WHEN THE PENNY DOESN'T DROP – MACROECONOMIC TAIL RISK AND CURRENCY CRISES

Chanelle Duley
University of Auckland

Prasanna Gai
University of Auckland

NIESR Discussion Paper No. 520
18 November 2020

About the National Institute of Economic and Social Research

The National Institute of Economic and Social Research is Britain's longest established independent research institute, founded in 1938. The vision of our founders was to carry out research to improve understanding of the economic and social forces that affect people's lives, and the ways in which policy can bring about change. Over eighty years later, this remains central to NIESR's ethos. We continue to apply our expertise in both quantitative and qualitative methods and our understanding of economic and social issues to current debates and to influence policy. The Institute is independent of all party political interests.

National Institute of Economic and Social Research
2 Dean Trench St
London SW1P 3HE
T: +44 (0)20 7222 7665
E: enquiries@niesr.ac.uk
www.niesr.ac.uk
Registered charity no. 306083

This paper was first published in November 2020.

When the penny doesn't drop – Macroeconomic tail risk and currency crises

Chanelle Duley and Prasanna Gai

Abstract

We extend the canonical global game model of currency crises to allow for macroeconomic tail risk. The exchange rate peg is attacked if fundamentals reach a critical threshold, or if there is a sufficiently large public shock. Large shocks generate doubt amongst investors about both the state of the world and about what others know, giving rise to multiple equilibria. We find a non-monotonic relationship between tail risk and the probability of (a fundamentals-based) crisis and show how this effect depends on the magnitude and direction of public shocks. Our analysis sheds new light on the way in which international financial contagion played a part in the sterling crisis of 1931.

Keywords: Global games, currency crises, rank beliefs, inter-war gold standard, sterling crisis of 1931.

JEL Classifications: F31, G01, E44, N24

Acknowledgements

We thank Kartik Anand, Jagjit Chadha, Alexandre Dmitriev, Galina Hale, Philipp K¨onig, Steffen Lippert, and seminar participants at the University of Auckland for helpful comments.

Contact details

Duley: Department of Economics, University of Auckland, Sir Owen Glenn Building, 12 Grafton Road, Auckland 1010, New Zealand. Email: chanelle.duley@auckland.ac.nz.

Gai: Department of Economics, University of Auckland, Sir Owen Glenn Building, 12 Grafton Road, Auckland 1010, New Zealand. Email: p.gai@auckland.ac.nz.

When the penny doesn't drop – Macroeconomic tail risk and currency crises*

Chanelle Duley† Prasanna Gai‡

November 9, 2020

Abstract

We extend the canonical global game model of currency crises to allow for macroeconomic tail risk. The exchange rate peg is attacked if fundamentals reach a critical threshold, or if there is a sufficiently large public shock. Large shocks generate doubt amongst investors about both the state of the world and about what others know, giving rise to multiple equilibria. We find a non-monotonic relationship between tail risk and the probability of (a fundamentals-based) crisis and show how this effect depends on the magnitude and direction of public shocks. Our analysis sheds new light on the way in which international financial contagion played a part in the sterling crisis of 1931.

Keywords: Global games, currency crises, rank beliefs, inter-war gold standard, sterling crisis of 1931.

JEL classification: F31, G01, E44, N24.

*We thank Kartik Anand, Jagjit Chadha, Alexandre Dmitriev, Galina Hale, Philipp König, Steffen Lippert, and seminar participants at the University of Auckland for helpful comments.

†Duley: Department of Economics, University of Auckland, Sir Owen Glenn Building, 12 Grafton Road, Auckland 1010, New Zealand. Email: chanelle.duley@auckland.ac.nz.

‡Gai: Department of Economics, University of Auckland, Sir Owen Glenn Building, 12 Grafton Road, Auckland 1010, New Zealand. Email: p.gai@auckland.ac.nz.

1 Introduction

The origin of currency crises has been a subject of long-standing debate. On one view, the deterioration of actual and expected macroeconomic fundamentals — such as large and unsustainable fiscal deficits — *pushes* an economy into crisis and leads to speculative currency attacks (Flood & Garber, 1984, Krugman, 1979). Another view highlights the role that coordination failure amongst investors plays in *pulling* the economy into crisis (Obstfeld, 1996). Crises can arise independently of fundamentals and there is a range of fundamentals over which the exchange rate may be subject to attack, with the trigger being a random, unpredictable, event or "sunspot". The literature on global games shows how these two perspectives can be reconciled if there is imperfect information across investors about the state of fundamentals. A unique equilibrium emerges in which the speculative currency attack is driven by both investor beliefs and macroeconomic fundamentals, rather than by one or other in isolation (Morris & Shin, 1998).[1]

The information structure that gives rise to the (globally) unique equilibrium in the "first-generation" global game model of Morris & Shin (1998) relies on the assumption of common knowledge of uniform *rank beliefs*. If a speculator is asked what rank in the population she occupies with respect to her payoff, any percentile between 0 and 100 is equally likely and this fact is commonly known among all speculators. The global games literature typically either fixes the distribution of the public signal and lets the noise in idiosyncratic private signals tend to zero, or allows both types of signal to be thin-tailed. In either case, rank beliefs become monotone in shocks and, when private information becomes increasingly precise, knowledge of uniform rank beliefs approaches common certainty (Morris et al., 2016). Restricting public and private signals in this fashion, thus, limits analysis of

[1] The literature on banking crises also distinguishes between fundamentals-based and sunspot-based crises. See, for example, Gorton (1988) and Diamond & Dybvig (1983). A global games perspective on bank runs is provided by Rochet & Vives (2004) and Goldstein & Pauzner (2005). See Morris & Shin (2003) and Angeletos & Lian (2016) for authoritative surveys of global games.

how variation in information structure influences the probability of crisis.

Recent work by Morris & Yildiz (2019) provides a "second-generation" global game model that establishes a middle ground between the complete information environment implicit in Obstfeld's (1996) model of currency crises and the first-generation global game approach.[2] Their rationale is grounded in the observation that sudden switches between equilibria tend to follow public events. Whilst relaxing the complete information assumption and retaining the emphasis on common beliefs, they show how fat-tailed public signals about fundamentals generate doubt about both the state of the world and about what others know. This alters the structure of rank beliefs and, if the shock is large enough, enables the rank belief to approach uniformity, making for a "local uniqueness" result. It is therefore possible to pinpoint uniquely rationalisable behaviour as a function of the level of the fundamental and the size of the agent's individual shock.[3]

In this paper, we extend the canonical currency crisis model of Morris & Shin (1998) to allow for fat tails in the distribution of economic fundamentals. In so doing, we provide a cross-generational synthesis that highlights the crucial role of rank beliefs in generating both multiplicity as well as unique predictions. We then consider how the probability of a fundamentals-based crisis responds to shifts in priors about the state of the economy, changes in tail risk, changes in the strength of traders' coordination motives, and the implementation of capital controls. The role of macroeconomic tail risk in currency crises has, surprisingly, received little attention in the vast literature on speculative currency attacks and our paper contributes to the theoretical analysis in this area.

Our results suggest that an improvement in expected fundamentals lowers the probability of a fundamentals-based crisis. Moreover, there is a non-monotonic relationship between

[2] In what follows, we refer to *first- and second-generation global games models*. This is *distinct* from the first- and second-generation nomenclature commonly used in the currency crisis literature to distinguish between models emphasising fundamentals and self-fulfilling beliefs.

[3] Priors needs not be the same across players for a uniquely rationalisable outcome to be realised. Izmalkov & Yildiz (2010) show that rank beliefs encode expectations held by individual players about fundamentals and about others' beliefs. For simplicity, we let the prior be identical across players in what follows.

macroeconomic tail risk and the probability of crisis. When expected fundamentals are good, a decrease in tail risk may reduce the probability of crisis, since the relative likelihood of an attack induced by concerns over tail probabilities falls. But when expected fundamentals are poor, a decrease in tail risk increases the relative likelihood of attack. This is because changes in tail risk alter how traders determine which shocks are considered 'large'. When tail risk is lowered, the coordination problem faced by traders is strengthened as the precision of public information allows them to deduce their ranking in the population with more accuracy. So public events are required to be larger to break down a trader's rank belief. The strength of the prior then determines the degree to which each threshold shifts. These findings suggest a very different transmission mechanism to Prati & Sbracia (2010) who also highlight a non-monotonic relationship between uncertainty and the probability of crisis in the context of a first-generation global game model.

The sterling crisis of September 1931 provides a vivid example of a currency attack triggered by the crystallisation of tail risk.[4] The spring and summer of 1931 was marked by a systemic financial crisis in Europe, heralded by the failure of the Creditanstalt bank in Austria on 11 May. Following a wave of bank failures, German authorities imposed a moratorium on external debt payments on 15 July that had a marked effect on UK banks, many of whom were heavily exposed to the continent through their role as guarantors of debt (Accominotti, 2012). Although UK macroeconomic fundamentals (unemployment, fiscal imbalances etc) had been weak for some time, the degree of UK bank exposure to financial conditions in Europe was a more salient measure of fundamentals from the perspective of traders, whose

[4]The collapse of oil prices in 2020 and the subsequent attacks on the exchange rate pegs of several Gulf countries is a more recent reminder of how large shocks can trigger a currency crisis. Oil prices are well known as an example of a macroeconomic variable whose underlying distribution is fat-tailed (Wilmott & Mason, 2013). On 21 April 2020, against the backdrop of an oil price war between Russia and Saudi Arabia, West Texas crude oil was driven to a negative price (-$37.63/barrel) for the first time in history. Forward markets subsequently priced in a significant depreciation of Gulf currencies, notably the Omani rial. The sharp plunge in oil prices may have served as a public signal that increased speculators' uncertainty about the peg's sustainability, causing their rank beliefs to become diffuse. Traders whose payoffs would have benefited notably from a collapse of the peg may, therefore, have responded by taking a short position on the Omani rial following the large shock to oil prices.

attention would have been focused on the deteriorating international environment.

We argue that the effect of the German moratorium was to diffuse speculators' rank beliefs and render their subsequent attack on sterling a uniquely rationalisable response. This transmission mechanism contrasts sharply with the standard view that public signals restore sufficient approximate common knowledge to set the stage for *possible* equilibrium shifts (e.g. Chwe (2013)). The historical evidence suggests that the economic environment and the Bank of England's policy response became highly uncertain after the moratorium, confounding investors (Accominotti, 2012, Lennard, 2020, Morris et al., 2016). Rank beliefs became more uniform as a consequence, ensuring that the collapse of the peg was the *only* rationalisable outcome. Our analysis, thus, formalises the decisions of market participants and conditions which culminated in the decision of the UK to abandon the gold standard.

Our comparative static results also indicate how the strength of traders' coordination motives and "sand in the wheels of international finance" influence the probability of crisis. When coordination motives are weak, traders place a much higher weight on fundamentals than on the anticipated actions of others. As a result, strong fundamentals are more effective in deterring attacks. But, at the same time, less coordination is also required to mount a successful attack. With weak coordination motives, traders' rank beliefs are diffused for smaller public signals, enabling a uniquely rationalisable response. As a result, outcomes are more predictable following both positive and negative public events. Finally, capital controls may need to be raised significantly to reduce the probability of crisis in situations where macroeconomic tail risks are material. This reflects the dominant effect that tail risks have over individual transaction costs in traders' payoffs when rank beliefs are non-monotone and these costs are relatively small.

The paper proceeds as follows. Sections 2 and 3 describe the model and present the main comparative static results. Section 4 discusses the non-monotonic relationship between macroeconomic tail risk and the probability of fundamentals-based crises. It also interprets the 1931 sterling crisis through the lens of our model. Section 5 relates our contribution to the literature and a final section concludes. Proofs of all propositions are reported in the Appendix.

2 Model

Actions and payoffs. The economy is characterised by a state of fundamentals, $\theta \in \mathbb{R}$. Absent government intervention, the exchange rate is given by $f(\theta)$, where f is strictly increasing in θ so that higher values of θ correspond to stronger fundamentals. We suppose that $f(\theta) = \theta$ in what follows, and that the exchange rate is initially pegged by the government at $e^* \geq \theta$ for all $\theta \in [0, 1]$.

There is a continuum of speculators who choose one of two actions: *attack* by short selling one unit of currency or *refrain* from short selling. The speculator's payoff from a successful attack is $e^* - \theta - t$, where $t > 0$ is a transaction cost associated with short selling. If the attack is unsuccessful, then the speculator incurs the transaction cost but does not receive any capital gain, so her payoff is $-t$. The payoff from refraining from attack is zero.

