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Self-fulfilling Runs:
Evidence from the U.S. Life Insurance Industry*

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Abstract

The interaction of worsening fundamentals and strategic complementarities among investors renders identification of self-fulfilling runs challenging. We propose a dynamic model to show how exogenous variation in firms' liability structures can be exploited to obtain variation in the strength of strategic complementarities. Applying this identification strategy to puttable securities offered by U.S. life insurers, we find that 40 percent of the $18 billion run on life insurers by institutional investors during the summer of 2007 was due to self-fulfilling expectations. Our findings suggest that other contemporaneous runs in shadow banking by institutional investors may have had a self-fulfilling component.

JEL Codes: G01, G22, G23, E44
Keywords: Shadow banking, self-fulfilling runs, life insurance companies, funding agreement-backed securities

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Introduction

Institutions and markets that are vulnerable to runs pose a threat to financial stability. In the traditional model of banking, individual banks fund long-term illiquid assets with short-term demand deposits, rendering them vulnerable to depositor runs. By contrast, in shadow banking, financial intermediation is performed by chains of institutions operating outside of the regulated banking sector (Cetorelli, Mandel & Mollineaux 2012). While chains of shadow banking institutions facilitate greater risk sharing in the economy, each link in the chain may be vulnerable to runs, potentially increasing the fragility of the financial system. Policies designed to address the threat to financial stability from runs have focused on traditional banks, where the causes of runs have been studied extensively, but there remains considerable debate among academics and policy makers on the causes of runs affecting shadow banking. Understanding the mechanisms behind these runs is vital to address the vulnerabilities of the financial system.

In this paper we study the role of self-fulfilling expectations in shadow bank runs, that is, when investors run because they expect other investors will run and there are strategic complementarities. In an empirical setting, we would like to analyze investors' responses to other investors' actions. But to study how actions of individuals in a group are associated with actions of the group requires us to confront the reflection problem (Manski 1993). The key empirical hurdle to identifying self-fulfilling runs is that investors may be running in response to common fundamentals.[1] Indeed, theory suggests that the two reasons are connected (Morris & Shin 1998, Goldstein & Pauzner 2005, He & Xiong 2012). Weak fundamentals trigger a run, which is amplified by investors' self-fulfilling expectations about other investors' actions. The interaction between fundamentals and strategic complementarities renders empirical identification of self-fulfilling runs very challenging (Goldstein 2012).

We tackle this empirical challenge using a strategy based on exogenous variation in investors' strategic complementarity. We first develop a dynamic model to show how firms' liability structures are associated with the degree of strategic complementarity

[1] The term fundamentals includes, for example, changes in investors' liquidity demand, risk appetite, regulatory constraints, or information about the liquidity of an issuer. Fundamentals may be revealed to all agents, as in Allen & Gale (1998), or asymmetrically, as in Chari & Jagannathan (1988). Other studies of fundamental-based runs include Gorton (1988), Jacklin & Bhattacharya (1988), Calomiris & Gorton (1991), Saunders & Wilson (1996), Chen (1999) and Calomiris & Mason (2003).

among investors.[2] Intuitively, the larger is the amount that investors might withdraw from a firm, the stronger is investors' strategic complementarity. As a consequence, a self-fulfilling run can arise in the model. As in Morris & Shin (1998), Goldstein & Pauzner (2005) and He & Xiong (2012), adverse fundamentals interact with potential investor withdrawals, amplifying the initial adverse fundamental shock. We derive the conditions under which a self-fulfilling run equilibrium is unique. And we show that the prospect of bad fundamentals can trigger a self-fulfilling run when the amount that can be withdrawn becomes high. Even a small probability that fundamentals may be bad in the future, when combined with a possibility of significant withdrawals by other investors, is enough for an investor to run today. The model suggests that progress towards identifying self-fulfilling runs can be made by exploiting exogenous variation in firms' liability structures.

We take this identification strategy to the data using contractual features of puttable liabilities issued by U.S. life insurers to institutional investors. Since the early 2000s, U.S. life insurers issued *extendible funding agreement-backed notes* (XFABN) to access short-term wholesale funding markets. On pre-determined recurring *election dates*, investors in these securities decide whether or not to extend the maturity of their holding.[3] Hence, XFABN are puttable in the sense that investors have the option not to extend the maturity of any or all of their holdings. In such cases, the non-extended holdings are converted into short-term fixed maturity securities with new security identifiers. This funding structure is analogous to an asset-backed commercial paper (ABCP) program with full liquidity guarantees from the issuers. XFABN are designed to appeal to short-term investors, such as money market mutual funds (MMFs), whose investment decisions may be constrained by liquidity and concentration requirements.[4]

We first document that institutional investors ran on U.S. life insurers' XFABN at the same time that they ran on the ABCP market (Covitz, Liang & Suarez 2013,

[2] Several recent papers have offered alternative sources of variation in strategic complementarity. Chen, Goldstein & Jiang (2010) use the liquidity of investments by U.S. mutual funds as a measure of strategic complementarities among investors in each fund. Hertzberg, Liberti & Paravisini (2011) exploit the 1998 reform of a national public credit registry in Argentina as a natural experiment that revealed investors' strategic complementarity. And Schmidt, Timmermann & Wermers (2014) use heterogeneity in the costs associated with investing in U.S. money market mutual funds (MMFs) as a proxy for the sophistication of investors in each fund, and thereby measure investors' strategic complementarity.

[3] For each note, there is a final maturity date beyond which no extensions are possible.

[4] For example, Regulation 2a-7 generally requires MMFs to hold securities with residual maturity not exceeding 397 days (SEC 2010).

Acharya, Schnabl & Suarez 2013, Schroth, Suarez & Taylor 2014) and the repo market (Gorton & Metrick 2012, Krishnamurthy, Nagel & Orlov 2014) when fundamentals rapidly deteriorated from the summer of 2007. To show this, we collected new data for each XFABN—including daily amounts outstanding, election dates, and terms for withdrawals—by hand from individual security prospectuses and Bloomberg corporate action records. At that time, widespread concerns about financial market liquidity had developed in concert with the subprime mortgage crisis and declining house prices.

Our identification strategy is based on variation in strategic complementarity among investors in the puttable XFABN market. We construct an instrument for investors' expectations about other investors' actions, using the contractual structure of XFABN. Our instrument is the maximum fraction of XFABN that could be withdrawn between election dates. The intuition for this instrument follows from the predictions of our theoretical model: If the number of potential other investors that can run is low (high), there is weak (strong) strategic complementarity among investors. Differences across each insurer's XFABN contractual terms creates variation over time in the instrument and across insurers. Crucially, the election dates are determined when the XFABN were first issued, often years before the run, and are therefore plausibly exogenous to changes in fundamentals during the run.

Our baseline IV estimates suggest that self-fulfilling expectations played a significant role in the run on XFABN. We find that about 40 percent of the observed $18 billion withdrawals by investors between the third quarter of 2007 and the end of 2008 can be attributed to expectations that other investors were also likely to withdraw.

To add weight to our IV findings, we implement a series of robustness tests, including controlling for group behavior unrelated to expectations, and exploring the sensitivity of our estimates to variation in the date at which the instrumental variable is calculated. We also estimate our IV specification including week fixed effects to address the reasonable concern that our results are driven by a common shock to fundamentals affecting the U.S. life industry as a whole, or a common shock to short-term investors' liquidity demand. And we argue that there is no risk of firesales that could be a potential source of bias for our estimates. Taken together, the results from these tests consistently suggest that there was a sizeable self-fulfilling component to the run on U.S. life insurers' XFABN in 2007.

The contributions of our paper are fourfold. First, our model shows how the design of liability structures affects the way in which investors' beliefs are formed and ultimately exacerbate runs. Second, our hand-collected data shed light on the connection between U.S. life insurers and shadow banking. Third, we provide a new empirical strategy, based on our theoretical finding, to identify strategic complementarities among investors. And fourth, we apply this method to our data and find compelling evidence that a run in the shadow banking system by institutional investors had a significant self-fulfilling component.

Our evidence of a self-fulfilling run on U.S. life insurers contributes to a deeper understanding of the vulnerability of shadow banking to runs. While the market for XFABN is small relative to the asset-backed commercial paper and repo markets, the same institutional investors participate in all of them. Since their behavior is likely to have been similar across markets, our study offers evidence that there may have been a self-fulfilling component to the contemporaneous runs by institutional investors in those larger markets.[5]

A better understanding of self-fulfilling runs by institutional investors is important because the traditional methods of dealing with self-fulfilling runs by bank depositors—that is, liability insurance and regulatory supervision of assets—are either infeasible or ineffective to cope with runs by institutional investors. Efforts to mitigate the run risk have been made at some links in the shadow banking intermediation chain by adapting the traditional methods of dealing with runs. For example, new rules imposed by the Securities and Exchange Commission are intended to reduce the likelihood of runs on MMFs (Cipriani, Martin, McCabe & Parigi 2014).[6] However, the wide range of liabilities and assets on institutional investors' balance sheets renders liability insurance and regulatory supervision impractical for dealing with runs by institutional investors. Our analysis suggests that some progress could be made by paying greater attention to

[5] There are two reasons why it is difficult to identify self-fulfilling runs in the repo and ABCP markets. First, one would need to find exogenous variation in those liability structures. Second, unlike the run on XFABN, the run on asset-backed commercial paper and the run on repo triggered asset fire sales. The absence of a fire sale following the run on XFABN implies that the price of assets funded by XFABN are unlikely to have changed because of the run. The absence of this channel alleviates some of the concern that fundamentals could have biased our estimates of the effect of self-fulfilling beliefs on the decisions of institutional investors.

[6] SEC 17 CFR Parts 230, 239, 270, 274 and 279. Release No. 33-9616, IA-3879; IC-31166; FR-84; File No. S7-03-13. See `https://www.sec.gov/News/PressRelease/Detail/PressRelease/1370542347679`.

firms' liability structures.

The remainder of the paper proceeds as follows: Section 1 presents a general model in which a firm's liability structure affects its vulnerability to self-fulfilling runs. In Section 2 we discuss the institutional background to our analysis. Section 3 presents our data and summary statistics on extendible funding agreement-backed securities. Section 4 presents our main empirical results, including our IV estimates and robustness tests. We conclude in Section 5 with some remarks on broader implications of our findings and suggests some avenues for further study.

