_2) < w_{S1}(z, y_1)$, since $\check{q}(\mu_1^*, z, y_2) > 1, \forall \mu_1^* \geq w_{S1}(z, y_1)$, and so $w_{S1}(z,y)$ is strictly decreasing in y. Suppose by contradiction that $z_2^{**} > z_1^{**}$. Then it must be that for all $\epsilon > 0$

$$w_{S1}(z_1^{**} - \epsilon, y_1) > w_{S1}(z_2^{**} - \epsilon, y_1) > w_{S1}(z_2^{**} - \epsilon, y_2) > 0,$$

$$w_{S1}(z_2^{**} + \epsilon, y_2) < w_{S1}(z_2^{**} + \epsilon, y_1) < w_{S1}(z_1^{**} + \epsilon, y_1) < 0.$$

But then, $z = z_2^{**}$ satisfies condition D1 when $y = y_1$, which contradicts that z^{**} is uniquely defined. To show that z^{**} is not independent of y, using (26), note that $\lim_{y\to\infty} w_{S1}(z,y) = 1 - z$ and $\lim_{y\to-\infty} w_{S1}(z,y) = 1 + \gamma - z$, implying $\lim_{y\to\infty} z^{**} = 1$ and $\lim_{y\to-\infty} z^{**} = 1 + \gamma$. □

A.9 Proof of Proposition 8

The proof is identical to that of Proposition 3, with a few adjustments. First, x_R^* is now defined as $x_R^* = x_{eq}^*(\theta_2)$ and x_D^* as $x_D^* = x_{eq}^*(\theta_1)$. Second, in the text below equation (22), $x_{eq}^*(0)$ should be replaced by $x_{eq}^*(\theta_2)$ and "$\forall\theta > 0$" should be read as "$\forall\theta > \theta_2$". Finally, one should note that $q\left(-\frac{\tau_y}{\tau_x}y, 0, z^*\right) = q\left(-\frac{\tau_y}{\tau_x}y, \theta_2, z^*\right)$, and so (10) is still obtained by solving (23). □

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