The government derives a benefit $v > 0$ from defending the exchange rate at the pegged level, but also faces a cost $c(A, \theta)$ from doing so. This cost is increasing in $A \in [0, 1]$, the aggregate number of speculators attacking the currency, and decreasing in θ, the level of fundamentals. The payoff to the government from abandoning the currency is zero. We assume that $c(0, 0) > v$ so that when fundamentals are sufficiently weak, the government prefers to abandon the peg, and $c(1, 1) > v$ so that when all speculators attack, the government abandons the peg even when fundamentals are strong. Additionally, $e^* - 1 < t$, i.e. when fundamentals are sufficiently strong, speculators prefer to refrain from short selling.

When fundamentals fall below $\underline{\theta}$, the value of θ which solves $c(0, \theta) = v$, the government has no reason to continue defending the fixed peg and, no matter how many speculators attack, the peg is abandoned. So provided that t is small relative to $e^* - \theta$, speculators will attack no matter what their beliefs are about the aggregate size of attack, A. Similarly, when fundamentals pass an upper threshold, $\overline{\theta}$, where $e^* - \theta = t$, speculators refrain from attack regardless of the size of A. Our focus is the interval $(\underline{\theta}, \overline{\theta})$ where, if a speculator believes that A is large enough to induce the government to abandon the peg, the rational action is to attack the currency. If there is perfect information about the value of θ defining payoffs, there are multiple self-fulfilling equilibria (Obstfeld, 1996).

Information environment. Following Morris & Yildiz (2019), speculators do not observe θ directly but, instead, receive a private signal

$$x_i = y + \sigma z_i, \tag{1}$$

where $y \in (\underline{\theta}, \overline{\theta})$ is a commonly known prior, z_i is a shock term and $\sigma > 0$ captures shock sensitivity, the inverse of which represents speculators' coordination motive. While the shock is observable only in aggregate to each speculator, it is in fact comprised of two components, namely

$$z_i = \eta + \varepsilon_i, \tag{2}$$

where η is a common shock affecting all speculators' payoffs and ε_i is an idiosyncratic component affecting the payoff of speculator i. The true level of fundamentals is the sum of the common prior and common shock term weighted by the shock sensitivity parameter, i.e., $\theta = y + \sigma\eta$.

The two shocks are independently drawn from the distributions G and H with corresponding probability density functions g and h. These distributions are symmetric around zero, i.e. $h(\varepsilon) = h(-\varepsilon)$ and $g(\eta) = g(-\eta)$, and weakly decreasing on $(0, \infty)$. The two shocks have zero mean and $H(\varepsilon) = 1 - H(\varepsilon)$ and $G(\eta) = 1 - G(\eta)$. We assume that the idiosyncratic component of the shock is log-concave and that the common component is such that

$$g(\eta) \propto \eta^{-\alpha}, \tag{3}$$

for $\alpha > 1$ when η is large. Thus, while the distribution of ε has thin tails, the distribution of η is fat tailed. In our exposition, $\varepsilon \sim \mathcal{N}(0,1)$ and $\eta \sim t(\nu)$, where ν is the degree of freedom.[5]

Modelling the common component as having fat tails relative to the idiosyncratic component reflects speculators' uncertainty about the data generating process for fundamentals. For example, as Hartmann et al. (2010) point out, fat tails may arise if governments operate an "unsteady hand" and orchestrate drastic changes in key macroeconomic variables. Thus, following a large shock which provides a signal that deviates significantly from their priors, speculators become highly uncertain about the strength of fundamentals and — crucially — about what other speculators believe. Let $\tilde{\theta} = \mathrm{E}[\theta|z_i]$ be the posterior expectation over fundamentals, given the individual speculator's shock, z_i.

Rank beliefs provide the basis for determining how a speculator thinks her payoffs from attacking will relate to others' payoffs. The speculator's rank belief is the probability that she assigns to the event that another speculator's shock, z_j, is lower than her own, i.e.

$$R(z) = \Pr[z_j \leq z_i | z_i = z] = \frac{\int H(\varepsilon)h(\varepsilon)g(z-\varepsilon)d\varepsilon}{\int h(\varepsilon)g(z-\varepsilon)d\varepsilon}. \tag{4}$$

The function $R(z)$ is differentiable, symmetric, and satisfies the single-crossing property. It also becomes uniform in the limit, i.e. $R(z) \to 1/2$ as $z \to \infty$.

Timing and equilibrium concept. First, Nature chooses the state of fundamentals, θ. Second, each speculator observes a private signal about these fundamentals, $x_i = y + \sigma z_i$. Conditional on θ, these signals are identical and independent across speculators. A specu-

[5] Each shock term has support $(-\infty, \infty)$.

lator then decides whether or not to attack the currency based on her signal. Finally, the government observes the aggregate size of the attack, A, and the level of fundamentals before deciding whether to defend or abandon the peg. We proceed backwards, solving first for the government's strategy at the final stage, before turning to the game between speculators. A Bayesian Nash equilibrium for this game consists of strategies for the government and the continuum of speculators such that no player has an incentive to deviate.

Equilibrium. Let $a(\theta)$ be the critical mass of speculators needed to trigger the government to abandon the peg at state θ. For $\theta \leq \underline{\theta}$, $a(\theta) = 0$ and for $\theta > 1$, $a(\theta) = 1$. Everywhere else, $a(\theta)$ is the value of A which solves $c(A, \theta) = v$. For analytical tractability, we assume $a(\theta) = f(\theta) = \theta$ for all $\theta \in [0, 1]$.

The optimal strategy for the government is to abandon the exchange rate only if the observed fraction of speculators attacking the currency A is greater than or equal to the critical mass $a(\theta)$ for a given state θ. The government's strategy, π_g, is thus:

$$\pi_g(A) = \begin{cases} \text{abandon} & \text{if } A \geq a(\theta) \\ \text{peg} & \text{otherwise.} \end{cases} \tag{5}$$

Turning to the game among speculators, suppose they each follow a switching strategy,

$$\pi_s(z) = \begin{cases} 1 & \text{if } z_i \leq \hat{z} \\ 0 & \text{otherwise,} \end{cases} \tag{6}$$

where 1 represents *attack* and 0 represents *refrain.* Denote by $s(\theta, \hat{z})$ the size of the aggregate attack by speculators when the state of fundamentals is θ and the shock forming the cutoff point is $\hat{z}$. Hence,

$$s(\theta, \hat{z}) = \Pr[z \leq \hat{z} | \theta]. \tag{7}$$

This suggests that the government abandons the peg once the attack has just passed the critical size $\Pr[z \leq \hat{z}|\theta] = a(\theta)$. For any given individual spectator, the payoff from attacking is calculated from the posterior distribution over the states, conditional on her private signal x_i. If a speculator observes a signal comprising the threshold shock $\hat{z}$, then her expected payoff from attacking is:

$$u(z,s) = \begin{cases} e^* - \tilde{\theta} - t & \text{if } s(\tilde{\theta}, \hat{z}) \geq a(\tilde{\theta}) \\ -t & \text{if } s(\tilde{\theta}, \hat{z}) < a(\tilde{\theta}), \end{cases} \tag{8}$$

where $a(\tilde{\theta})$ is the speculator's expected critical attack size, conditional on observing z_i.[6] Since the speculator gets a payoff of zero by refraining from short selling, the rational decision conditional on observing z_i depends on whether $u(z,s)$ is positive or negative. So if the government follows its optimal strategy and the state of fundamentals is θ, π_s is a rationalisable strategy of the three-stage game if $\pi_s(z) = 1$ whenever $u(z,s) \geq 0$ and $\pi_s(z) = 0$ whenever $u(z,s) < 0$.

The threshold speculator's expectation of the size of the attack is equal to her rank belief. Since $s(\tilde{\theta}, \hat{z}) = R(z)$ at the threshold $\hat{z}$, we can write (8) as

$$u(z,s) = \begin{cases} e^* - \tilde{\theta} - t & \text{if } R(z) \geq a(\tilde{\theta}) \\ -t & \text{if } R(z) < a(\tilde{\theta}). \end{cases} \tag{9}$$

The rank belief function is non-monotonic in z. Crucially, this gives rise to a largest and smallest threshold strategy – the threshold speculator expects the government to abandon

[6] We are implicitly assuming here that speculators know v and $c(\cdot)$, i.e. the benefits and costs to the government of defending the peg.

the peg at the point at which the rank belief reaches the anticipated critical size, i.e.

$$R(z) = a(\tilde{\theta}). \tag{10}$$

Let z^* and z^{**} be the largest and smallest solutions to (10) and let $a^*(\tilde{\theta}) = a(\mathbb{E}[\theta|z_i = z^*])$ and $a^{**}(\tilde{\theta}) = a(\mathbb{E}[\theta|z_i = z^{**}])$ denote the corresponding expected critical attack sizes, conditional on observing these threshold shocks.[7] The strategies associated with these threshold shocks are

$$\begin{aligned} \pi_s^*(z_i) &= \begin{cases} 1 & \text{if } z_i \leq z^* \\ 0 & \text{otherwise.} \end{cases} \\ \pi_s^{**}(z_i) &= \begin{cases} 1 & \text{if } z_i \leq z^{**} \\ 0 & \text{otherwise.} \end{cases} \end{aligned} \tag{11}$$

Figure 1 illustrates the rationalisable actions of speculators when the common component of fundamentals has fat tails.

We next define the threshold fundamentals corresponding to z^* and z^{**}. Conditional on the state of fundamentals, shocks follow a normal distribution with mean η and variance equal to one. The CDF function with respect to the argument $\hat{z}$ is the aggregate attack function $\Phi(\hat{z} - \eta) \equiv s(\theta, \hat{z})$. When speculators follow strategy $\pi_s^{**}(z)$, denote by $\theta^{**} = y + \sigma\eta^{**}$ to be the value of fundamentals for which

$$\Phi(z^{**} - \eta) = y + \sigma\eta. \tag{12}$$

And when speculators follow strategy $\pi_s^*(z)$, let $\theta^* = y + \sigma\eta^*$ be the value of fundamentals

[7] To simplify analysis, we assume that $e^* - f(\tilde{\theta}) = 2t$, so that $z^{**} < \tilde{z} < z^*$, where $\tilde{z}$ is the shock at which attack becomes risk dominant. Attack is risk dominant whenever $\frac{1}{2} \geq t/(e^* - f(\tilde{\theta}))$. This assumption is not crucial for our results: Relaxing it, for example, by changing the functional form of $f(\theta)$, could cause the risk-dominance threshold $\tilde{z}$ to replace z^{**} or z^* as the upper or lower bound defining the uniquely rationalisable strategies of the game. Comparative statics on $\tilde{z}$ are reported in the Appendix.

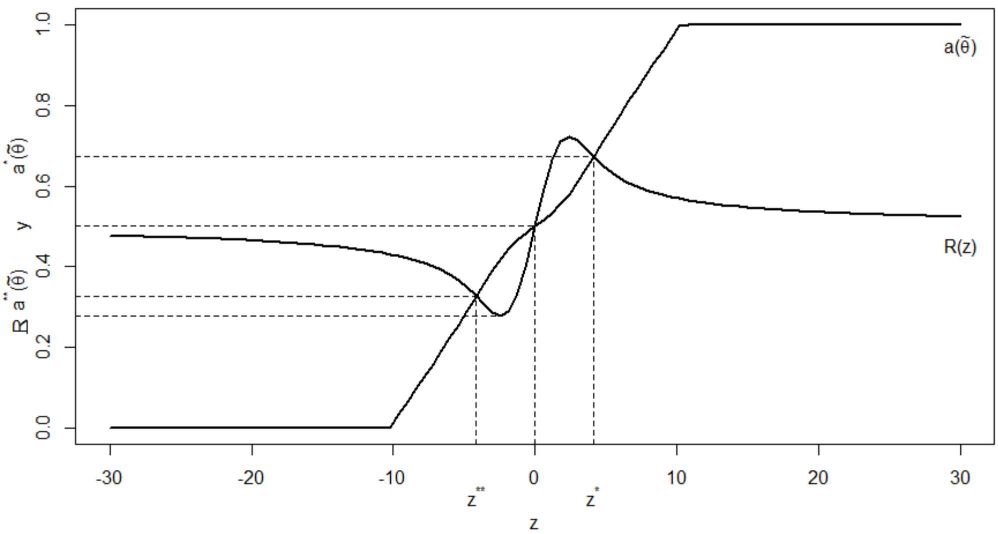

Figure 1: Extremal cutoffs when there is tail risk among speculators. Attack is uniquely rationalisable when $z \leq z^{**}$ and refrain is uniquely rationalisable when $z > z^*$. Both actions are rationalisable in the interval $(z^{**}, z^*]$.