1 A model of liability structure and self-fulfilling runs

In this section, we describe a novel link between a firm's liability structure and strategic complementarity among investors, which can give rise to a self-fulfilling run. We propose a dynamic model in which a firm finances a risky asset by issuing a mix of puttable and non-puttable securities in a way that makes its liability structure vary over time. As in Goldstein & Pauzner (2005) and He & Xiong (2012), self-fulfilling expectations can be triggered by the prospect of a deterioration in asset fundamentals, and lead to a run.[7] Unlike those papers, which assume a firm's liability structure is fixed, we show that variations in the firm's liability structure has a significant impact on investors' propensity to run. In particular, we show that concerns about bad fundamentals can trigger a self-fulfilling run only when the fraction of puttable securities becomes high.[8]

Multiple equilibria can arise in this model, and we derive the conditions under which the self-fulfilling run equilibrium is unique. We show that a self-fulfilling run equilibrium is unique if investors face noisy withdrawal costs, which is a refinement similar to the noisy private signals in Morris & Shin (1998). In this case, we show that there is still strategic complementarity among investors, but the noisy withdrawal costs allow investors to coordinate their withdrawal decisions in a unique equilibrium in a way that is similar

[7] In seminal theoretical work, Bryant (1980) and Diamond & Dybvig (1983) show that firms issuing demandable liabilities are potentially vulnerable to swift changes in investors' beliefs about the actions of other investors. Such a run is in contrast to a fundamental-based run, in which investors decide to withdraw based on a signal they receive about the state of fundamentals as in Chari & Jagannathan (1988), Jacklin & Bhattacharya (1988) and Allen & Gale (1998). Our theory follows recent work suggesting that the two reasons are connected (Goldstein 2012).

[8] In Appendix A, we show how fixing the firm's liability structure in our model results in a simple version of He & Xiong (2012).

to the mechanism in Frankel & Pauzner (2000). An important implication of the model is that exogenous variation in liability structures can be exploited to make some progress in identifying a self-fulfilling component to runs.

The remainder of this section presents and analyzes the model. The model captures a general situation in which a varying amount of a firm's liabilities becomes puttable at different times. Examples of this situation include banks providing full liquidity guarantees to ABCP programs set up to finance their loan off-balance sheet, and insurance companies issuing funding agreement-backed securities structured as notes with embedded put options or commercial paper.[9]

Time is continuous and infinite. A firm finances a long-term asset by issuing securities to a continuum of investors. Investors are risk-neutral and discount the future at rate $\rho > 0$. The asset generates a constant stream of coupon $r > 0$, and matures at a random date following a Poisson process with arrival rate $\phi > 0$. The pay-off upon maturity depends on a publicly observable state s of the asset's *fundamental* value. If the asset fundamental is *good*, denoted by $s = g$, investors receive their unit of investment back. If the asset fundamental is *bad*, denoted by $s = b$, investors get nothing. The asset fundamental switches from good (bad) to bad (good) according to a Poisson process with arrival rate π_{gb} (π_{bg}).

The firm finances the asset by issuing *puttable* and *non-puttable* securities to investors. Investors in puttable securities have the option to withdraw, but this option can only be exercised on certain dates and exercising the option is costly. The arrival of option exercise dates is idiosyncratic and follows a Poisson process with arrival rate $\delta > 0$. On any given option exercise date, an investor draws an i.i.d. withdrawal cost ω from a distribution $\mathbf{\Omega}$ with a support over $[0, 1]$ and no mass point.[10] Upon withdrawal the investor receives $1-\omega$. Securities for which investors exercise their put option are replaced by new puttable securities, unless the asset is liquidated by the firm (more on this later). Investors in non-puttable securities do not have the option to withdraw. The fraction of puttable securities outstanding at time t is denoted by $e_t \in [0, 1]$, and summarizes the firm's liability structure.

Puttable and non-puttable securities can mature before the asset. Upon maturity,

[9] See Appendix B for a description of funding agreement-backed commercial paper.

[10] We assume that $\forall\ \tilde{\omega} > 0\ \mathbf{\Omega}(\tilde{\omega}) > 0$ to guarantee that there is a positive measure of investors with withdrawal cost less than or equal to any arbitrarily small $\tilde{\omega}$.

investors receive their principal back and the firm replaces the maturing securities with a mix of new puttable and non-puttable securities. The replacement process for the maturing securities makes the firm's liability structure fluctuate over time. We do not explicitly model the firm's replacement decision. Instead, we assume that a fixed fraction η of randomly selected securities matures at random dates τ with a Poisson arrival rate $\varepsilon > 0$. The maturing securities are uniformly selected from all securities, so the ratio of puttable securities among the maturing securities reflects the firm's liability structure just before τ, which we denote by e_{τ^-}.

The firm replaces all maturing securities with a random proportion c_τ being puttable. This proportion $c_\tau = c(e_{\tau^-})$ is a random variable drawn from a Beta distribution with parameters $\alpha = e_{\tau^-}$ and $\beta = 1 - e_{\tau^-}$.[11] As a result, the fraction of puttable securities evolves according to

$$e_\tau = (1-\eta)e_{\tau^-} + \eta c(e_{\tau^-}) \ , \tag{1}$$

and it follows that the firm's liability structure e_t is a jump process.[12]

A run occurs if all investors in puttable securities exercise their put. During a run, the firm may be able to rollover its debt by issuing new puttable securities. As long as the firm can rollover, a run does not affect the firm's liability structure. However, the firm may be forced to liquidate the asset if it cannot issue new securities. Liquidation of the asset during a run follows a Poisson process with arrival rate $\theta \cdot e \cdot \hat{\Omega} \geq 0$, where $\hat{\Omega}$ is the fraction of investors exercising their put option and $e \cdot \hat{\Omega}$ is the flow of withdrawals.[13] Note that a larger fraction of puttable securities and/or a larger fraction of investors withdrawing on their election dates increases the likelihood of liquidation. Note also there can be no asset liquidation with an individual (measure zero) investor withdrawal. Upon liquidation of the asset, investors in puttable securities receive $L(e_t)$, where $L(.) : \ [0,1] \to [0,1]$ is a strictly decreasing smooth function with $L(1) = 0$ and $L(0) = 1$. The function $L(\cdot)$ represents the asset liquidation cost and captures the *run externality*, which is the source of strategic complementarity among investors.

We now discuss the value function associated with investing in one unit of a puttable security.[14] Assume that each investor takes as given the pair of values $\bar{V} = \{\bar{V}^g, \bar{V}^b\}$

[11]We also assume $c(e) = e$ for $e = 0$ and 1 to ensure c_τ is a continuous function of e.

[12]Note that e_t is a martingale process since $E[c(e)] = e$.

[13]As we will describe below, the fraction of withdrawing investors $\hat{\Omega}$ is related to the distribution of withdrawal costs $\mathbf{\Omega}$.

[14]We do not study the value of investing in a non-puttable security, since investors in those securities

that other investors derive from investing in one unit of a puttable security in the good and bad states. Moreover, assume for now that these value functions are continuous and decreasing functions of e.[15] It follows that an investor's required return on one unit of a puttable security in the fundamental state $s \in \{g, b\}$ should be equal to the expected increment in her continuation value, which is given by the following functional equation

$$\begin{aligned} \rho V^s\left(e;\bar{V}\right) \;=\; & \varepsilon(1-\eta)\cdot\left(\mathbf{E}_{c|e}\left[V^s\left((1-\eta)\cdot e+\eta\cdot c;\bar{V}\right)\right]-V^s\right) \\ & +\pi_{s\tilde{s}}\cdot\left(V^{\tilde{s}}-V^s\right) \\ & +r+\phi\cdot\left(\mathbf{1}_{\{s=g\}}-V^s\right) \\ & +\theta\cdot e\cdot\mathbf{\Omega}(1-\bar{V}^s(e))\cdot\left(L\left(e\right)-V^s\right) \\ & +\varepsilon\eta\cdot\left(1-V^s\right)+\delta\cdot\left(\mathbf{E}_{\mathbf{\Omega}}\left[\max\left\{V^s,1-\omega\right\}\right]-V^s\right)\;, \end{aligned} \tag{2}$$

where the arguments of V^s are omitted in the right hand side when they are same as the arguments in the left hand side.

The left-hand sides of equation (2) denotes the return from investing in the puttable security in state $s \in \{g, b\}$. The term on the first line of the right-hand side captures the expected change in value caused by variations in the firm's liability structure according to the law of motion in equation (1). The second line captures changes in the asset fundamental. The third line captures the return generated by the asset before maturity, and its payoff at maturity. The fourth line captures the strategic complementarity through the run externality imposed by other investors. The fifth line captures changes due to the securities maturing and due to the investor withdrawing by exercising her put option. Naturally, investors always choose to withdraw if the value of their investment is less than one minus the withdrawal cost ω.

The degree of strategic complementarity depends on the fraction of puttable securities e in two ways. First, the likelihood of a liquidation in the event of a run depends on the flow of withdrawals $e \cdot \hat{\Omega}$. The fraction of investors exercising their put option $\hat{\Omega}$ is itself a function of the measure of investors for whom the cost of withdrawal ω is less than $1-\bar{V}^s(e)$, that is $\hat{\Omega} = \mathbf{\Omega}(1-\bar{V}^s(e))$. Second, upon liquidation, investors receive $L(e) \leq 1$, which is strictly decreasing in e. Note that an investor becomes more sensitive to changes

do not make any decision.

[15]We verify later that this is indeed the case.

in the firm's liability structure when other investors' value of holding a puttable security decreases. Consequently, an investor's decision to withdraw is affected by her expectation about other investors' valuations, and this strategic complementarity is greater when a higher fraction of securities are puttable.

To understand better the strategic complementarity among investors, we begin by establishing that an investor's valuation is uniquely determined by other investors' valuation.