such that

$$\Phi(z^* - \eta) = y + \sigma\eta. \tag{13}$$

Aggregate short sales are decreasing in θ whenever $\theta \in [\underline{\theta}, \theta^{**}]$ and $\theta \in [\theta^*, \overline{\theta}]$, while $a(\theta)$ is increasing in θ over this entire region, resulting in the locally unique thresholds θ^* and θ^{**} for $s(\theta, z^*)$ and $s(\theta, z^{**})$ respectively.[8] The government, for its part, finds it uniquely rationalisable to abandon the peg whenever $\theta \leq \theta^{**}$ and to defend the peg whenever $\theta > \theta^*$,

[8]The multiplicity region is effectively reduced from $(\underline{\theta}, \overline{\theta}]$ to $(\theta^{**}, \theta^*]$, since both actions (abandon, peg) are rationalisable in the region $\theta \in (\theta^{**}, \theta^*]$.

i.e.

$$\pi_g^*(\theta) = \begin{cases} \text{abandon} & \text{if } \theta \leq \theta^*, \\ \text{peg} & \text{otherwise.} \end{cases}$$
$$\pi_g^{**}(\theta) = \begin{cases} \text{abandon} & \text{if } \theta \leq \theta^{**}, \\ \text{peg} & \text{otherwise.} \end{cases} \tag{14}$$

Proposition 1. *(π_g^*, π_s^*) and (π_g^{**}, π_s^{**}) are Bayesian Nash equilibria. Attack is uniquely rationalisable whenever it is risk dominant and $z_i \leq z^{**}$ and refrain is uniquely rationalisable whenever it is risk dominant and $z_i > z^*$. Both actions are rationalisable whenever $z^{**} < z_i \leq z^*$.*

Proposition 1 establishes that when rank beliefs are non-monotonic in z and there is tail risk, the Bayesian Nash equilibria are (π_g^*, π_s^*) and (π_g^{**}, π_s^{**}) and they bound all rationalisable strategies. In addition, the range of intermediate values of θ for which attack and refrain are rationalisable depends on the information structure of the game. It is shaped, in particular, by the degree of tail risk $g(\eta)$ and the strength of the coordination motive amongst speculators, represented by $1/\sigma$.

In order to compare these results with Morris & Shin (1998), we must make two adjustments, with important implications for speculators' strategy profiles. First, we alter the rank belief function so it is monotonic in shocks (and both idiosyncratic and common shocks follow a normal distribution, i.e. $\varepsilon \sim \mathcal{N}(0, s^2)$ and $\eta \sim \mathcal{N}(0, \tau^2)$). And second, we increase the precision of speculators' idiosyncratic shocks to the extent that they adopt Laplacian beliefs and "side step" considerations about $a(\tilde{\theta})$ and what others are doing (so $R(z) \to 1/2$ as the precision of idiosyncratic shocks $\tau^2/s \to \infty$).

The rank belief function approaches that of a 'Generation 1' global game when the tails of $g(\eta)$ become thinner. As the excess kurtosis $\kappa - 3$ of $g(\eta)$ diminishes, the distance $d(z^{**}, z^*) = |z^{**} - z^*|$ expands, making multiplicity prevalent. But as we let the precision of idiosyncratic shocks increase such that $\tau^2/s \to \infty$, the local thresholds give way to a *globally* unique switching point $(\theta^*_{MS}, \tilde{z})$, where $\tilde{z}$ is the risk dominance threshold, and this is equivalent to the unique equilibrium in Morris & Shin (1998).

Proposition 2. *As the tails of $g(\eta)$ become thinner and as idiosyncratic precision becomes infinite, there is a globally unique equilibrium, θ^*_{MS}, at which the government abandons the peg if and only if $\theta \leq \theta^*_{MS}$.*

The result in Proposition 2 highlights the important difference between first and second-generation global games as manifested in speculators' strategies. Once the rank belief function becomes uniform, speculators no longer consider $a(\tilde{\theta})$ relative to $R(z)$ because a constant rank belief function for all z_i provides *approximate common certainty of uniform rank beliefs.* Accordingly, the risk dominant shock, $\tilde{z}$ becomes the unique switching point for attack.

In second-generation global games, both rank beliefs and the expected critical attack size vary with the shock term z_i. While the equivalence of expected payoffs from *attack* and *refrain* under Laplacian beliefs was significant for the 'Generation 1' threshold, in the 'Generation 2' game, the non-negativity of the expected payoff from attacking is insufficient to form an equilibrium strategy. Speculators' responses also depend on the expected aggregate attack size. Figure 2 illustrates the Bayesian Nash equilibria in the presence of tail risk and contrasts them with the globally unique equilibrium of the first-generation model and the thresholds for fundamentals under complete information.

3 Comparative statics

We next turn to the influence that different parameters exert on the locally unique switching points z^* and z^{**}. The probability of a fundamentals-based crisis, i.e $\Pr[\theta \leq \theta^{**}]$ is proportional to these thresholds — the government abandons the peg whenever the realised size of attack, A, exceeds $a(\theta)$ and this happens when negative shocks are large enough in

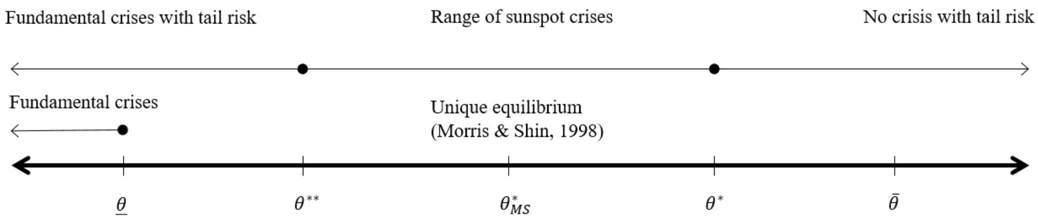

Figure 2: Bayesian Nash equilibria and fundamental thresholds under complete information $(\underline{\theta}, \overline{\theta})$, first-generation global games (θ^*_{MS}) and those with tail risk (θ^{**}, θ^*). In the limit, as beliefs become monotone and as the precision of idiosyncratic shocks tends to infinity, θ^*_{MS} becomes the globally unique switching point for all θ.

magnitude to induce such an attack size. Higher shock thresholds increase the aggregate attack size for a given θ, and this raises the level of fundamentals at which the government is indifferent between defending and abandoning the peg. Ceteris paribus, the probability of this type of crisis is increasing in z^{**} and z^*. The size of the interval is important since it determines how prevalent multiplicity becomes relative to the uniquely rationalisable equilibrium outside these bounds. The interval $d(z^{**}, z^*) = |z^{**} - z^*|$ is proportional to the probability of a "sunspot" based crisis, i.e. $\Pr[\theta^{**} < \theta \leq \theta^*]$. As $d(z^{**}, z^*)$ increases, the game tends towards one with multiple equilibria for all values of $\theta \in (\underline{\theta}, \overline{\theta})$ as in the complete information case; while as $d(z^{**}, z^*) \to 0$, the game becomes dominance solvable as per first-generation global games. Thus, partially differentiating z^{**} and z^* with respect to the core parameters sheds light on both the probability of crisis and the nature of the coordination game being played.

Stronger expected fundamentals. As priors about fundamentals improve, a successful attack appears less plausible to speculators when they consider the likely actions of others. Both cutoffs decrease and this lowers the probability of crisis at any given θ. Since the aggregate attack size is increasing in z^{**} and z^* respectively, the fall in speculators' propensity to attack also causes a reduction in the region of fundamentals at which the peg is always abandoned, i.e. all $\theta \leq \theta^{**}$. Moreover, the region in which the peg is always defended, $\theta > \theta^*$, increases. Formally,

Proposition 3. *An increase in the common prior results in a decrease in z^{**} and z^*, lowering the probability of crisis.*

Figure 3 illustrates. In the left panel, an increase in the common prior for almost all values of $y > \frac{1}{2}$ increases the region of multiplicity. Conversely, an increase in the common prior for almost all values of $y < \frac{1}{2}$ decreases the region of multiplicity.[9] Changes in the common prior do not alter the rank beliefs of speculators; however, a shared view of stronger fundamentals increases the perceived critical attack size required to topple the peg at all levels of individual shocks z_i. When y is initially high and it increases further, speculators find themselves with two rationalisable actions for a greater range of negative shocks. Therefore, a very large negative public event is required to counteract the weighting that speculators place on ex ante expectations about fundamentals.

Precision of public information. An increase in the precision of public information produces a greater range of multiplicity and reduces the range of fundamentals over which refrain is uniquely rationalisable. Conversely, as the excess kurtosis of the common shock increases, making the tail of the distribution 'fatter', the range of shocks over which there is multiplicity of equilibria is reduced. Proposition 4 and Figure 4 summarise this result.

Proposition 4. *As the precision of public information increases, thereby reducing tail risk,*

[9] Using the equilibrium condition to substitute y into the comparative static, we obtain:

$$\frac{\partial z^{**}}{\partial y} = \frac{1}{R'(z) - \frac{\mathbb{E}'(z)}{\mathbb{E}(z)}\left[R(z) - y\right]}, \tag{1}$$

and $\partial z^*/\partial y$ is calculated in the same way. Owing to the shape of $R(z)$ and the assumption that $a(\tilde{\theta})$ is an increasing function of z, the magnitude of the decrease in z^{**} is almost always at least as large as that of z^* for high values of y and the converse holds for low values of y. The exceptions are values of y which are very close to $\underline{y}$ and $\overline{y}$, where $\underline{y}$ denotes the smallest y for which there exists $z < 0$ such that $R(z) \leq a(\tilde{\theta})$ and, by symmetry, $\overline{y} = 1 - \underline{y}$. In this case, changes in z^{**} and z^* may be relatively large owing to the shrinking slope of $R(z)$.

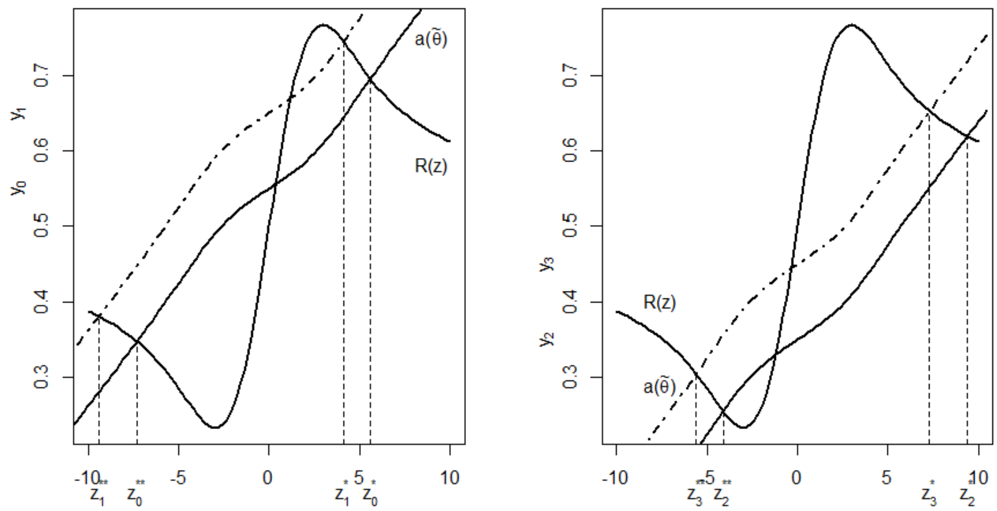

Figure 3: Effect of an increase in prior y on threshold shocks z^{**} and z^{*}. Left panel: $y_0 = 0.55$; $y_1 = 0.65$; $|z_0^* - z_0^{**}| = 12.9$; $|z_1^* - z_1^{**}| = 13.5$. Right panel: $y_2 = 0.35$; $y_3 = 0.45$; $|z_2^* - z_2^{**}| = 13.5$; $|z_3^* - z_3^{**}| = 12.9$. In both panels, $\sigma = 0.05$.

z^{**} decreases and z^{*} increases. The interval $d(z^{**}, z^{*})$ increases as a result. The converse holds for a decrease in the precision of public information.

As the tail of the t-distribution becomes thinner, rank beliefs widen as speculators attribute an increasing proportion of the shocks they observe to idiosyncratic noise and less to the possibility of a tail event. As a result, speculators face two rationalisable actions for a greater range of shocks. There is thus a decrease in the lower threshold z^{**} and an increase in the upper threshold z^{*}, widening the range of multiplicity. In the limit, as public information becomes infinitely precise, tail risk is eliminated entirely and the game collapses back to Morris & Shin (1998) in which speculators play the risk-dominant action in equilibrium. An increase in the precision of public shocks makes coordination concerns

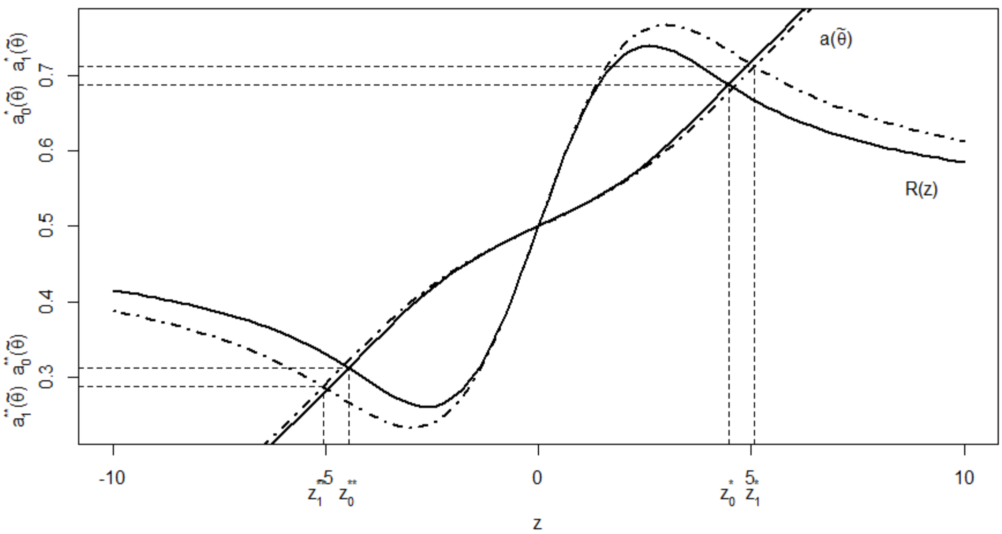

Figure 4: Extremal cutoffs as public information becomes more precise. The solid lines are with $\eta \sim t(2)$ and the dashed lines are with $\eta \sim t(3)$. In both cases, $\sigma = 0.05$ and $y = 0.5$.

more salient for speculators. As a result, both positive and negative shocks need to be much larger to trigger the uncertainty which diffuses speculators' rank beliefs and gives rise to a single rationalisable action.

Coordination motive of speculators. Coordination motives are dampened when shock sensitivity increases, since shocks have a relatively larger impact on a speculator's beliefs about her ability to topple the peg — regardless of the actions of her peers. And since an individual trader is less reliant on collective activity to mount a successful attack, she is more concerned about the state of fundamentals in forming her decision.

Proposition 5. *For all $\underline{\sigma} < \sigma < \overline{\sigma}$, a weaker coordination motive (i.e. an increase in shock sensitivity) increases z^{**} and lowers z^*, thereby reducing $d(z^{**}, z^*)$. The converse holds* *when the coordination motive is stronger.*

Once shock sensitivity passes a threshold, $\overline{\sigma} = R'(0)/\mathrm{E}'[\eta|z = 0]$, the game becomes dominance solvable. Shocks change speculators' perceptions about fundamentals to such an extent that they are no longer concerned with the actions of others. In this case, attack may be uniquely rationalisable without being risk dominant. Similarly, when shock sensitivity is very low, i.e. $\sigma < \underline{\sigma}$, where $\underline{\sigma}$ is an arbitrarily small positive number, the game resembles a complete information game and invites a large range of multiplicity. In this case, most shocks do not provide speculators with any information at all; all they really have is a common prior. Changes in σ do not affect speculators' rank beliefs, but instead change the degree of coordination among speculators which is required to topple the peg for any given level of fundamentals.

To the extent that shock sensitivity determines $d(z^{**}, z^{*})$, the parameter indicates how the second-generation global game model (Morris & Yildiz, 2019) occupies a middle ground between the currency crisis models of Obstfeld (1996) and Morris & Shin (1998). As Figure 5 illustrates, the first-generation global game framework of Morris & Shin (1998) is dominance solvable at one end of the spectrum, whereas coordination is paramount in Obstfeld (1996) at the other end.

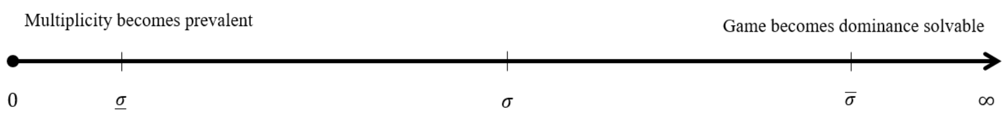

Figure 5: Effect of σ on the overall coordination game.

Figure 6 illustrates the effect of an increase in σ. The effect is to reduce the region of multiplicity so that the respective regions in which attack and refrain are uniquely rationalisable widen. This invites a unique response to relatively smaller negative and positive public events.

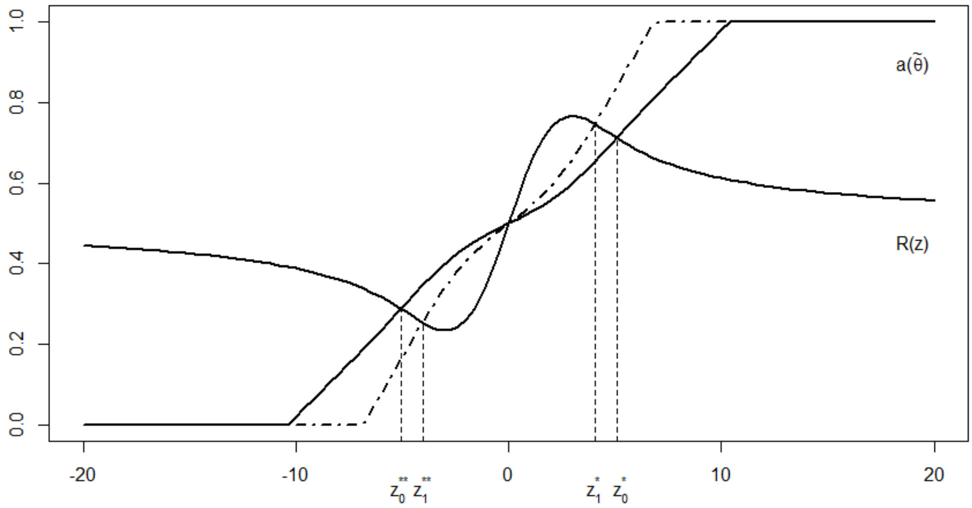

Figure 6: Extremal cutoffs as shock sensitivity rises. The expected critical shock function $a(\tilde{\theta})$ has $\sigma = 0.05$ (solid) and $\sigma = 0.08$ (dashed). In both cases, $y = 0.5$.

Changes in transaction costs. As a final exercise, we examine shifts in t, the transaction cost associated with short selling. In our set-up, provided that $z^{**} < \tilde{z} < z^{*}$, an increase in trading costs does not affect the Bayesian Nash equilibria and the thresholds z^{**} and z^{*} are unchanged. But transaction costs do influence the risk dominance threshold $\tilde{z}$. So, in principle, a large change in transaction costs that causes $\tilde{z}$ to surpass one of the extremal thresholds may lower the overall probability of crisis. Proposition 6 summarises:

Proposition 6. *An increase in transaction costs lowers $\tilde{z}$, the risk dominance threshold. If $\tilde{z} < z^{**}$, then an increase in t reduces θ^{**}, lowering the probability of crisis. But if $z^{**} < \tilde{z} < z^{*}$, then the overall probability of crisis is unaffected.*

If $\tilde{z} > z^{**}$, although an increase in transaction costs causes a speculator's individual net benefits from attacking to be reduced at any given level of fundamentals, at the lower threshold z^{**}, attacking the currency is already a risk dominant response, and so speculators still expect a positive payoff from attacking the currency whenever $z_i \leq z^{**}$. In this way, changes to individual transaction costs do not cause an aggregate reduction in attack size.

Our strong assumption on $f(\theta)$ means that the level of capital controls does not affect the probability of a speculative attack. This is clearly unrealistic. But our analysis does suggest that in more general environments, the size of the speculator's individual shock, z_i, at which attack becomes risk dominant may lie below the critical threshold z^{**}. Capital controls do not affect speculators' rank beliefs. But given that capital controls affect the range of fundamentals over which attack is risk dominant, capital controls lower speculators' propensity to attack if they cause $\tilde{z} < z^{**}$. In such circumstances, capital controls may be effective in curbing crises in the sense of reducing the probability $\Pr[\theta \leq \theta^{**}]$. Whilst previous work (e.g. Eichengreen et al. (1995)) emphasises the potential efficacy of capital controls, our results qualify such assessments and suggest that — in the presence of tail risks — capital controls may only be effective if they are raised significantly or when the risk-dominance threshold binds in equilibrium.[10]

4 Discussion

Tail risk and the probability of crisis. Proposition 3 confirms the finding of Prati & Sbracia (2010) that an improvement in expected fundamentals always lowers the probability of crisis. An increase in the common prior raises expectations that the government is able to defend the peg $a(\theta)$, and lowers the posterior which speculators hold about the event that others observe sufficiently low signals (which causes a drop in z^{**}). Together with

[10]Formally, an increase in transaction costs lowers $\Pr[\theta \leq \theta^{**}]$ if $\Delta t > \hat{\Delta} t$, where $\hat{\Delta} t$ is the increase in t such that $\frac{\partial \tilde{z}}{\partial t} \Delta t = d(z^{**}, \tilde{z})$. See Appendix F for the extent to which a change in transaction costs causes a change in $\tilde{z}$ – the unique equilibrium threshold in the first-generation game.

Proposition 4, our results suggest a *non-monotonic relationship* between tail risk and crises. An increase in the precision of public signals, ν, may lower the probability of crisis when common priors are high ($y \geq \frac{1}{2}$) but increase the probability of crisis when priors are low ($y < \frac{1}{2}$). Although increased precision of public signals always results in a decrease in θ^{**}, when priors are low this decrease is small relative to the increase in θ^{*}. Accordingly, if there is an equal likelihood of crisis and no crisis for $\theta^{**} < \theta \leq \theta^{*}$, then the probability of crisis *relative* to no crisis increases when ν increases and y is low. In other words, the total range of θ over which attack is rationalisable increases, relative to that over which refrain is the rationalisable action. When common priors are high, by contrast, there is an increase in the total range of θ over which refrain is the rationalisable strategy relative to attacking. Figure 7 illustrates.

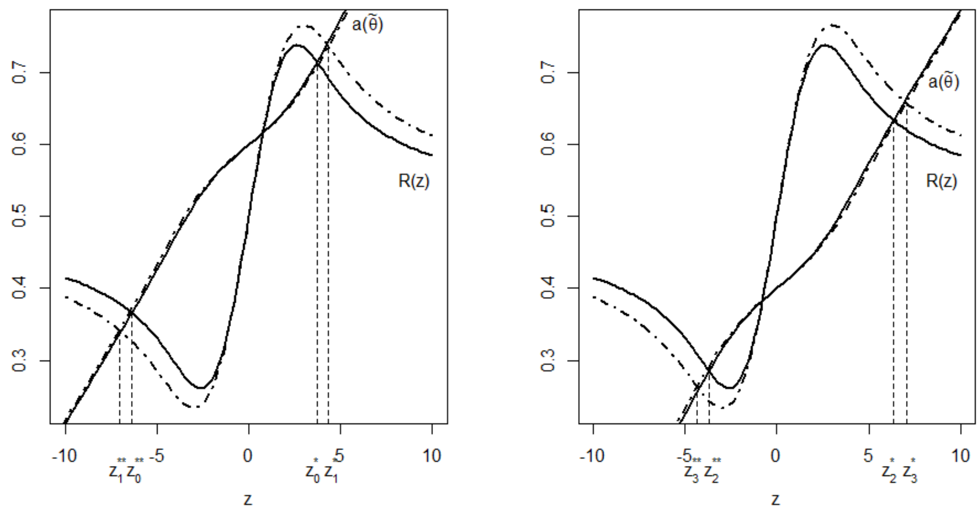

Figure 7: Impact of the common prior on the probability of crisis following an increase in the precision of public signals. Left panel: $y = 0.6$; $|z_0^{**} - z_1^{**}| = 0.79$; $|z_0^{*} - z_1^{*}| = 0.64$. Right panel: $y = 0.4$; $|z_2^{**} - z_3^{**}| = 0.64$; $|z_2^{*} - z_3^{*}| = 0.79$. In both panels, $\sigma = 0.04$.

The mechanism that gives rise to the non-monotonic relationship between public signal precision and the probability of crisis in our model differs from the first-generation global games approach of Prati & Sbracia (2010).[11] The fat-tail assumption means that the crystallisation of 'large shocks' or tail risks creates doubts among speculators about the state of the world and their respective ranking in the population. Increasing the precision of information changes which events are considered 'large' and thereby trigger a unique response by speculators. We expect, therefore, that the probability of crisis can only be determined by analysing both the precision of public information and the magnitude and direction of shocks.