Lemma 1.1 *Given the pair of values $\bar{V}$ that other investors derive from investing in one unit of puttable security, there are unique value functions V^s for $s \in \{g, b\}$ that solve equation (2). Moreover, these value functions are continuous and decreasing in the fraction of puttable securities e.*

Proof Define the operator $\mathcal{L}$ on V^s for $s \in \{g, b\}$ as follows

$$\mathcal{L}V^s\left(e;\bar{V}\right) = \frac{r+\phi\cdot\mathbf{1}_{\{s=g\}}+\pi_{s\tilde{s}}\cdot V^{\tilde{s}}+\theta e\cdot\mathbf{\Omega}(1-\bar{V}^s(e))\cdot L\left(e\right)+\varepsilon\eta+\delta\cdot\mathbf{E}_{\mathbf{\Omega}}\left[\max\left\{V^s,1-\omega\right\}\right]}{\rho+\phi+\varepsilon+\pi_{s\tilde{s}}+\theta e\cdot\mathbf{\Omega}(1-\bar{V}^s(e))+\delta}$$

$$+\frac{\varepsilon(1-\eta)}{\rho+\phi+\varepsilon+\pi_{s\tilde{s}}+\theta e\cdot\mathbf{\Omega}(1-\bar{V}^s(e))+\delta}\cdot\mathbf{E}_{c|e}\left[V^s\left((1-\eta)\cdot e+\eta\cdot c;\bar{V}\right)\right], \qquad (3)$$

where $\mathbf{\Omega}(1-\bar{V}^s(e))\cdot L\left(e\right)$ is a strictly decreasing continuous function and

$$\frac{\varepsilon(1-\eta)+\delta}{\rho+\phi+\varepsilon+\pi_{s\tilde{s}}+\theta e\cdot\mathbf{\Omega}(1-\bar{V}^s(e))+\delta}\leq\frac{\varepsilon(1-\eta)+\delta}{\rho+\phi+\varepsilon+\delta}<1\ .$$

It follows that $\mathcal{L}$ is a contraction on the set of bounded decreasing continuous functions of e. The result follows since the fixed point $\mathcal{L}V^s = V^s$ solves (2) ∎

An implication of Lemma 1.1 is that investors are more likely to run when the firm has a higher fraction of puttable securities outstanding. To see this point, note that the probability that an investor withdraws in state s conditional on e is given by $\hat{\Omega} = \mathbf{\Omega}(1-V^s(e))$. Since V^s is decreasing in e, the probability that she withdraws is increasing in e. In addition, Lemma 1.1 implies that $V^g(e) > V^b(e)$ so that investors are more likely to run in the bad state.

We now turn to the definition of a symmetric equilibrium. In a symmetric equilibrium, an investor's expectation about other investors' value functions should be consistent with the value functions implied by the other investors' optimal withdrawal decisions. Formally, a symmetric equilibrium consists of a pair of functions $V = \{V^g, V^b\}$ such that V solves equation (2) for $\bar{V} = V$. In other words

$$\mathcal{L}V^s(e; V) = V^s(e; V) \text{ for } s \in \{g, b\} , \tag{4}$$

where $\mathcal{L}$ is defined in equation (3). Proposition 1.2 below establishes the conditions under which there exists a unique symmetric equilibrium.

Proposition 1.2 *Given that* $L(\cdot) : [0,1] \to [0,1]$ *is a strictly decreasing and continuous function, the withdrawal cost distribution* $\mathbf{\Omega}$ *does not have any mass point over its support on* $[0,1]$*, and* $\theta < \rho + \phi + \varepsilon\eta$*, there is a unique pair of value functions* $V^* = \{V^{g*}, V^{b*}\}$ *which solves equation (4).*

Proof Define the operator $\mathcal{F}$ on the set of pair of value functions from $[0,1]$ to $\mathbf{R}_+$ as follows

$$\begin{aligned} \mathcal{F}\bar{V}(e) &= V(e; \bar{V}) \\ \text{s.t.} \quad & \mathcal{L}V^s(e; \bar{V}) = V^s \text{ for } s \in \{g, b\} \text{ and } \forall e \in [0,1] , \end{aligned} \tag{5}$$

where $\mathcal{L}$ is defined in equation (3). Since $\mathcal{L}$ is a contraction and has a fixed point, $\mathcal{F}$ is well defined. Note that $\mathcal{F}\bar{V}$ captures the value of investing in a puttable security when other investors value it at $\bar{V}$.

It can be shown that $\mathcal{F}$ satisfies the Blackwell sufficient conditions. In particular, if $\bar{V} < \bar{V}'$, then starting from any arbitrary continuous decreasing pair of functions $V^0 = \{V^{0g}, V^{0b}\}$, it is easy to see that $\forall n \in \mathbf{N}_+$, $\mathcal{L}^n V^{0s}(e; \bar{V}) \leq \mathcal{L}^n V^{0s}(e; \bar{V}')$ for $s \in \{g, b\}$ and $e \in [0,1]$. Thus the fixed point of the contraction operator $\mathcal{L}$ for $\bar{V}$ is less than the fixed point for $\bar{V}'$. That is, $\mathcal{F}$ satisfies the monotonicity condition. Furthermore, if $\bar{V}^{s\prime}(e) = \bar{V}^s(e) + a$ for $s \in \{g, b\}$ and $\forall e \in [0,1]$, it can be shown $\mathcal{F}\bar{V}^{s\prime}(e) \leq \mathcal{F}\bar{V}^s(e) + \frac{\theta}{\rho+\phi+\varepsilon\eta} \cdot a$. Given $\theta < \rho + \phi + \varepsilon\eta$, the operator $\mathcal{F}$ satisfies the discounting condition. It follows that $\mathcal{F}$ is a contraction on the set of decreasing continuous functions defined on $[0,1]$, and the fixed point of $\mathcal{F}$ is the unique solution of the symmetric equilibrium characterized by equation (4) ∎

The uniqueness of a symmetric equilibrium results from the noisy withdrawal cost

ω, playing a similar role as the noisy private signals in Morris & Shin (1998). If the withdrawal cost is $\omega = 0$ for all investors so that $\mathbf{\Omega}(0) = 1$, there could be a continuum of equilibria. These equilibria are characterized by thresholds e^g and e^b for which all investors in puttable securities run if and only if $e > e^s$ for $s \in \{g, b\}$. In this case, the value functions V^s have a single discontinuity at e^s, and equilibria with higher run thresholds $\{e^g, e^b\}$ deliver higher values since investors coordinate on avoiding runs when e is below the run thresholds. In other words, strategic complementarity results in Pareto-ranked multiple equilibria as in Bryant (1980) and Diamond & Dybvig (1983).

It is worth highlighting that there is strategic complementarity among investors even when there are noisy withdrawal costs and the symmetric equilibrium is unique. To see this, note that the operator $\mathcal{F}$ defined in equation (5) is monotone. That is, the value of investing in a puttable security $V = \mathcal{F}\bar{V}$ is higher for an investor when the other investors' value $\bar{V}$ is higher, since they are less likely to run. However, with noisy withdrawal costs, investors coordinate their asynchronous withdrawal decisions yielding a unique equilibrium. This mechanism is similar to the one described in Frankel & Pauzner (2000).

The equilibrium definition highlights a sharp distinction between runs due to a deterioration in asset fundamentals only, and runs *amplified* by self-fulfilling expectations. There is no run when investors' withdrawal decisions are not sensitive to the fraction of securities that becomes puttable, which occurs when $V^{s*}(1; \cdot) \geq 1$ for $s \in \{g, b\}$. In contrast, investors withdraw regardless of their expectations about other investors' withdrawals when $V^s(0; \mathbf{1}) < 1$ for $s \in \{g, b\}$, which corresponds to a "pure" fundamental run. However, when $V^{s*}(0; V^*) \geq 1$ and $V^{s*}(1; V^*) < 1$, strategic complementarities can play a role. As the amount of puttable securities rises, an investor is increasingly likely to withdraw because she expects other investors also to withdraw. In this case, a run can occur with a self-fulfilling component.[16]

The model suggests that some progress can be made towards identify the self-fulfilling component of a run using variation in liability structures. In an ideal experiment, this variation would be orthogonal to fluctuations in fundamentals.[17] In the next section, we describe how U.S. life insurers' use of puttable securities backed by institutional funding

[16] In Appendix A, we provide examples of pure fundamental and self-fulfilling runs.

[17] For experimental studies showing that institutions and markets can be vulnerable to self-fulfilling runs, see Madies (2006), Garratt & Keister (2009), Arifovic, Hua Jiang & Xu (2013), and Kiss, Rodriguez-Lara & Rosa-García (2012).

agreements provides one such institutional environment which is close to such an ideal setup.

2 Institutional Background

The use of institutional funding agreements by U.S. life insurers emerged as a response to long-run macroeconomic and regulatory changes that affected the industry. Life insurers traditionally offer insurance to cover either the financial position of dependents in the event of the death of the main income earner, or individuals at risk of outliving their financial wealth. Under this model, policyholders make regular payments to an insurance company in exchange for promised transfers from the insurer at a future date. The promised transfers are long-term illiquid liabilities for insurers, which are backed by assets funded by the regular payments from policyholders. The assets backing insurance liabilities need to be low risk and highly liquid to pay insurance claims as required. Ideally, these assets also deliver high returns to improve insurers' profitability.

Throughout the middle part of the twentieth century, U.S. life insurers enjoyed easy profits as high interest rates on safe long-term U.S. Treasuries that were attractive during World War II were replaced with high interest rates on long-term corporate bonds (Briys & De Varenne 2001). Soon after, however, pension funds emerged, offering higher returns to savers and challenging the traditional business model of life insurers. Pension funds could afford to offer much higher returns because they could invest freely in booming equity markets. Life insurers responded to the threat from pension funds by pursuing more aggressive investment strategies and offering products with higher (sometimes guaranteed) yields and greater flexibility to withdraw funds early.

The combination of greater liability run-risk and risky assets resulted in an insurance crisis in the late 1980s. Many insurers failed as capital losses on high-risk assets caused surrender runs by policyholders, intensified by falling credit ratings of insurers (DeAngelo, DeAngelo & Gilson 1994). Realizing that life insurers had overweighed their portfolios with risky assets, the National Association of Insurance Commissioners (NAIC) proposed several model reforms for state insurance regulation, including risk-based capital (RBC) requirements, financial regulation accreditation standards, and an initiative to codify accounting principles.[18] For their part, life insurers redressed the balance of their portfolios towards safer and more liquid assets.