The Sterling Crisis of 1931. Our model offers a new perspective on how the systemic financial crisis in central Europe triggered the devaluation of sterling in 1931, marking the UK's exit from the gold standard. On 11 May, 1931, the failure of Austria's largest bank, Creditanstalt, precipitated a wave of banking panics and currency crises across central Europe. In response to the growing financial instability, and following the failure of the Darmstädter bank on 13 July, the German authorities imposed a moratorium on external debt payments on 15 July in order to avoid depreciation of the Reichsmark. International creditors agreed to reschedule all German short-term debt through standstill agreements (Accominotti, 2012, Cairncross & Eichengreen, 2003).

From the standpoint of investors at the time, the exposure of the UK banking system to the continent was a more apposite measure of fundamentals than other macroeconomic variables. In the years preceding the crisis, macroeconomic fundamentals in the UK were

[11] Earlier work by Sbracia & Zaghini (2001) put forward an additional non-monotonic relationship between the precision of public signals and the propensity of speculators to attack the currency. They suggest that improving the precision of public signals may be more effective in preventing an attack when fundamentals are 'relatively bad' and may, in fact, promote an attack when fundamentals are 'relatively good'. Similarly, we claim in Proposition 4 that, *regardless of expectations about fundamentals*, an increase in the precision of public information may cause speculators to exhibit lower average propensity to attack following negative public events (i.e., z^{**} decreases), and that speculators may exhibit a higher propensity to attack following positive public events (i.e., z^{*} increases). Our mechanism, however, differs from Sbracia & Zaghini (2001), who assume that there is common knowledge of agents' actions.

gradually worsening. Unemployment among insured workers was 16% in 1930, there was a notable dependence of short-term capital inflows and, on some estimates, sterling was overvalued by as much as 10% (Dimsdale & Hotson, 2014, Eichengreen & Hsieh, 1996). But the problems in Austria rendered illiquid some £5 million of British deposits in Vienna, while the German moratorium resulted in £70 million worth of debt to British banks being frozen (Cairncross & Eichengreen, 2003). The immobilisation of short-term assets hindered liquidity to the British financial system, and to London merchant banks in particular (Accominotti, 2012).[12] The famous Macmillan Report (U.K. Parliament, 1931), released on day of the Darmstädter bank failure, further highlighted the UK's "precarious" reliance on short-term external debt.

Our finding of a non-monotonic relationship between tail risk and the probability of crisis suggests that publication of the Macmillan Report may have increased the precision of public information about UK fundamentals following the onset of the Central European panic. Given the already low priors held by investors (i.e., high levels of unemployment and external illiquidity), the increase in public signal precision may have allowed them to better "connect the dots" by painting a clearer picture of the UK's poor economic outlook. Our model suggests that this may have heightened the probability of a crisis relative to no crisis because the range of fundamentals over which attack is rationalisable increases. Indeed, pressure on the peg began to pick up following release of the report. Figure 8a shows how forward prices began to decouple from spot prices from 13 July. Investors who would have otherwise refrained from attacking the peg may have been moved to action by the shift in their rank beliefs brought on by the revelation of public information, although it was only much later that the market's response became strong enough to topple the peg completely (Eichengreen & Hsieh, 1996, Hallwood & Marsh, 2004). The combination of relatively poor

[12] Merchant banks in London acted as guarantors of short-term commercial debts of German merchants. These acceptances represented contingent liabilities which were matched by claims on the debtor. Since no resources needed to be mobilised for these agreements, the banks were able to accept a large number of bills relative to their capital. As a result, the systemic risk accompanying these agreements was not internalised.

fundamentals and accurate public information lengthened the shadow cast over the peg's sustainability.

Viewed through the lens of our model, the German moratorium was a *significant public event* that heightened investors' uncertainty about UK financial stability and, crucially, created doubts about what other investors may have been thinking. Figure 8b shows the steady rise in economic policy uncertainty in the UK following the German moratorium, confirming that investors had become highly uncertain about the environment. The summer of 1931 was a time of political upheaval — the incumbent Labour government collapsed on 23 August 1931 as a result of its perceived inability to rein in fiscal imbalances, and "a general feeling of nervousness" surrounded the intentions of the replacement National Government, renewing speculative pressure on the exchange rate (Cairncross & Eichengreen, 2003).

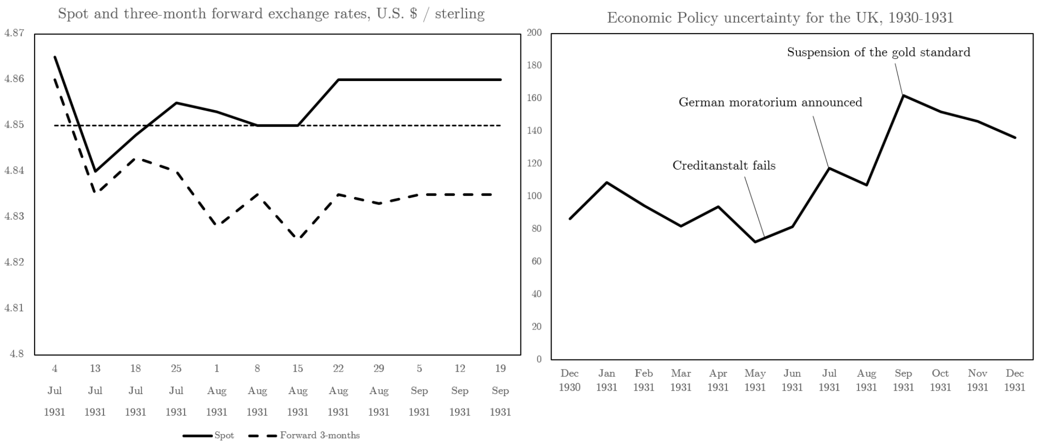

Figure 8: (a) Spot and forward exchange rates leading up to devaluation. Sources: Einzig (1937) and Eichengreen & Hsieh (1996). (b) Economic policy uncertainty for the United Kingdom. Source: Lennard (2020).

The behaviour of market participants during the summer of 1931 also conveys a sense that the rank beliefs of investors were diffuse. Cairncross & Eichengreen (2003) note that in the wider press there was little awareness of the crisis conditions of the time, with the media opting to characterise the event as a "temporary symptom of illiquidity on the Continent rather than as a fundamental loss of confidence in sterling." Hallwood & Marsh (2004) also suggest that devaluation was not expected immediately following the Central European panic or announcement of the moratorium, but rather emerged towards the end of August amidst the Bank of England's dwindling credits. The central bank's policy response to the moratorium also sent mixed signals (Cairncross & Eichengreen, 2003). Market participants had expected the Bank of England to raise official interest rates immediately to signal a commitment to the parity. In the event, the Bank rate was raised after some delay, by one point to 3.5 percent on 23 July, and again by another point to 4.5 percent on 30 July (Figure 9a). Market observers were also perturbed by the Bank of England's seeming reluctance to use its own reserves in strong support of sterling (Figure 9b). A deep intellectual cleavage within the Bank, between Governor Montagu Norman and Deputy Governor Harvey, over the appropriate response to exchange rate pressures served to confound market expectations in the lead-up to the UK's departure from the gold standard on 20 September (Morrison, 2016).[13]

An implication of the second-generation global games approach considered here is that large shocks *will* lead to a crisis (in the sense of a uniquely rationalisable outcome) not that they *may*. The traditional argument is that public signals serve as a focal point and restore common knowledge, thereby introducing multiple equilibria and opening up the *possibility* of a crisis (Chwe, 2013, Morris & Shin, 2003). In our setting, by contrast, large shocks or outsized public signals heighten strategic uncertainty through their effect on rank beliefs, and it is through this mechanism that a crisis becomes *inevitable*.

Informed observers of the time certainly took the view that the Central European shock

[13] At the time of the moratorium, Montagu Norman believed that a Bank rate of 7 or 8 percent would be needed to curb speculative pressure on the exchange rate. By contrast, Harvey believed fiscal profligacy was the root cause of the flight from sterling and favoured reliance on foreign loans, or credits, as a means of ensuring that urgent action to balance the budget could be taken (Morrison, 2016, Williamson, 1984).

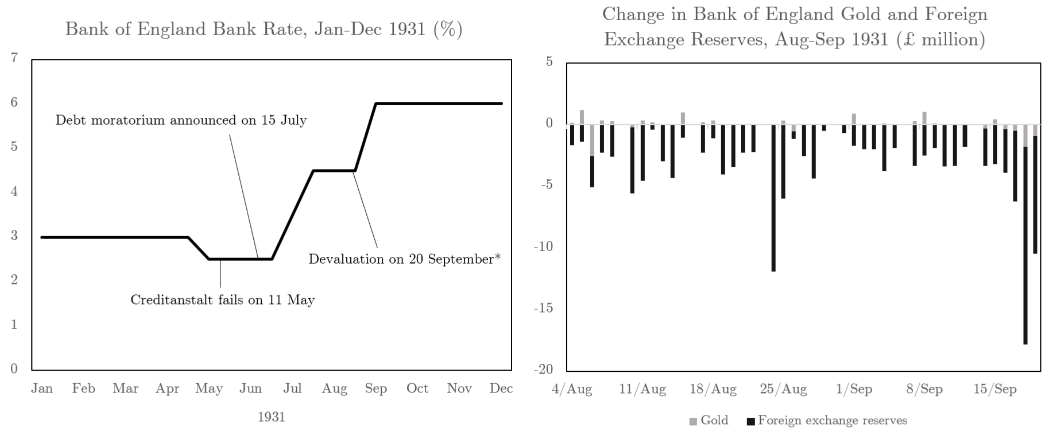

Figure 9: (a) Bank of England Bank Rate. Source: Hills et al. (2017). (b) Bank of England gold and foreign exchange reserves. Source: Cairncross & Eichengreen (2003). *The Bank Rate was left unchanged during the final stages of the crisis and was raised to 6% on 21 September, *after* the departure from gold was announced.

and the events of 15 July had made the collapse of the peg inevitable, consistent with the second-generation global game perspective.[14] Einzig (1932) observed that the suspension of sterling from the gold standard "did not come as a surprise", while Keynes noted in a letter of 5th August to Prime Minister Ramsay MacDonald that:

"...it is now nearly certain that we shall go off the existing parity at no distant date. Whatever may have been the case some time ago, it is now too late to avoid this... But when doubts about the prospects of a currency, such as now exist about sterling, have come into existence, the game is up."[15]

Table 1 provides a brief summary of events and relates it to key elements of the model.

[14]The release of the May Report on 31 July, which painted a bleak picture of the UK's fiscal situation, was the final nail in the coffin that crystallised opinions about the future of sterling (Cairncross & Eichengreen, 2003).

[15]Quoted in Cairncross & Eichengreen (2003), p. 69.

Date	Event	Relation to model
January – May 1931	Central European financial crisis places stress on liquidity of the UK banking system	Fundamentals enter an intermediate range $(\underline{\theta}, \overline{\theta})$
13 July 1931	Macmillan Report is released, exposing the precariousness of UK fundamentals; forwards exchange rate markets begin to decouple from spot rates	Precision of public information is increased in the presence of low priors – z^{**} falls by a lesser degree than the rise in z^{*}
15 July 1931	German debt moratorium is announced; EPU rises steadily	A large negative public shock, η, is observed by speculators, diffusing rank beliefs, increasing uncertainty and making the risk-dominant action uniquely rationalisable
23 July 1931	Bank of England raises Bank Rate by one point to 3.5%	Speculators' uncertainty is amplified
30 July 1931	Bank of England raises Bank Rate by one point to 4.5%; speculators become confounded by lack of commitment by the Bank	Rank beliefs are further diffused
August – September 1931	Pressure on the peg mounts and informed commentators agree that a devaluation is inevitable	Speculators take the action which provides a higher expected payoff under equal likelihood of each outcome
20 September 1931	UK departs from the gold standard	

Table 1: Timeline of the sterling crisis.

5 Relationship to the literature

Our paper is most closely related to the global games literature and, in particular, recent work by Morris & Yildiz (2019) that explores how informational events ("large shocks") trigger equilibrium shifts in coordination games. Indeed, our paper applies their work to the canonical currency crisis setting of Morris & Shin (1998).[16] Our synthesis clarifies how their second-generation global games framework relates to the traditional first-generation global games literature through its emphasis on rank beliefs (Morris et al., 2016).

Relatively few theoretical papers in the currency crisis literature have focused on the role of uncertainty. Flood & Marion (2000) capture uncertainty about fundamentals by introducing a time-varying risk premium in the interest parity condition. Risk averse foreign investors attach this risk premium to domestic currency assets and, as uncertainty about the state of the economy increases, the subsequent change in investor expectations manifests as a change in the actual exchange rate variance of the shadow exchange rate. In this way, they show how decreased uncertainty always lowers the probability of a crisis.

Prati & Sbracia (2010) is, perhaps, the most significant recent theoretical analysis of the link between uncertainty and currency crises. They use a first-generation global game model, in which both public and private signals are normally distributed, to show that (a) an improvement in expected fundamentals always lowers the probability of a speculative attack; and (b) that the effect of uncertainty on the probability of crisis is non-monotonic and varies with expected fundamentals. But the transmission mechanism is very different to the one articulated in this paper. In their model, as information about fundamentals becomes less precise, investors are less reliant on it when deciding whether or not to attack. As information about good fundamentals becomes less reliable, investors lose confidence in economic conditions and are prompted to speculate against the currency. But when information about bad fundamentals becomes less reliable, investors become less certain about the success of an attack and exchange rate pressures subside. The large shock result is absent from their analysis.

[16] Our work, moreover, differs from Heinemann & Illing (2002) who show how the first-generation global game results of Morris & Shin (1998) hold under a broad class of probability distributions, and consider the effect of transparency on the probability of attack.

The literature on the 1931 sterling crisis views the event through the lens of conventional currency crisis models (Krugman, 1979, Obstfeld, 1996). Cairncross & Eichengreen (2003) provide the seminal account of the sterling crisis, while Williamson (1984) and Morrison (2016) shed light on the Bank of England's role during the crisis. In highlighting the role of international contagion as a key factor in the demise of sterling in 1931, our paper is most closely related to Accominotti (2012). He argues forcefully that the shock emanating from the systemic crisis in Central Europe and the ensuing scramble for liquidity was a key trigger for the speculative attack on sterling, and our paper provides formal backing for this view. Eichengreen & Jeanne (2000) present a model in which unemployment is the fundamental variable driving the 1931 crisis. Their approach, which is based on multiple equilibrium "second-generation" currency crisis models with common knowledge (e.g.Obstfeld (1996)), suggests that the sterling crisis is best understood in terms of the pressure brought to bear by foreign shocks on fragile governments with less than credible domestic policy commitments. Schnabel (2004) examines the twin currency and banking crises in Germany, highlighting how political shocks were instrumental in triggering a run on the Reichsmark, while excessive risk-taking by banks that were too-big-to-fail precipitated depositor runs. She emphasises the role of short-term foreign debt as a key factor allowing currency crises and bank runs to feed off each other in a vicious circle.

Our paper also relates to the literature on self-fulfilling debt crises (Calvo, 1988, Cole & Kehoe, 2000) in which coordination failure can lead to subsequent default. Cole & Kehoe (1996), in particular, present a model in which there is a crucial range of fundamentals for which a crisis may occur if there is an unfavourable realisation of the sunspot variable. But a favourable realisation of the sunspot variable results in no crisis. Cole and Kehoe calibrate their model to Mexican data and find that, during the 1994/95 debt crisis, the very short average maturity of domestic debt meant that there was a very large range of fundamentals over which a crisis was possible.

Finally, our paper has points of contact with the literature on disaster risk and exchange rates. Farhi & Gabaix (2016) build on Rietz (1988) and Barro (2006) to argue that rare disasters are an important determinant of risk premia in asset markets. Their focus, however, is on classic exchange rate puzzles (excess volatility, failure of uncovered interest parity), the links between exchange rates and option prices, and the co-movement structure in exchange rates. On the empirical front, Brunnermeier et al. (2008) and Burnside et al. (2011) study the link between currency crash risk and the carry trade premium. And Hartmann et al. (2010) show that when macroeconomic fundamentals are fat-tailed and exchange returns are a linear function of both domestic and foreign fundamentals, a crash in one currency return implies a positive probability of the other currency breaking down as well.

6 Conclusion

First-generation global games provide the analytical grounds for equilibrium selection under incomplete, but very precise, private information. A second-generation global games framework put forward by Morris & Yildiz (2019) demonstrates how agents make decisions in the face of large shocks. We provide a synthesis of the two generations of global games models and analyse how macroeconomic tail risk can trigger a currency crisis. We identify a novel mechanism to explain why there may be a non-monotonic relationship between tail risk and the probability of crisis. Our analysis also casts new light on the events leading up to the UK's suspension of the gold standard in 1931. Application of the second-generation global games framework to other contexts would seem to be a fruitful area for future research.

Appendix

A Proof of Proposition 1

We use the results of Van Zandt & Vives (2007) to show that the game is monotone supermodular, which is sufficient to prove that π_s^* and π_s^{**} form Bayesian Nash equilibria (π_s^*, π_g^*) and (π_s^{**}, π_g^{**}).[17]

First, we establish monotonicity of beliefs. We write $F(\eta, z_{-i}|z_i)$ to denote interim beliefs about the fundamentals of the economy and about what other speculators are likely to observe from the perspective of a given speculator observing z_i. Since $z_j = \eta + \varepsilon_j$, where ε_j is independent of ε_i and η for each $j \neq i$, it suffices to show that $F(\eta|z_i)$ is decreasing in z_i, where $F(\eta|z_i)$ is the conditional distribution of the common shock. Formally,

$$F(\hat{\eta}|z_i) = \Pr[\eta \leq \hat{\eta}|z_i] = \frac{\int_{-\infty}^{\hat{\eta}(\hat{z})} g(\eta)h(z_i - \eta)d\eta}{\int_{-\infty}^{\infty} g(z_i - t)h(t)dt}, \tag{1}$$

for some threshold shock $\hat{z}$ and expected common shock $\hat{\eta}$.

To show that the function $F(\eta|z_i)$ is decreasing in z_i, it suffices to show that the joint density, $p(\eta, z_i) = g(\eta)h(z_i - \eta)$, of these two variables is log-supermodular. Hence,

$$\log\, p(\eta, z_i) = \log\, g(\eta) + \log\, h(z_i - \eta) \tag{2}$$

is supermodular.[18] A function is supermodular if $p(\eta, z_i) + p(\eta, z_i') \leq p(\eta, z_i \wedge z_i') + p(\eta, z_i \vee z_i')$, for any z_i, z_i' in the domain, where $\wedge$ and $\vee$ denote the meet and join respectively of the ordered set $\{Z\}$ (which must be a lattice) (Cooper, 1999).

This establishes that η and z_i are affiliated, and thus interim beliefs are increasing in

[17] And these two extremal monotone equilibria bound all rationalisable strategies Milgrom & Roberts (1990). That is, π_s^* and π_s^{**} are the highest and lowest strategies which survive iterated deletion of strictly dominated strategies.

[18] $\log\, g$ is trivially supermodular and $\log\, h(z_i - \eta)$ is supermodular because $\log\, h$ is concave.

shocks, z, in the sense of first-order stochastic dominance.[19] Moreover, h has thinner tails than g. To see this, recall that we assume that the distribution, h, has thin tails, i.e.

$$\lim_{z\to\infty} \frac{h(z)}{\exp(-cz)} = 0, \tag{3}$$

for some $c > 0$. Therefore, for any non-negative z and z',

$$\lim_{\lambda\to\infty} \frac{h(\lambda z)}{g(\lambda z')} = \lim_{\lambda\to\infty} \frac{h(\lambda z)}{\exp(-c\lambda z)} \frac{\exp(-c\lambda z)}{g(\lambda z)} \frac{g(\lambda z)}{g(\lambda z')} = 0, \tag{4}$$

for all $z, z' \in \mathbb{R}\backslash\{0\}$.[20]

This is sufficient to establish that payoffs are supermodular in speculators' actions, since $u(1, z_{-i}, \theta) - u(0, z_{-i}, \theta)$ is increasing in z_{-i}, where the expected payoff to an attacking speculator i is

$$u(1, z_i, \hat{z}) = \int_{-\infty}^{\hat{\eta}(\hat{z})} (e^* - \tilde{\theta}) f(\eta, z_{-i}|z_i) d\eta - t. \tag{5}$$

Next we show the uniqueness of fundamental thresholds for each shock threshold. Conditional on the state of fundamentals, shocks follow a normal distribution with mean η. The associated cumulative distribution function taking argument $\hat{z}$ is the aggregate attack function: $\Phi(\hat{z} - \eta) \equiv s(\theta, \hat{z})$. When speculators follow strategy $\pi_s^{**}(z)$, we denote by $\theta^{**} = y + \sigma\eta^{**}$ the value of the fundamentals for which the following condition holds:

$$\Phi(z^{**} - \eta) = y + \sigma\eta.$$

Similarly, when speculators follow strategy $\pi_s^*(z)$, we denote by $\theta^* = y + \sigma\eta^*$ the value of fundamentals such that:

$$\Phi(z^* - \eta) = y + \sigma\eta.$$

[19] That is, beliefs about fundamentals are increasing in speculators' individual shocks, z_i.

[20] Since g has regularly-varying tails, $\lim_{\lambda\to\infty} \exp(-cz)/g(\lambda z) = 0$ and $\lim_{\lambda\to\infty} g(\lambda z)/g(\lambda z') \in \mathbb{R}$.

Aggregate short sales are decreasing in θ when $\theta \in (\underline{\theta}, \theta^{**}]$ and when $\theta \in [\theta^*, \overline{\theta})$, while $a(\theta)$ is increasing in θ over this entire region, resulting in locally unique thresholds, θ^{**} and θ^*, for $s(\theta, z^{**})$ and $s(\theta, z^*)$ respectively.

The monotonicity of interim beliefs, compactness of the action set, continuity and supermodularity of the payoff function — and the uniqueness of threshold $\hat{\theta}$ for each threshold $\hat{z}$ — imply that (π_g^*, π_s^*) and (π_g^{**}, π_s^{**}) are Bayesian Nash equilibria and that all rationalisable strategies coincide whenever $\pi_s^* = \pi_s^{**} \Rightarrow \pi_g^* = \pi_g^{**}$.[21] □

B Proof of Proposition 2

To prove the limit uniqueness θ^*_{MS}, we first vary the degree of freedom of $g(\eta)$, which represents the precision of public information. By the law of large numbers, $g(\eta)$ approaches a normal distribution as the degrees of freedom, ν, become infinitely large, and the excess kurtosis of $g(\eta)$ falls to zero.

To see the effects of an increase in ν on the equilibria, we first consider how it influences the threshold shocks, z^{**} and z^*, from which changes to θ^{**} and θ^* automatically follow. An increase in ν causes a 'fattening' of the $R(z)$ function in (4) as follows

$$\frac{\partial R}{\partial \nu} = \frac{Hh * \frac{\partial g}{\partial \nu}(z) h * g(z) - Hh * g(z) h * \frac{\partial g}{\partial \nu}(z)}{[h * g(z)]^2}. \tag{1}$$

At the threshold shock $z^{**} < 0$, this results in a fall in $R(z)$, while it induces a rise in $R(z)$ at threshold shock $z^* > 0$.

An increase in ν also causes a 'tilt' in the expected critical attack size $a(\tilde{\theta})$, which is

[21] If we were to relax our assumption on $\tilde{z}$, then the condition $R(\hat{z}) \geq (<)\ a(\theta|\hat{z})\ \forall z \leq (>)\ \hat{z}$ may no longer be sufficient for $\hat{z}$ to form the lower (upper) shock threshold. We would further require that $F(\hat{\eta}|z_i) \geq (<)\ t/(e^* - \tilde{\theta})\ \forall z \leq (>)\ \hat{z}$.

given by

$$\frac{\partial a(\cdot)}{\partial \nu} = \frac{\sigma\left[\int g(t)h(z-t)dt \cdot \int \eta \frac{\partial g}{\partial \nu}(\eta)h(z-\eta)d\eta - \int \eta g(\eta)h(z-\eta)d\eta \cdot \int \frac{\partial g}{\partial \nu}(t)h(z-t)dt\right]}{\left(g * h(z)\right)^2}. \tag{2}$$

At the threshold shocks, an increase in ν results in an increase and a fall in $a(\tilde{\theta})$ at $z^{**} < 0$ and $z^* > 0$ respectively. Then, by the equilibrium condition (10), this implies $\partial z^{**}/\partial \nu < 0$ and $\partial z^*/\partial \nu > 0$. Since threshold shocks determine the switching point for the government, this also implies that $\partial \theta^{**}/\partial \nu < 0$ and $\partial \theta^*/\partial \nu > 0$.