Insurers' re-focus on safe assets after the crisis of the late 1980s gave rise to a new problem as interest rates on safe assets continued the decline they had begun in the early 1980s. The prospect of persistently low interest rates meant life insurers were at risk of being unable to deliver the guaranteed returns promised to policyholders when the expected path of interest rates was higher. This rising interest rate risk led insurance industry state regulators to adopt new regulations requiring life insurers to hold higher statutory reserves in connection with term life insurance policies and universal life insurance policies with secondary guarantees.[19] However, higher risk-based capital requirements necessarily imply a lower return on equity, as larger reserves must be backed by safe, low-yield assets.[20]

Life insurers responded to higher capital requirements and falling interest rates by finding innovative ways to increase their return on equity. One way is to reduce the risk-based capital requirement by shifting insurance risk off-balance sheet to captive reinsurers (Koijen & Yogo 2014).[21] Another way is to loan out securities to raise cash and fund a portfolio of longer-term, higher return assets (Foley-Fisher, Narajabad & Verani 2015). And yet another way is to fund an expansion of the insurer's portfolio of high yield assets using funding agreement-backed securities (FABS), which is known in the industry as an "institutional spread business."[22]

Life insurers issue FABS and invest the proceeds in a portfolio of relatively higher yield assets such as mortgages, corporate bonds and private label ABS, to earn a spread. In a

[18]Under the state-based insurance regulation system, each state operates independently to regulate its own insurance market, typically through a state insurance department. State insurance regulators created the NAIC in 1871 to address the need to coordinate regulation of multistate insurers. The NAIC acts as a forum for the creation of model laws and regulations.

[19] NAIC Model Regulation 830 (Regulation XXX) and Actuarial Guideline 38 (Regulation AXXX).

[20] The new statutory reserve requirements are typically higher than the reserves that life insurers' actuarial models suggest will be economically required to back policy liabilities. For context, insurers' statutory reserves tend to be much higher than reserve requirements for banks under U.S. generally accepted accounting principles (GAAP).

[21] Captive reinsurers are onshore and offshore affiliated unauthorized reinsurers that are not licensed to sell insurance in the same state as the ceding insurer, and do not face the same capital regulations as the ceding insurer. Koijen & Yogo (2014) estimate that the regulatory capital reduction from transferring insurance liabilities to captives increased from $11 billion in 2002 to about $324 billion in 2012.

[22] Funding Agreement Backed Notes (FABN) are sometime referred to as Guaranteed Investment Contract-Backed Notes (GICBN), and were created in 1994 by Jim Belardi, former president of SunAmerica Life Insurance Company and Chief Investment Officer of AIG Retirement Services, Inc., and current Chairman & CEO of Athene Holding.

typical FABS structure, shown in Figure 2, a hypothetical life insurer sells a single funding agreement to a special purpose vehicle (SPV).[23] The SPV funds the funding agreement by issuing smaller denomination FABS to institutional investors. Importantly, FABS issuance programs inherit the ratings of the sponsoring insurance company, and investors are treated *pari passu* with other insurance obligations since the funding agreement issued to the SPV is an insurance liability. This provides FABS investors with seniority over regular debt holders, and it implies a lower cost of funding for the insurer relative to senior unsecured debt. For example, this structure allows a AA-rated life insurer to "borrow" at AAA and earn a sizeable return by investing the funds in BAA- or lower-rated assets. A further benefit is that FABS do not increase standard measure of leverage as a funding agreement is legally an insurance obligation.

The U.S. FABS market grew rapidly during the early 2000s. Figure 1 shows the end-of-year total FABS amount outstanding by insurance company. At its peak in 2007, new issuance reached over \$50 billion, with more than \$170 billion in notes outstanding, or about 90 percent of the Auto ABS market. It is apparent from Figure 1 that only the largest highly rated U.S. life insurer issue FABS.

FABS are flexible capital market instruments that may feature different types of embedded put option to meet demands from various investors, including short-term investors, such as MMFs. One particular type of FABS designed for short-term investors is an Extendible Funding Agreement-Backed Note (XFABN) that gives investors the option to extend again the maturity of their investment. In normal times, the maturity of these instruments is always extended, allowing insurers to borrow long-term at shorter-term interest rates. Investors in XFABN typically receive a higher interest rate than on other short-term securities and have the option to *withdraw* by not extending the maturity of the note. Consequently, XFABN programs are similar to ABCP programs with full liquidity guarantees from the sponsoring firm, bank or otherwise. In these ABCP programs the securities can be put back to the sponsoring firm at rollover dates. In an XFABN program, the securities can be put back to the insurer with some month notice, usually less than

[23] Note that FABS can only be issued by life insurers since a funding agreement is a type of annuity product.

397 days to be attractive to MMFs.[24, 25]

Each XFABN prospectus specifies *election dates* on which investors may extend the maturity by a pre-specified term of some or all of their holdings.[26] If the holder chooses to extend, the XFABN maturity date is extended by some pre-specified term and the option to extend carries over to the next election date, or until the maturity date reaches a pre-specified *final maturity date.* The period over which the XFABN maturity may be extended is called the *election window.* Importantly, information about an insurer's liability structure is public knowledge among participating institutional investors.[27]

If some or all of a particular XFABN is not extended, that portion is converted into a new zero-coupon security, called a *spinoff.* Each spinoff is given a different identifier (CUSIP) from that of the original XFABN. These new securities are no longer eligible for extension and have a pre-specified fixed duration. Any remaining portion of the XFABN continues to be eligible for extension and retains its original CUSIP identifier.

The decision to extend the maturity of an XFABN trades off the risk of future illiquidity for the coupon offered on the security. Insolvency is rarely an issue for life insurers. In the event that they breach the regulatory capital threshold, which happens much sooner than insolvency, life insurers are immediately taken over by their State regulator. Consequently, insurance liability holders can be reasonably certain they will eventually be repaid. However, there could be tremendous uncertainty over *when*

[24] Referring to their XFABN program circa 2000, the then director of new initiatives at Aegon Institutional Markets stated "It is possible to sell contracts as long as a 12-month put if you were to sell into the [MMFs] illiquid basket. That's where the salespeople get very important. You need to have the right kinds of salespeople because selling into an illiquid basket of a 2a-7 fund is considerably harder than selling into the liquid basket with a seven-day put. The 12-month put business is effectively all that Aegon does. We actually like the business. It's a perpetual contract. The contract holder can't get out of the contract unless they give a 12-month notice. Part of risk management is case specific underwriting. Each ticket, as I mentioned before, is pretty large and a lot of risk management needs to happen at the individual sale each time you make the sale." (Society of Actuaries 2000)

[25] XFABN are not concentrated among MMFs. On a case by case basis, we can observe individual MMF exposure to XFABN conduits through their Securities and Exchange Commission Form N-Q and N-CSR filings. For example, in the third quarter of 2007, Fidelity and JPMorgan held 3.7 percent and 0.5 percent respectively of all outstanding XFABN.

[26] Typically, holders only notify the XFABN dealer on or around each election date if they want to extend the maturity of their XFABN (either in part or the entire security). In the event that no notification is made, the security holder is assumed to have elected not to extend the security. See Appendix C for an example of the first three pages of an XFABN prospectus specifying the election dates and relevant conditions; the overall prospectus totals over 900 pages.

[27] Referring to their XFABN program circa 2000, the then director of new initiatives at Aegon Institutional Markets explained "The customers that we sell to are pretty sophisticated. They know exactly what they're buying. They are generally investment managers in their own right. [...] [T]he computer systems have been developed to a point that everybody knows exactly what options are on each contract. At any point in time most of our customers know what's on first and who's on second." (Society of Actuaries 2000)

investors will get their money back. This uncertainty is of great concern to MMFs that are extremely sensitive to possible disruption to timely redemption and the rating of their investments (Hanson, Scharfstein & Sunderam 2013).

The issuance of XFABN is not the first time that funding agreements have been used to access short-term wholesale funding markets. During the 1990s, life insurers accessed short-term funding from the money market by issuing floating rate funding agreements, often with put options, directly to MMFs. And these liability structures also exposed issuers to run risk. In 1999, a $30 billion highly-rated life insurer, General American, had $6.8 billion in outstanding funding agreements with put options, of which about $5 billion were issued to MMFs with seven-day put options (Moody's 1999). At the end of July 1999, Moody's downgraded General American by one notch to A3 amid general concerns about the insurer's liquidity. There was never any concern about the insurer's solvency. Nonetheless, over a two-week period around the time of the rating downgrade, MMFs exercised put options totaling over $4 billion, leading to a severe liquidity crisis. On August 10, the company announced that, although it believed it was still solvent, it could not meet investors' claims. Within days General American was seized by the Missouri Department of Insurance and acquired by Metropolitan Life at a steep discount. While the rescue meant that General American would remain liquid, and the outstanding funding agreements would inherit MetLife's high rating and pay a relatively attractive yield, MMFs still requested their money back from MetLife at the time the purchase was announced (Lohse & Niedzielski 1999).

This anecdote illustrates a general principle that short-term institutional investors withdraw when facing even a small risk of illiquidity. Their run on ABCP in August 2007 (Covitz et al. 2013) and the run on repo in September 2007 (Gorton & Metrick 2012) were an early signal of an impending financial crisis, with widespread illiquidity. Coincident with those runs, the XFABN market collapsed. Beyond the anticipation of broader distress, investors may plausibly have been concerned about insurers' holdings of asset backed securities, or use of securities lending programs.

Importantly, the actual trigger for the run on U.S. life insurers does not play a role in our empirical strategy. What matters is that, once the run begins, investors's decisions take into account their expectations about other investors' decisions, and there are strategic complementarities. The contractual terms (initial maturity date, election dates, extension term, spinoff duration, and final maturity) described above allow us to separate these decisions over time. Intuitively, investors that are deciding how much of their holdings to extend on a particular election date need to take into account whether or not other security holders will have an opportunity to run before their next election date. If no-one can run before the next election date, there is no need for the investors making a decision today to take other security holders' potential actions into account. But if many other investors can withdraw before the next election date, investors today need to factor into their decision today some belief about whether other security holders will run. In the next section, we give an overview of our database and describe the run on XFABN that began in the summer of 2007.

3 Data

The main source of data about XFABN is our database of all FABS issued by U.S. life insurers covering the period beginning when FABS were first introduced in the mid-1990s. To construct our dataset, we combined information from various market observers and participants on FABS conduits and their issuance. We then collected data on contractual terms, outstanding amounts, and ratings for each FABS issue to paint a complete picture of the market for FABS at any point in time. Finally, we added data on individual conduits and insurance companies, as well as aggregate information about the insurance sector and the broader macroeconomy. A more detailed description of our FABS database is provided in Appendix B.

Our data for XFABN were collected by hand from individual security prospectuses and the Bloomberg corporate action record. We use these sources to construct the universe of XFABN CUSIP identifiers, and pair them with their spinoffs' CUSIP identifiers. Thus, we obtain a complete panel of all XFABN outstanding, those still eligible for extensions, and those whose holders elected to spinoff their holdings earlier than the final maturity date.

In total, we record 54 XFABN issuances during the period of our analysis, from which 106 individual spinoffs were issued. The average XFABN issuance amount is $470 million, while the average spinoff amount is $190 million, or roughly 40 percent of their parent XFABN. About 70 percent of spinoffs mature in 397 days or less, consistent with an issuance strategy that targets investment by MMFs.[28] Summary statistics for all the variables used in the analysis are displayed in Table 1.

Figure 4 shows the daily time series of outstanding XFABN and outstanding spinoffs from the beginning of 2006 to the end of 2009. The amount of XFABN issued almost tripled between 2004 and 2006, when issuance peaked at \$6.4 billion. The green line shows that the amount of XFABN outstanding as of June 2007 was about \$23 billion, or about 20 percent of total U.S. FABS outstanding. From August 2007, institutional investors in XFABN began to exercise their put. The same type of investors withdrew from the ABCP and repo markets, amid rising concerns about sub-prime mortgages in the face of a sharp drop in house prices. These concerns may plausibly have spilled over onto life insurers through their holdings of mortgage-backed securities and use of securities lending programs.

The figure contrasts the decline in the amount of XFABN outstanding (green line) with the fastest possible withdrawal that investors could have made from August 1, 2007 (black line). The gap between these two series shows that, while investors did withdraw swiftly, the run was not as immediate as it could have been. This means that there was scope for investors to form expectations about other investors' future actions—it is unlikely that everyone expected everyone else to withdraw immediately. The blue line in the figure shows the cumulative outstanding amounts of XFABN and their spinoffs. The total outstanding amount remained roughly flat throughout the run period, and declined in 2008 as the spinoffs created during the run matured. This second decline might mislead an observer of insurers' total liabilities to conclude that investors withdrew later in 2008. In fact, the run occurred almost a year earlier. The question we address in the next section is how much of the run was amplified by panic and how much was a response to the triggers.

4 Empirical results

Figure 3 shows a stylized timeline of the decision process for XFABN holders. At time t, holders of a particular XFABN have the option to withdraw (spinoff) and receive a payout at time $t + m$. If they choose instead to extend their holdings, the option to withdraw

[28] The median initial maturity at issuance for all XFABN in our sample is about 2 years, less than one-quarter of the median duration at issue of the entire sample of FABN (roughly 8 years).

will move to time $t+1$. In the time between t and $t+1$, holders of other XFABN may have the option to withdraw. The red dashed lines show the potential spinoffs. Our basic hypothesis for a self-fulfilling run is that investors will make decisions at time t taking into account their expectations about future decisions on other XFABN between t and $t+1$.

Our empirical analysis begins by establishing that there was a positive correlation between investors' decisions to convert and their expectations that holders of other XFABN issued by the same insurer will convert *in future*, while controlling for obvious economic fundamentals that might be driving the run. The unit of observation throughout our analysis is the election date t of an individual XFABN i issued by insurer j, yielding a sample of 1,129 security-election date observations from January 1, 2005 to December 31, 2010. Our main specification is summarized by Equation 6 below.

$$D_{ijt} = \gamma_0 + \gamma_1 S_{ijt+1} + \gamma_2 Q_{ijt} + \mathbf{x}'_{jt}\beta + \epsilon_{ijt} \tag{6}$$

The dependent variable, D_{ijt}, is the fraction of XFABN i issued by insurer j that is converted into a spinoff on election date t. The "ideal" explanatory variable is the unobservable expectation, $\boldsymbol{E}_t S_{ijt+1}$, of the fraction of all other XFABN from insurer j that will be converted into spinoffs between the current election date t and the next election date $t+1$. We invoke rational expectations to the extent that S_{ijt+1} and $\boldsymbol{E}_t S_{ijt+1}$ are not orthogonal and are correlated. Our main explanatory variable is then the realized future spinoffs, S_{ijt+1}, between the current election date t and the next election date $t+1$. This fraction is indexed by i because it excludes decisions made in respect of the XFABN i itself.

In all specifications, we control for Q_{ijt}, which is calculated for each issuer j in reference to the maturity date $t+1+m$ of a spinoff created from XFABN i at date t. The variable is constructed as the sum of all spinoffs created prior to election date t plus fixed maturity FABS that are scheduled to mature before or on the maturity date $t+m+1$. Intuitively, this variable is a control for the amount of claims on the insurer that are already ahead of any spinoff created by decision D_{ijt}.[29] We also control for a number of issuer, time,

[29] In effect, Q_{ijt} controls for rollover risk stemming from insurers' entire FABS program. Recall that insurers issue FABS that mature at different points in time. Consequently, an insurer could appear to be risky if it had a lot of FABS maturing between an election date t and the time at which the converted XFABN is set to come due, even though the amount of outstanding XFABN may be relatively small.

and aggregate controls, contained in the vector $\mathbf{x}_{jt}$. Throughout the empirical analysis in this paper, we specify robust standard errors.

4.1 Reduced form estimates

Column 1 of Table 2 reports the results from estimating Equation 6 by OLS. This specification includes in $\mathbf{x}_{jt}$ insurer fixed effects to control for persistent insurer characteristics that could affect their vulnerability to runs by institutional investors. We find that withdrawals by other XFABN holders between t and $t+1$ are positively correlated with the decision to spinoff on date t and the association is statistically significant at less than the one percent level. The coefficient estimate on S_{ijt+1} suggests that, on average, a one standard deviation (10 percentage point) increase in investors' withdrawal from insurer j's XFABN between election t and $t+1$ is associated with a 0.3 standard deviation (7.6 percentage point) increase in the fraction of a particular XFABN on election date t that is withdrawn.

Columns 2 and 3 of Table 2 attempt to control, at least partially, for fundamental developments in the financial sector and at individual insurers. Column 2 controls for the expansion of shadow bank liquidity creation using the one-month log difference in the amount of asset-backed commercial paper outstanding. It also attempts to control for the development of concerns about the stability of the financial system using the one-month log difference in the VIX. Column 3 of Table 2 controls for insurer-specific time-varying fundamentals using market-based measures of issuer financial health such as insurer holding company stock prices, 5-year credit default swap spreads and 1-year Moody's KMV expected default probabilities.[30] In both cases, the estimated coefficient on S_{ijt+1} remains positive and significant.

Taken together, these reduced form results suggest that investors' decisions to withdraw today are related to their expectations about other investors' future withdrawals. This correlation survives controlling for measures of obvious fundamentals that could affect life insurers and the broader financial system. Of course, while the correlation is consistent with an amplification effect driven by expectations about future withdrawals, it does not imply that there was any self-fulfilling component. In particular,

[30] This specification can only be estimated on about 40 percent of the original sample, because of data availability.

the likely presence of unobservable fundamentals (ϵ_{ijt}) correlated with both current (D_{ijt}) and future decisions (S_{ijt+1}) prevents us from drawing inference on the importance of self-fulfilling expectations. We turn to an instrumental variable approach in an effort to purge from our main explanatory variable, S_{ijt+1}, the possibly confounding effect of fundamentals, and to tease out the self-fulfilling component in the run.

4.2 Instrumental variable approach

The contractual structure of XFABN allows us to construct an instrument for S_{ijt+1} that is plausibly unrelated to fundamentals. Importantly, our instrumental variable approach is not a test of self-fulfilling expectations against fundamentals, as a driving force for the run on XFABN. Rather, our test for the self-fulfilling component is conditional on the effect of fundamentals developing during the run. Hence, this approach is fully consistent with the application of global games framework to understanding runs (Goldstein 2012) and the dynamic debt run models of He & Xiong (2012) and in Section 1. We take the state of fundamentals as given and tease out the amplification effect that comes from exogenous variation in expectations about future withdrawal decisions. The source of this exogenous variation is insurers' liability structures.

Denoted by RE_{ijt+1}, our instrumental variable is the ratio of XFABN from issuer j that is up for election between election date t and $t+1$. That is, RE_{ijt+1} is the maximum fraction of XFABN that can potentially be converted into short-term fixed maturity bonds between an individual XFABN i's election dates t and $t+1$. By definition, the space of future withdrawals between election date t and $t+1$, S_{ijt+1}, is bounded by 0 and RE_{ijt+1}. The contractual terms spelled out in the publicly available XFABN prospectuses allow all investors to calculate and use RE_{ijt+1} when forming expectations about S_{ijt+1}. For example, if no XFABN from issuer j have election dates between t and $t+1$, everyone knows that everyone's expectation about S_{ijt+1} is trivially 0. On the other hand, if $RE_{ijt+1} > 0$, investors may form non-trivial expectations about the decision of other investors to convert their XFABN between t and $t+1$.

Variation in our instrumental variable, RE_{ijt+1}, comes from three main sources. First, the timing of election dates generally varies across XFABN; even the periodicity of election dates can vary across securities. Second, there is often a gap between when an XFABN is issued and its first election date. And third, there is usually a gap between the last election date and the final maturity date.

We use RE_{ijt+1} as an instrumental variable, rather than as a proxy for expectations directly in Equation 6. While in some simple cases, such as our stylized model in Section 1, RE_{ijt+1} may be a sufficient statistic for expectations, investors generally use other information when forming expectations about future withdrawals. In our view, future realizations are a better proxy for expectations because they offer a more complete representation of the factors used to form expectations. Our approach separates the component of realized decisions that is correlated with a single factor determining expectations. That factor was predetermined by the contractual structure of all XFABN issued by an insurer *before* the run began.