When $\nu \to \infty$, both the idiosyncratic and common shocks approach a normal distribution, with variance s^2 and τ^2 respectively (and $s^2 = \tau^2 = 1$ if the shocks follow a standard normal distribution). The rank belief function simplifies to the following

$$R_{s,\tau}(z) = \Phi\left(\sqrt{\frac{s^2}{(s^2+2\tau^2)(s^2+\tau^2)}}z\right), \tag{3}$$

where $\Phi(\cdot)$ is the cumulative distribution function of standard normals. This is illustrated in Figure 10.

Theorem 2 in Morris & Shin (1998) holds that as the precision of private shocks increases indefinitely, a unique equilibrium strategy (π_s^*, π_g^*) emerges. If we let $s/\tau^2 \to 0$, the rank belief function tends to the following

$$R_{s,\tau}(z) \to \Phi(0) = \frac{1}{2}. \tag{4}$$

Since this pointwise convergence to uniform rank beliefs occurs for all shocks, there is approximate common certainty of uniform rank beliefs, as in Morris et al. (2016).[22] Therefore,

[22]This convergence is not uniform in the tails. For any (s, τ), $R(z) \to 0$ as $z \to -\infty$ and $R(z) \to 1$ as $z \to \infty$. However, it is sufficient that there is approximate common certainty of uniform rank beliefs for the risk-dominant action to be uniquely rationalisable.

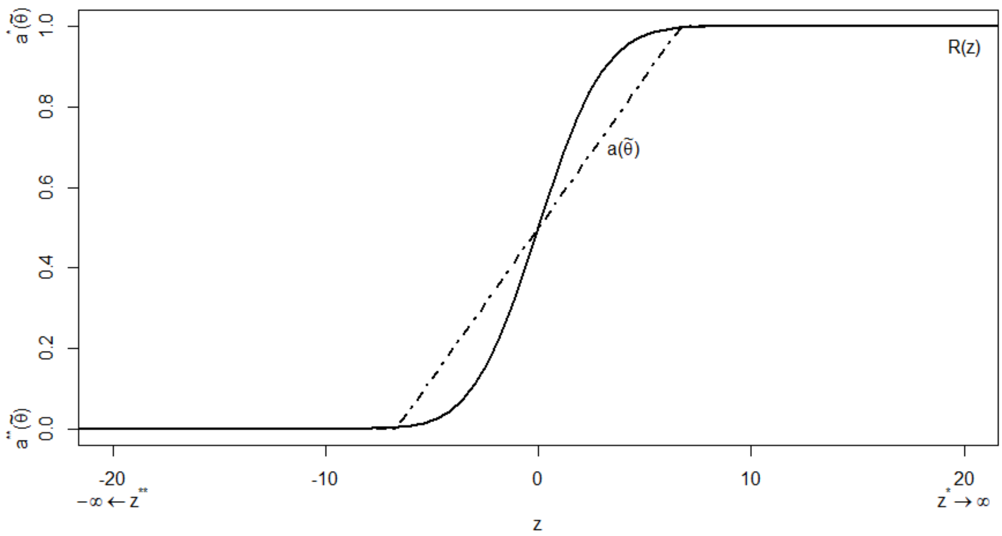

Figure 10: Threshold shocks in the limit as $R(z)$ becomes monotonic. In this limit, both $h(\varepsilon)$ and $g(\eta)$ approximate the standard normal distribution. The large shock results disappear and shocks invoking a uniquely rationalisable action coincide with dominance triggers.

given this approximate common certainty and an equal likelihood of a successful attack and a failed attack, the threshold shock must be the point at which speculators are indifferent between attacking and refraining. This is given by $\tilde{z}$, the solution to $\frac{1}{2}[e^* - f(\theta|z_i)] = t$, and is illustrated in Figure 11.[23] Expected payoffs to a speculator who observes $\tilde{z}$ are positive for all shocks to the left of $\tilde{z}$ and negative for all shocks to the right of it.

By construction, $t > 0$ and $0 < e^* \leq 1$ which implies that $t/[e^* - f(\tilde{\theta})]$ is strictly

[23] Heinemann (2000) corrects the error in Theorem 2 of Morris & Shin (1998) and shows that θ^*_{MS} is implicitly defined by the unique solution to $1 - \theta = t/(e^* - \theta)$. With approximate common knowledge of uniform rank beliefs, speculators can only ever believe with probability $\frac{1}{2}$ that another speculator has observed a shock lower than their own, and that this speculator, in turn, believes that θ is lower than any given point. Therefore, the probability of a successful attack collapses to $\frac{1}{2}$ for all shocks (i.e., $F(\mathbb{E}[\theta|z_i]|z_i) = \frac{1}{2}\ \forall z_i$), making $\tilde{z}$ the unique switching point.

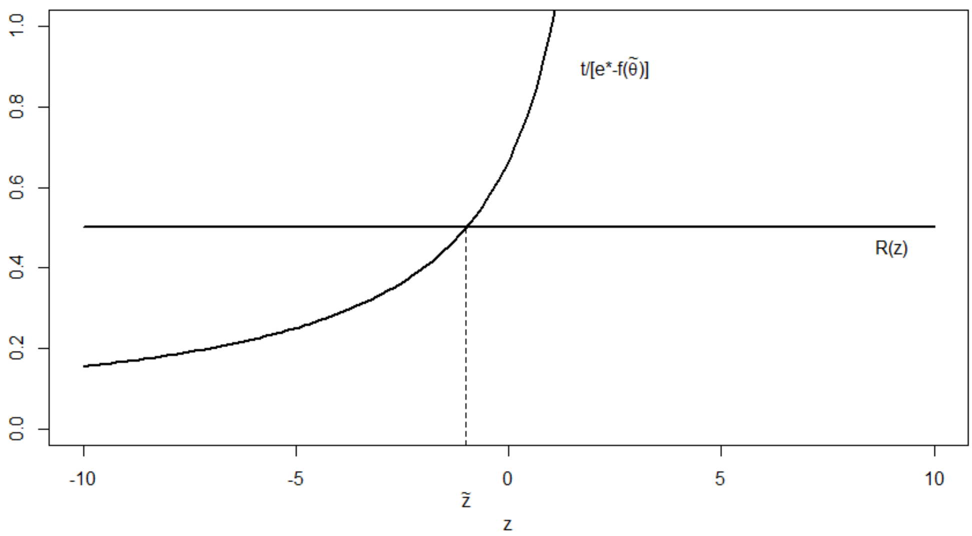

Figure 11: Unique threshold shock in the limit as private information becomes infinitely precise. The indifference condition is the point at which the expected payoff from attacking is equivalent to the expected payoff from refraining.

increasing in z for all $f(\tilde{\theta}) < e^*$. Since $R(z)$ is constant for all z, there is a unique shock $\tilde{z}$ such that the net expected payoff from attacking is exactly zero. Given the unique switching point $\tilde{z}$, we turn to aggregate conditions. Since aggregate short sales $s(\theta, \tilde{z})$ are decreasing in θ and since $a(\theta)$ is strictly increasing in θ, we now have a *globally* unique trigger, θ^*_{MS}, forming the equilibrium switching point for the government. $\square$

C Proof of Proposition 3

The impact of an increase in the common prior, y, on threshold z^{**} is determined as follows

$$\frac{\partial z^{**}}{\partial y} = \frac{1}{\frac{\partial R(z)}{\partial z} - \sigma \frac{\partial \mathbb{E}[\eta|z]}{\partial z}} < 0. \tag{1}$$

The sign of the partial derivative of z^{**} with respect to y is the same as that of z^*. Both are non-positive since $\partial R(z)/\partial z \leq 0$ and $\sigma \partial \mathbb{E}[\eta|z]/\partial z > 0$ at the smallest and largest solutions to (10). To see this, first consider the rank belief function $R(z)$. Observe that $R(z)$ can be defined as follows:

$$R(z) = \frac{Hh * g(z)}{h * g(z)}, \tag{2}$$

where $f_1 * f_2(z) = \int f_1(t) f_2(z-t) dt$ denotes the convolution of f_1 and f_2. Since convolution is associative, and provided that $\partial g(z-\varepsilon)/\partial z$ exists for all $\varepsilon \in \mathbb{R}$, we can evaluate $\partial R(z)/\partial z$ at points z^{**} and z^* as follows

$$\frac{\partial R(z)}{\partial z} = \frac{h * g(z) \cdot Hh * \frac{\partial g}{\partial z}(z) - Hh * g(z) \cdot h * \frac{\partial g}{\partial z}(z)}{(h * g(z))^2}. \tag{3}$$

Next, we show that (1) is non-positive. First, $z^{**} \leq \overline{z}(\underline{R}) < 0$ as per the proof of Proposition 4 by Morris & Yildiz (2019), where $\underline{R}$ is the minimum rank belief, given distributions g and h. Further, by the definition of $\underline{R}$ and the uniform limit rank beliefs property, $\partial R(z)/\partial z \leq 0$ for all $z \leq \overline{z}(\underline{R})$. By symmetry, $z^* \geq \overline{z}(\overline{R}) > 0$, where $\overline{R} = 1 - \underline{R}$ and, by the definition of $\overline{R}$ and the uniform limit rank beliefs property, $\partial R(z)/\partial z \leq 0$ for all $z \geq \overline{z}(\underline{R})$.

Now consider the conditional expectation function

$$\mathbb{E}[\eta|z] = \frac{\int \eta g(\eta) h(z-\eta) d\eta}{\int g(t) h(z-t) dt}. \tag{4}$$

As with the rank belief function, provided that $\partial h(z-\eta)/\partial z$ exists for all $\eta \in \mathbb{R}$, $\partial \mathbb{E}[\eta|z]/\partial z$

is given by

$$\frac{\partial \mathbb{E}[\cdot]}{\partial z} = \frac{\int g(t)h(z-t)dt \cdot \int \eta g(\eta)\frac{\partial}{\partial z}h(z-\eta)d\eta - \int \eta g(\eta)h(z-\eta)d\eta \cdot \int g(t)\frac{\partial}{\partial z}h(z-t)dt}{(g * h(z))^2}. \tag{5}$$

Since η and z are affiliated, $\partial\mathbb{E}[\eta|z]/\partial z$ is positive for all z and since $\sigma > 0$ by assumption, we obtain $\partial z/\partial y < 0$ at points z^{**} and z^*, as desired.

The decrease in z^{**} is proportional to a decrease in the threshold θ^{**}, below which the government's optimal response is to abandon the peg. By total differentiation of the government's indifference condition (12) we obtain the following:

$$\frac{\partial \Phi(\cdot)}{\partial s}\left[\frac{\partial s}{\partial z^{**}}\frac{\partial z^{**}}{\partial y} + \frac{\partial s}{\partial \eta}\frac{\partial \eta}{\partial y}\right] - 1 - \sigma\frac{\partial \eta}{\partial y} = 0, \tag{6}$$

where $s = z^{**} - \eta$. Rearranging the above gives us

$$\frac{\partial \eta}{\partial y} = \left[1 - \phi(z^{**} - \eta)\frac{\partial z^{**}}{\partial y}\right]\left[-\phi(z^{**} - \eta) - \sigma\right]^{-1} < 0. \tag{7}$$

We have already established that $\partial z^{**}/\partial y < 0$. This makes the numerator is positive, since the density function $\phi(z^{**} - \eta)$ is non-negative for all values of z^{**} and η. We also have that $\sigma > 0$ by assumption; this is sufficient to show that the denominator is negative and thus $\partial \eta^{**}/\partial y < 0$. Since $\partial z^*/\partial y$ is also non-positive, we have that $\partial \eta^*/\partial y < 0$ and, therefore, both fundamental thresholds are decreasing in the common prior, as desired. □

D Proof of Proposition 4

By the proof of Proposition 2, we have established that $\partial z^{**}/\partial \nu < 0$ and $\partial z^*/\partial \nu > 0$. This is sufficient to show that $d(z^{**}, z^*) = |z^{**} - z^*|$ widens.

Since the CDFs in the government's indifference conditions in (12) and (13) are increasing in z^{**} and z^* respectively, this suffices to show that $\partial\eta^{**}/\partial\nu < 0$ and $\partial\eta^*/\partial\nu > 0$ and, hence, the respective regions in which the peg is always abandoned and always defended are both reduced. □

E Proof of Proposition 5

First consider the effect of an increase in σ on z^{**}. This is given by the partial derivative of z^{**} with respect to σ, given by

$$\frac{\partial z^{**}}{\partial \sigma} = \frac{\mathbb{E}[\eta|z_i = z^{**}]}{\frac{\partial R(z)}{\partial z} - \sigma\frac{\partial \mathbb{E}[\cdot]}{\partial z}}, \tag{1}$$

From the proof of Proposition 3, we have $\partial R(z)/\partial z \leq 0$ and $\sigma\partial\mathbb{E}[\cdot]/\partial z > 0$ at $z^{**} < 0$ when $\sigma < R'(0)/\mathbb{E}'[\eta|z = 0]$ and when $y \in (\underline{y}, \overline{y})$, where $\underline{y}$, as the smallest y for which there exists $z < 0$ such that:

$$R(z) \leq a(\tilde{\theta}), \tag{2}$$

and $\overline{y} = 1 - \underline{y}$.