A key concern is that, while RE_{ijt+1} is pre-determined, it is not necessarily independent from changes in fundamentals *after* a run begins. On the one hand, RE_{ijt+1} changes when investors begin to convert their XFABN, since an increase in S_{ijt+1} necessarily implies that fewer XFABN will be up for election on future dates. Thus, if an increase in S_{ijt+1} is caused by fundamentals, RE_{ijt+1} could be correlated with fundamentals. On the other hand, new XFABN issuance would increase RE_{ijt+1}. For example, an insurer experiencing a run on its existing XFABN may try to secure funding by issuing new XFABN, rendering RE_{ijt+1} positively correlated with fundamentals.

To eliminate the possible effect of issuance or spinoffs during the run on our instrumental variable, we calculate RE_{ijt+1} with a three month lag, RE_ex3m_{t+1}. That is, we construct what investors, three months before election date t, thought would be the fraction of XFABN from issuer j up for election between election date t and $t+1$. Since the majority of XFABN in the sample are converted between August 1, 2007 and October 31, 2007, this lag length removes the potential bias associated with any conversion or new issuance during the run.[31] Through pre-determined and lagged variation, we eliminate the direct and indirect effects, respectively, of fundamentals on our instrumental variable.

4.2.1 Instrumental variable estimates

Columns 4 and 5 of Table 2 report our baseline instrumental variable (IV) results estimated using a two-stage least square procedure. In the first-stage regression, reported in column 4, we instrument for the dependent variable, S_{ijt+1}, using RE_ex3m_{ijt+1}.

[31] We explore the robustness of this assumption in section 4.3.

The regression includes the controls from the specification in column 1 of Table 2. Consistent with the discussion above, the first-stage results suggest there is a large positive association between S_{ijt+1} and RE_ex3m_{ijt+1} that is significant at less than the one percent level. The column also reports that the instrument passes the Stock & Yogo (2005) weak instrument test. From column 4 of Table 2, a one standard deviation (31 percentage point) increase in RE_ex3m_{ijt+1} is associated with a 0.37 standard deviation (4 percentage point) increase in S_{ijt+1}.

Column 5 shows the second-stage regression results, including the IV coefficient on the predicted value of S_{ijt+1} from the first-stage estimation. The coefficient estimate is not statistically different from its OLS counterpart in the reduced form specification (column 1). The magnitude suggests that a one standard deviation (10 percentage point) increase in the XFABN conversion rate between t and $t+1$ expected by investors at election date t raises the probability that investors convert their XFABN at election date t by 0.91 standard deviations (22 percentage points).

In dollar terms, the IV coefficient implies that a one standard deviation (7.2 percent) increase in expected future XFABN withdrawals between election dates t and $t+1$ is associated with $38 million of additional withdrawals from the median outstanding XFABN on date t. As an alternative economic interpretation, we estimate the overall contribution of the self-fulfilling component to total withdrawals during the run. To compute this estimate, we first calculate the model-implied expected future withdrawals, $\hat{S}_{ijt+1}$, between election dates t and $t+1$ from the first-stage regression. We then multiply this figure by the estimated IV coefficient from the second-stage regression and by the amount of XFABN up for election on date t. This yields a model-implied estimate of the dollar amount of each XFABN withdrawn due to self-fulfilling expectations on each election date. We compare the sum of these estimates with the sum of actual withdrawals that occurred between June 30, 2007 and December 31, 2008. The calculation suggests that 41 percent of the observed $18 billion withdrawn during that period can be attributed to the self-fulfilling component. These estimates suggest that self-fulfilling expectations played a significant role in the run on XFABN.

4.3 Robustness of the IV coefficient estimate

In this subsection, we test the robustness of our findings to omitted or latent variables, to the construction of our instrumental variable, and to sample selection bias. The results of these tests are summarized in Table 3.

A significant concern about our baseline analysis is that there could be a common shock to fundamentals affecting the U.S. life insurance industry as a whole. This is especially likely since the run on XFABN coincided with the runs in asset-backed commercial paper and repo markets, and quickly evaporating liquidity in general. In an effort to address this concern, Columns 1 and 2 of Table 3 control further for common shocks to the industry by adding week fixed effects. The week fixed effects absorb any aggregate variables, including the amount of ABCP outstanding, VIX, and aggregate market returns. Intuitively, this test assumes that news about fundamentals are either broadly good or broadly bad for a whole week. On the first day of the week in which fundamentals are bad, if RE_ex3m_{ijt+1} is high, many investors will run. On the second day, if RE_ex3m_{ijt+1} is low, few investors will run. Our identification strategy could be challenged if, systematically and within each week, good news about fundamentals coincided with days when RE_ex3m_{ijt+1} were low and bad news coincided with days when RE_ex3m_{ijt+1} were high. However, we argue that this is a highly unlikely scenario since fundamentals were generally worsening across financial markets throughout the run period. The second-stage coefficient estimate on expected future spinoffs between t and $t+1$, S_{ijt+1}, remains statistically significant at less than the 5 percent level, and is not statistically different from its counterpart in column 5 of Table 2.

A further substantial concern is that the three-month lag is insufficient to properly eliminate potential effects of the run on the instrumental variable. We investigated the robustness of our estimate to alternative lag lengths, removing developments over longer time horizons (the results are available on request). Broadly speaking, we find that the instrument remains strong, in the Stock and Yogo sense, and that the IV coefficient estimate is little changed with lags up until 24 months and thereafter becomes weak. As an alternative to the lagged instruments, we also fixed the date on which the instrumental variable is calculated at June 1, 2007, for all election dates thereafter. Intuitively, this calculation eliminates any possible developments in issuance or spinoffs during the run period that might possibly affect the instrumental variable. The results of this robustness test are reported in columns 3 and 4 of Table 3. The second-stage coefficient estimate on expected future spinoffs between t and $t+1$, S_{ijt+1}, is statistically significant at less than the 1 percent level.

The inclusion of week fixed effects alleviates some of the concerns that withdrawals are simply a response to an aggregate shock to the insurance industry or to short-term institutional investors. Using an instrument measured on a single day before the start of the run helps alleviate some of the concerns that the withdrawal could be driven by other aggregate and idiosyncratic latent fundemental effects. However, it remains plausible that withdrawals could be driven by systematic changes in fundamentals that affect demand. For example, deteriorating fundamentals could have weighed on institutional investors causing them to exercise their put options around the same time. Columns 3 and 4 of Table 3 address this concern by including the lagged dependent variable, D_{ijt-1}, in the baseline IV specification. Intuitively, D_{ijt-1} should capture group behavior unrelated to expectations about future withdrawals. The coefficient on D_{ijt-1} is statistically insignificant, adding weight to the argument that withdrawals are unlikely to be driven by a common shock.

Another potentially important omitted variable that could be correlated with our instrument is the time until next rollover date. Longer election cycles could be associated with a greater amount of XFABN up for election between two election dates. Consequently, an insurer with longer XFABN election cycles may be experiencing greater withdrawal because the probability that investors or the insurer are, for example, hit by a liquidity shock in the interim period is greater. That said, columns 3 and 4 of Table 3 suggest that controlling for the number of days between rollover date has little effect on the IV coefficient estimate.

Our robustness tests have so far addressed the construction of the instrumental variable and potential omitted variables. An alternative concern is that the sample is improperly selected. With little variation in withdrawals during the non-run period, the standard errors estimated using both run and non-run periods may potentially be biased downwards, inflating the statistical significance of the estimated coefficients. As a robustness check, reported in columns 7 and 8 of Table 3, we restrict the sample to the run period from June 31, 2007 to December 31, 2008. This reduces our sample size by about 65 percent. Nevertheless, the second-stage IV coefficient estimate on expected future spinoffs between t and $t+1$, S_{ijt+1}, remains statistically significant at less than the 1 percent level.

4.4 Robustness to alternative mechanisms

In a second set of tests, reported in Table 5, we explore whether alternative mechanisms might explain our findings: time-series persistence in the instrumental variable, fragility of the market by design, and the firesale of assets.

A first concern is that the IV estimate of the coefficient on S_{ijt+1} is driven by time-series persistence in the instrumental variable RE_ex3m_{ijt+1}, rather than expectation about future XFABS conversion by investors. To test this hypothesis, we consider the lag of our instrument RE_ex3m_{ijt}, defined as the fraction of XFABS that is up for election between the previous election date $t-1$ and the current election date t. Table 4 suggests that there may indeed be significant time-series persistence, with a correlation coefficient of about 0.6 between RE_ex3m_{ijt+1} and RE_ex3m_{ijt}. Columns 1 and 2 of Table 5 report the first and second stage regression results using RE_ex3m_{ijt} as an instrument for S_{ijt+1}, respectively. The results suggest that RE_ex3m_{ijt} is a weak instrument for S_{ijt+1}. Moreover, the coefficient of S_{ijt+1} treated by RE_ex3m_{ijt} in the second stage is not statistically different from zero. This result suggests that, despite some persistence in the instrumental variable over time, lagged values of the instrument, RE_ex3m_{ijt}, are not a good instrument for expectations about future XFABN withdrawals.

A second concern is that insurers deliberately designed their XFABN securities to be fragile. That is, insurers may have offered a liability structure that would itself respond to bad fundamentals. By so doing, they could encourage investment and lower further their cost of funding. To test the hypothesis that the liability structure was designed to be fragile, we define $RE@I_{ijt+1}$ as the fraction of XFABN that will be up for election between election dates t and $t+1$, computed when XFABN i was issued. Table 5 suggests that the correlation between RE_ex3m_{ijt+1} and $RE@I_{ijt+1}$ is only 0.35. Unsurprisingly, $RE@I_{ijt+1}$ is a poor instrument, as reported in column 3 and 4 of Table 5. This finding suggests that it is unlikely that insurers designed their institutional spread margin business to be fragile.

Lastly, while an asset fire sale could be a source of bias in the estimate of the self-fulfilling effect, it is unlikely to be significant in the XFABN market. In principle, if life insurers had participated in a fire sale of assets funded by XFABN then institutional investors might have worried that the losses incurred by insurers could affect their repayment, and this fundamental effect could have contributed to the run. However, XFABN issuers had access to a backstop: Federal Home Loan Banks (FHLBs).[32] As shown in Figure 5, FABS issuers accessed funding from the third quarter of 2007 by issuing funding agreements, collateralized by their real estate-linked assets, directly to one of the twelve Federal Home Loan Banks. In fact, nearly all of the increase in the Federal Home Loan Bank advances to the insurance industry from 2007 was to FABS issuers. Moreover, as shown in Figure 1 of Ashcraft, Bech & Frame (2010), the cost of funding from Federal Home Loan Banks remained low and stable between June 2007 and June 2008, while the cost of funding implied by the one-month LIBOR and ABCP AA-rated 30 day interest rate surged, as the ABCP and repo markets experienced runs. Thus, the FHLBs played a key role in re-intermediating term funding to life insurers experiencing runs by institutional investors, such as money market funds.[33] The availability of low-cost, stable FHLB funding during the run and at the time the converted XFABN came due obviated the need for XFABN issuers to participate in asset fire sales.

Importantly, while the FHLBs did provide a backstop to FABS issuers and greatly mitigated the risk of fire sale, there was considerable uncertainty at the time about the survival of the FHLB system. This uncertainty stemmed from the aggressive lending by FHLBs to thousands of member banks during the real estate boom, many of which became troubled when house prices collapsed. For example, IndyMac increased its borrowings from the Federal Home Loan Bank of San Francisco more than 500 percent from the end of 2004 through early 2008, before failing in July 2008; and Countrywide gambled for resurrection during 2007 by borrowing about $50 billion from the Federal Home Loan Bank of Atlanta before its near collapse in 2008 (Coy 2008). The uncertainty about the availability of a backstop to FABS issuers around the time of the run did nothing to reassure short-term institutional investors.

[32] To be a member of a Federal Home Loan Bank, a life insurer needs to have at least 10 percent of its assets linked to real estate and can obtain advances in proportion to its membership capital that are fully collateralized by real estate-linked and other eligible assets (Frame 2016).

[33] This goes beyond the point noted by Ashcraft et al. (2010) that "at the outset of the financial crisis, money market investors ran away from debt issued or sponsored by depository institutions and into instruments guaranteed explicitly or implicitly by the U.S. Treasury. As a result, the Federal Home Loan Bank System was able to re-intermediate term funding to member depository institutions through advances."

5 Conclusion

In this paper, we study the vulnerability of shadow banking to self-fulfilling runs. We first establish in a dynamic model the connection between a firm's liability structure and self-fulfilling runs. We build on Goldstein & Pauzner (2005) and He & Xiong (2012) to show that variation in a firm's liability structure plays a critical role in a firm's vulnerability to self-fulfilling runs. This theoretical result suggests that we can potentially exploit exogenous variation of a firm's liability structure to make some progress in identifying the self-fulfilling component in a run, without relying on structural assumptions about fundamentals.[34]

We take the insight we obtain from the model, and we apply it to a run on U.S. life insurers that began in the summer of 2007. We exploit the contractual structure of a particular type of puttable security—extendible funding agreement-backed notes (XFABN)—used to access short-term funding markets. These securities provide a source of exogenous variation in strategic complementarity. The contractual terms permit investors to withdraw only on certain pre-determined dates. By carefully tracking when decisions can be made, we construct an instrument for investors' expectations that other investors might withdraw. Intuitively, when few investors can withdraw from an insurer the degree of strategic complementarity is low. We find robust evidence that the run on U.S. life insurers' XFABN in the second half of 2007 had a significant self-fulfilling component.

Our findings suggest that there may have been a significant self-fulfilling component to other contemporaneous runs by institutional investors. For example, the runs in the $1.2 trillion ABCP market in the fall of 2007 involved the same short-term institutional investors as in the XFABN market. ABCP programs that carry full liquidity guarantees from the same issuers effectively grant investors the option to put their holdings back to the issuing firm at commercial paper rollover dates, which is precisely the environment described by our model. The most famous example is Citigroup providing full liquidity support to commercial paper backed by collateralized debt obligations it had issued prior to 2007. These puttable collateralized debt obligations were identified by the Financial Crisis Inquiry Commission investigators as a primary cause of the bailout of Citigroup in

[34] For examples of structural estimation of runs, see Schroth et al. (2014) and Wei & Yue (2014).

2008, the biggest bank bailout in history.[35]

Consequently, our results have important implications for the regulation of non-bank financial institutions. A large regulatory effort since the 2008-09 financial crisis has focused on strengthening the liquidity and solvency standards of non-bank financial institutions. However, if the self-fulfilling effect identified in this paper was a culprit for the disruptions to financial intermediation by the shadow banking sector during the crisis, more emphasis should be given to addressing the risk of self-fulfilling runs. Our results suggest that some progress could be made by paying greater attention to the liability structure of financial firms.

Finally, this paper informs the debate on the systemic risk posed by asset managers to financial markets. For example, while efforts have been made to mitigate the risk of runs *on* MMFs by adapting tools from traditional banking regulations—for example, suspension of convertibility—the vulnerability of the financial system to runs *by* MMFs on the issuers of short-term liabilities remains largely unaddressed. Moreover, the wide and constantly evolving array of liabilities and assets on institutional investors' balance sheets implies that tools from traditional banking regulation, such deposit insurance and asset monitoring by regulators, may be impractical or infeasible for dealing with runs by institutional investors.

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[35]FCIC (2011) reports that Citigroup was liable for $25 billion in liquidity puts on commercial paper backed by collateralized debt obligations issued by Citigroup.

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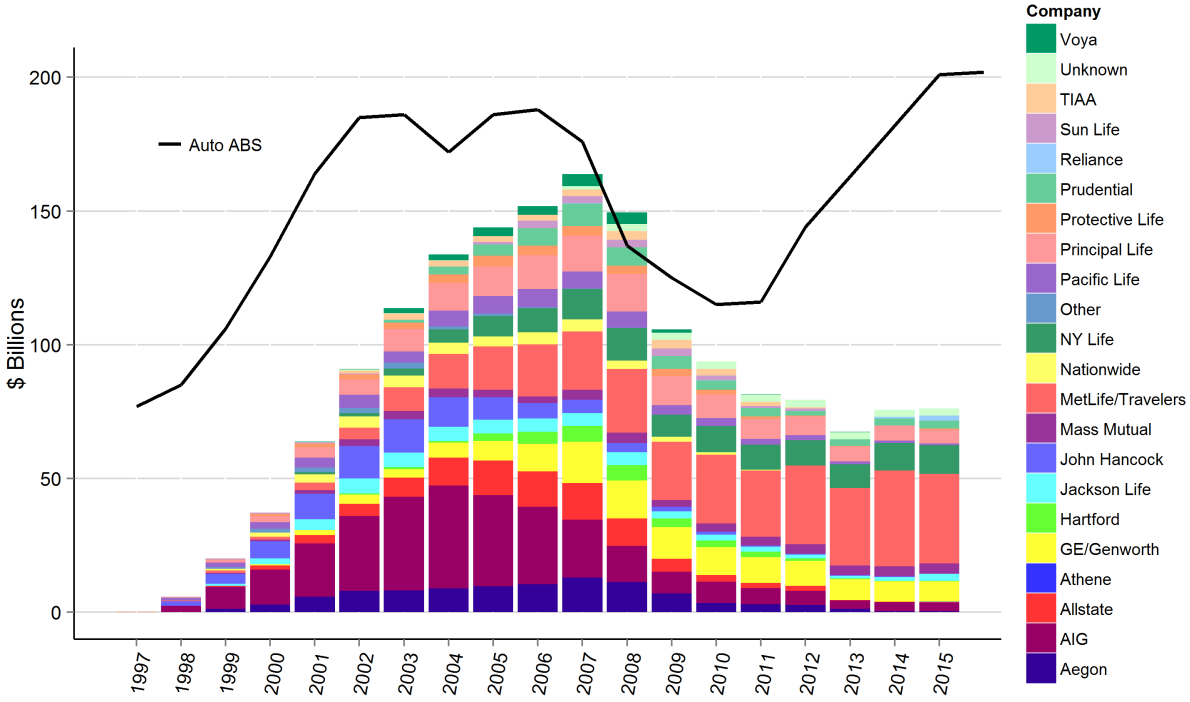
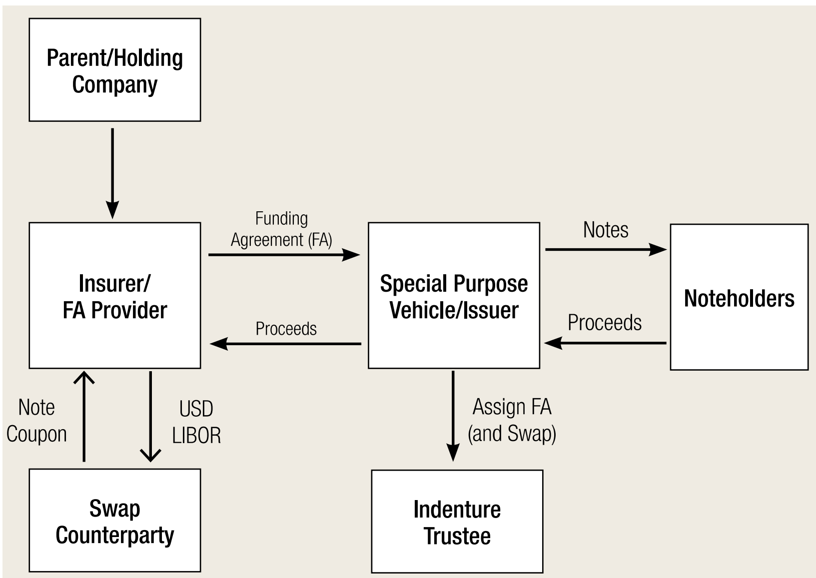
Figures and Tables

Figure 1: FABS and Auto ABS Amount Outstanding



Source: authors' calculations based on data collected from Bloomberg Finance LP, and Moody's ABCP Program Index. Data as of December 31, 2015.