Since η and z_i are affiliated, $z^{**} < 0 \Rightarrow \mathbb{E}[\eta|z^{**}] < 0$. We have shown that both the numerator and denominator of (1) are negative, so we have $\partial z^{**}/\partial\sigma > 0$.

Next, consider the effect of an increase in σ on z^*, given by

$$\frac{\partial z^{*}}{\partial \sigma} = \frac{\mathbb{E}[\eta|z_i = z^{*}]}{\frac{\partial R(z)}{\partial z} - \sigma\frac{\partial \mathbb{E}[\cdot]}{\partial z}}. \tag{3}$$

Again, from the proof of Proposition 3, we have $\partial R(z)/\partial z \leq 0$ and $\sigma\partial\mathbb{E}[\cdot]/\partial z > 0$ at $z^* > 0$. Since η and z_i are affiliated, $z^* > 0 \Rightarrow \mathbb{E}[\eta|z^*] > 0$, and we obtain $\partial z^*/\partial\sigma < 0$. This is sufficient to show that $d(z^{**}, z^*) = |z^{**} - z^*|$ shrinks following an increase in σ.

In the limit, when $\sigma \to R'(0)/\mathbb{E}'[\eta|z = 0]$, these thresholds converge so that $d(z^{**}, z^*) =$

$|z^{**} - z^*| \to 0$ and when $\sigma > R'(0)/\mathbb{E}'[\eta|z = 0]$, $R(z) \geq a(\tilde{\theta})$ for all $z_i \leq z^{**} = z^*$ and $R(z) < a(\tilde{\theta})$ for all $z_i > z^{**} = z^*$ so that a unique equilibrium (π_g^*, π_s^*) is obtained for all $\theta \in (\underline{\theta}, \overline{\theta})$.

□

F Proof of Proposition 6 and changes to the risk-dominance threshold

The individual indifference condition under uniform rank beliefs is the value of z_i which solves

$$1/2[e^* - f(\theta|z_i)] = t. \tag{1}$$

Changes in transaction costs, t, induce changes in the risk-dominance threshold $\tilde{z}$ given by

$$\frac{\partial \tilde{z}(\tilde{\theta})}{\partial t} = -2\left[\frac{\partial f(\theta|z)}{\partial z}\right]^{-1} < 0. \tag{2}$$

By assumption, $f'(\theta|z) \geq 0$ for all z. This suffices to show that $\partial\tilde{z}/\partial t < 0$.

If $d(z^{**}, \tilde{z})$ is sufficiently small that Δt causes $\tilde{z}' < z^{**}$, the increase in t also causes a proportional decrease in θ^{**}. To see this, note that $\tilde{z'}$ becomes the extremal threshold which determines η^{**} as follows:

$$\Phi(\tilde{z}' - \eta) - y - \sigma\eta = 0. \tag{3}$$

A decrease in $\tilde{z}$ lowers η^{**}, i.e. the value of η for which (3) holds. This suffices to show that θ^{**} falls following an increase in t, and so $\tilde{z}$ replaces z^{**} as the extremal threshold and equilibrium switching point.

The risk dominance threshold also depends on our other parameters. As the common prior, y, increases, $\tilde{z}$ decreases. A stronger initial outlook means that refrain is risk dominant for a greater range of shocks. This change is given by

$$\frac{\partial \tilde{z}}{\partial y} = -\frac{\partial f(y+\sigma\mathbb{E}[\eta|z])}{\partial y}\left[2\frac{\partial f(y+\sigma\mathbb{E}[\eta|z])}{\partial z}\right]^{-1} \leq 0. \tag{4}$$

Since $f(\theta|z)$ is strictly increasing in θ, $\partial f(\cdot)/\partial y \geq 0$ and $\partial f(\cdot)/\partial z > 0$ for all $z \in \mathbb{R}$.

As public information becomes increasingly precise, the effect on $\tilde{z}$ is as in the proof of Proposition 2, given our assumption that $a(\tilde{\theta}) = f(\tilde{\theta}) = \tilde{\theta}$. The change is given by the following

$$\frac{\partial f(\cdot)}{\partial \nu} = \frac{\sigma\left[\int g(t)h(z-t)dt \cdot \int \eta\frac{\partial g}{\partial \nu}(\eta)h(z-\eta)d\eta - \int \eta g(\eta)h(z-\eta)d\eta \cdot \int \frac{\partial g}{\partial \nu}(t)h(z-t)dt\right]}{(g * h(z))^2}. \tag{5}$$

When $\tilde{z} < 0$, $\partial\tilde{z}/\partial\nu > 0$ and when $\tilde{z} \geq 0$, $\partial\tilde{z}/\partial\nu < 0$.

The risk-dominance threshold, $\tilde{z}$, falls as shock sensitivity, σ, increases. A higher value of σ implies weaker coordination motives, as speculators' expected payoffs become increasingly dependent on the strength of fundamentals rather than on the actions of other speculators. This lowers the risk-dominance threshold at each value of fundamentals. The change is given by

$$\frac{\partial \tilde{z}}{\partial \sigma} = -\frac{\partial f(\theta|z)}{\partial \sigma}\left[2\frac{\partial f(\theta|z)}{\partial z}\right]^{-1} \leq 0. \tag{6}$$

Since $f(\theta|z)$ is strictly increasing in z and σ, we have $\partial f(\cdot)/\partial\sigma \geq 0$ and $\partial f(\cdot)/\partial z > 0$ for all $z \in \mathbb{R}$. □

References

Accominotti, O. (2012). London merchant banks, the Central European panic, and the sterling crisis of 1931. *The Journal of Economic History*, 1–43.

Angeletos, G.-M., & Lian, C. (2016). Incomplete information in macroeconomics: Accommodating frictions in coordination. In *Handbook of macroeconomics* (Vol. 2, pp. 1065–1240). Elsevier.

Barro, R. J. (2006). Rare disasters and asset markets in the twentieth century. *The Quarterly Journal of Economics*, *121*(3), 823–866.

Brunnermeier, M. K., Nagel, S., & Pedersen, L. H. (2008). Carry trades and currency crashes. *NBER Macroeconomics Annual*, *23*(1), 313–348.

Burnside, C., Eichenbaum, M., & Rebelo, S. (2011). Carry trade and momentum in currency markets. *Annual Reviews*.

Cairncross, A., & Eichengreen, B. (2003). The 1931 devaluation of sterling. In *Sterling in decline* (pp. 27–110). Springer.

Calvo, G. A. (1988). Servicing the public debt: The role of expectations. *The American Economic Review*, 647–661.

Chwe, M. S.-Y. (2013). *Rational ritual: Culture, coordination, and common knowledge.* Princeton University Press.

Cole, H. L., & Kehoe, T. J. (1996). A self-fulfilling model of Mexico's 1994/95 debt crisis. *Journal of International Economics*, *41*, 309–330.

Cole, H. L., & Kehoe, T. J. (2000). Self-fulfilling debt crises. *The Review of Economic Studies*, *67*(1), 91–116.

Cooper, R. (1999). *Coordination games*. Cambridge University Press.

Diamond, D. W., & Dybvig, P. H. (1983). Bank runs, deposit insurance, and liquidity. *Journal of Political Economy*, *91*(3), 401–419.

Dimsdale, N., & Hotson, A. (2014). *British financial crises since 1825*. Oxford University Press.

Eichengreen, B., & Hsieh, C.-T. (1996). Sterling in decline again: The 1931 and 1992 crises compared. In *European economic integration as a challenge to industry and government* (pp. 355–392). Springer.

Eichengreen, B., & Jeanne, O. (2000). Currency crisis and unemployment: Sterling in 1931. In *Currency crises* (pp. 7–43). University of Chicago Press.

Eichengreen, B., Tobin, J., & Wyplosz, C. (1995). Two cases for sand in the wheels of international finance. *The Economic Journal*, *105*(428), 162–172.

Einzig, P. (1932). *The tragedy of the pound*. London: K. Paul, Trench, Trubner.

Einzig, P. (1937). *Theory of forward exchange*. Macmillan and Company, London.

Farhi, E., & Gabaix, X. (2016). Rare disasters and exchange rates. *The Quarterly Journal of Economics*, *131*(1), 1–52.

Flood, R. P., & Garber, P. M. (1984). Collapsing exchange-rate regimes: Some linear examples. *Journal of International Economics*, *17*(1-2), 1–13.

Flood, R. P., & Marion, N. P. (2000). Self-fulfilling risk predictions: An application to speculative attacks. *Journal of International Economics*, *50*(1), 245–268.

Goldstein, I., & Pauzner, A. (2005). Demand–deposit contracts and the probability of bank runs. *The Journal of Finance*, *60*(3), 1293–1327.

Gorton, G. (1988). Banking panics and business cycles. *Oxford Economic Papers*, *40*(4), 751–781.

Hallwood, C. P., & Marsh, I. W. (2004). Exchange market pressure on the pound–dollar exchange rate: 1925–1931. *The North American Journal of Economics and Finance*, *15*(2), 249–264.

Hartmann, P., Straetmans, S., & de Vries, C. G. (2010). Heavy tails and currency crises. *Journal of Empirical Finance*, *17*(2), 241–254.

Heinemann, F. (2000). Unique equilibrium in a model of self-fulfilling currency attacks: Comment. *American Economic Review*, *90*(1), 316–318.

Heinemann, F., & Illing, G. (2002). Speculative attacks: Unique equilibrium and transparency. *Journal of International Economics*, *58*(2), 429–450.

Hills, S., Thomas, R., & Dimsdale, N. (2017). A millennium of macroeconomic data for the UK. *The Bank of England's Historical Macroeconomic and Financial Statistics: Version*, *3.1*.

Izmalkov, S., & Yildiz, M. (2010). Investor sentiments. *American Economic Journal: Microeconomics*, *2*(1), 21–38.

Krugman, P. (1979). A model of balance-of-payments crises. *Journal of Money, Credit and Banking*, *11*(3), 311–325.

Lennard, J. (2020). Uncertainty and the great slump. *The Economic History Review*.

Milgrom, P., & Roberts, J. (1990). Rationalizability, learning, and equilibrium in games with strategic complementarities. *Econometrica*, *58*(6), 1255–1277.

Morris, S., & Shin, H. S. (1998). Unique equilibrium in a model of self-fulfilling currency attacks. *American Economic Review*, 587–597.

Morris, S., & Shin, H. S. (2003). Global games: Theory and applications. In *Advances Economics And Econometrics Theory And Applications Eighth World Congress* (Vol. 1).

Morris, S., Shin, H. S., & Yildiz, M. (2016). Common belief foundations of global games. *Journal of Economic Theory*, *163*, 826–848.

Morris, S., & Yildiz, M. (2019). Crises: Equilibrium shifts and large shocks. *American Economic Review*, *109*(8), 2823–54.

Morrison, J. A. (2016). Shocking intellectual austerity: The role of ideas in the demise of the gold standard in Britain. *International Organization*, *70*(1), 175–207.

Obstfeld, M. (1996). Models of currency crises with self-fulfilling features. *European Economic Review*, *40*(3-5), 1037–1047.

Prati, A., & Sbracia, M. (2010). Uncertainty and currency crises: Evidence from survey data. *Journal of Monetary Economics*, *57*(6), 668–681.

Rietz, T. A. (1988). The equity risk premium a solution. *Journal of monetary Economics*, *22*(1), 117–131.

Rochet, J.-C., & Vives, X. (2004). Coordination failures and the lender of last resort: Was Bagehot right after all? *Journal of the European Economic Association*, *2*(6), 1116–1147.

Sbracia, M., & Zaghini, A. (2001). Expectations and information in second generation currency crises models. *Economic Modelling*, *18*(2), 203–222.

Schnabel, I. (2004). The German twin crisis of 1931. *Journal of Economic History*, 822–871.

U.K. Parliament. (1931). *Report of the Committee of Finance and Industry* [Macmillan Report]. Parliament Paper.

Van Zandt, T., & Vives, X. (2007). Monotone equilibria in Bayesian games of strategic complementarities. *Journal of Economic Theory*, *134*(1), 339–360.

Williamson, P. (1984). A 'Bankers' Ramp'? Financiers and the British political crisis of August 1931. *The English Historical Review*, *99*(393), 770–806.

Wilmot, N. A., & Mason, C. F. (2013). Jump processes in the market for crude oil. *The Energy Journal*, *34*(1).