Figure 2: Typical FABS Structure



Source: A.M. Best Methodology Note, 2011, "Rating Funding Agreement-Backed Securities Programs". http://www.ambest.com/ratings/fundagreementmethod.pdf

Figure 3: Timeline for XFABN election date decisions

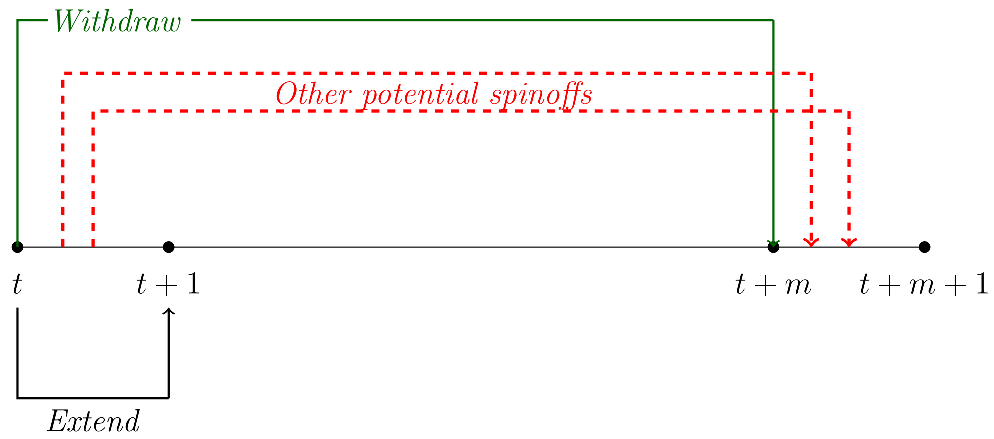
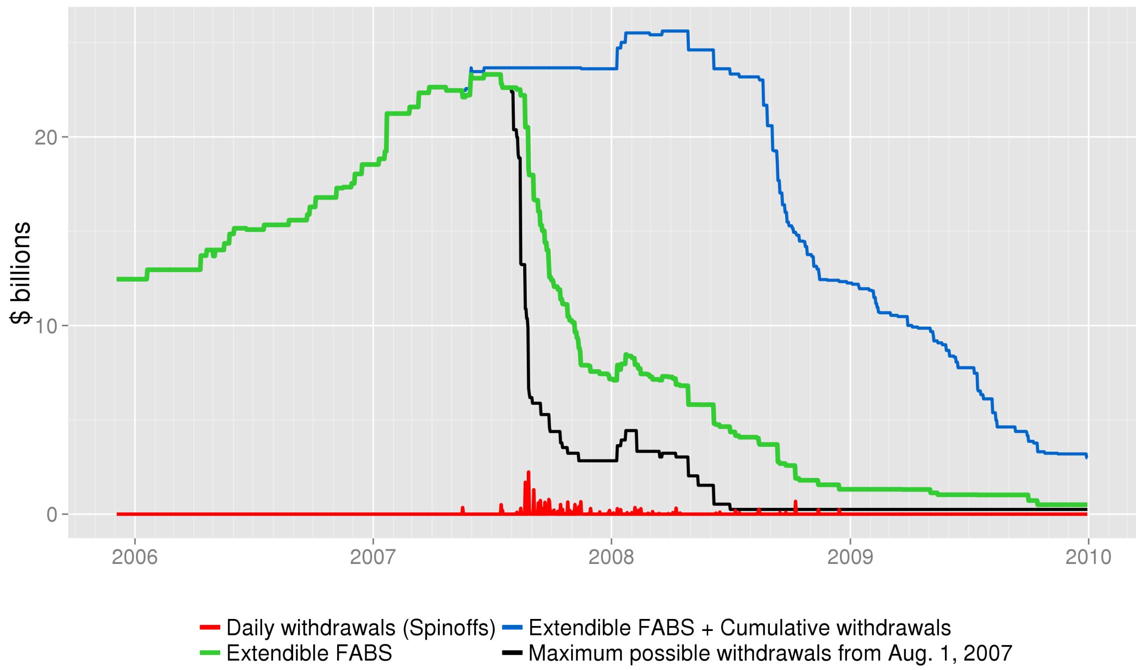
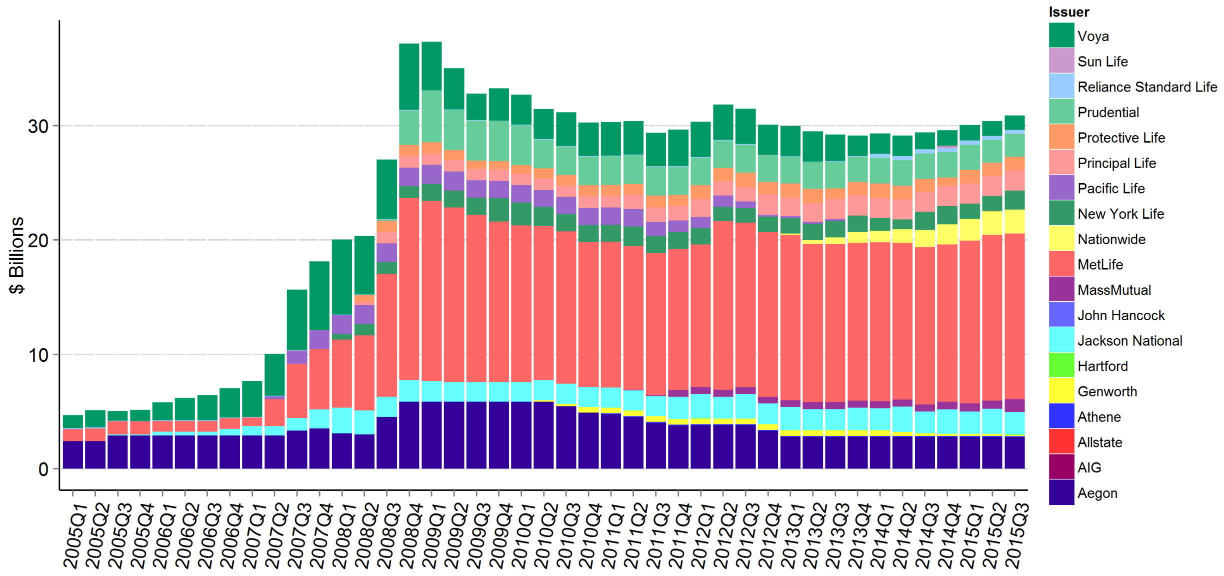


Figure 4: Run on Extendible FABN



Source: authors' calculations based on data collected from Bloomberg Financial LP.

Figure 5: FHLB Advances to FABS Issuers



Source: authors' calculations based on the Federal Home Loan Bank database, provided by the FHLB Office of Finance.

Table 1: Descriptive Statistics

This table displays descriptive statistics for the main variables used in the analysis in the sample extending from January 1, 2005 to December 31, 2010. When an XFABN is not extended, it is “spunoff” into a new security with a separate CUSIP identifier.

	Obs.	Median	Mean	Std. Dev.	Min	Max
Number of XFABN	54	.	.	.	.	.
Number of spinoffs	106	.	.	.	.	.
Number of election dates across all XFABN	1129	.	.	.	.	.
Number of days between election dates	1076	31	47.3	35.9	28	365
Issuance amount of XFABN (USD million)	53	350	468.4	333.3	100	2000
Issuance amount of spinoffs (USD million)	106	134.5	191.5	193.3	0.2	1338.5
Maturity of spinoffs (days)	53	367	504.7	215	302	1006
Fraction of XFABN that is converted into spinoff (D_{ijt})	768	0	0.1	0.3	0	1
Spinoffs created during election period as a fraction of all XFABN (S_{ijt+1})	914	0	0	0.1	0	1
Fraction of all XFABN that can potentially be turned into spinoffs (RE_ex3m_{ijt+1})	1128	0.44	0.44	0.35	0	1
Maturing FABS (Q_{ijt})	1076	0.2	0.18	0.15	0	1

Source: authors’ calculations based on data collected from Bloomberg Finance LP.

Table 2: Runs on Extendible FABN

This table summarizes the main results on the run on U.S. life insurers that occurred in the summer of 2007. The unit of observation is the election date t of an individual XFABN i issued by insurer j, and the sample extends from January 1, 2005 to December 31, 2010. The dependent variable D_{ijt} is the fraction of XFABN i issued by insurer j that is converted into a fixed maturity bond at election date t. The potentially endogenous explanatory variable S_{ijt+1} is the fraction of all XFABN from insurer j that is converted between the current election date t and the next election date $t+1$. The variable Q_{ijt} is calculated as the fraction of XFABN from insurer j that were converted prior to election date t plus the fixed maturity FABN scheduled to mature between t and $t+1$. Columns 1 through 5 include insurer fixed effects. Column 2 includes the one-month log change in VIX and the amount of U.S. ABCP outstanding. Column 3 includes sponsoring insurer stock price, 5-year CDS, and 1-year EDF. Column 4 and 5 summarize the main instrumental variable results. We instrument S_{ijt+1} with RE_ex3m_{ijt+1}, calculated as the maximum fraction of XFABN that can be converted into short-term fixed maturity bonds between an XFABN i's election dates t and $t+1$, removing any changes stemming conversion or new issue in the three months leading up to election date t. Robust standard errors are reported in parentheses. ***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

Dependent variable: D_{ijt}	(1) Reduced Form	(2) VIX & ABCP	(3) Financial Health	(4) Instrumental Variable First Stage	(5) Instrumental Variable Second Stage
S_{ijt+1} (endogenous)	0.731***	0.429***	0.497**		2.124***
	(0.144)	(0.143)	(0.231)		(0.396)
RE_ex3m_{ijt+1}				0.125***	
				(0.0160)	
Q_{ijt}	0.743***	0.673***	1.052***	0.108**	0.505***
	(0.168)	(0.156)	(0.362)	(0.0429)	(0.177)
$\Delta_{1m}\ln(\text{VIX}_t)$		-0.0438	-0.103**		
		(0.0367)	(0.0501)		
$\Delta_{1m}\ln(\text{ABCP outstanding}_t)$		-1.793***	-2.197***		
		(0.334)	(0.463)		
5 Year CDS Spread (bps)			-0.000102		
			(0.000235)		
1 Year Expected Default Frequency (%)			-0.0139		
			(0.0499)		
Stock Price ($)			0.000325		
			(0.00187)		
Observations	747	747	312	747	747
Adjusted R^2	0.204	0.283	0.398	0.272	-0.086
Insurer FE	Y	Y	Y	Y	Y
Robust KP Wald F-stat					61.17
Stock-Yogo Critical Value 10%					16.38

Source: authors' calculations based on data collected from Bloomberg Finance LP, Markit and Center for Research in Security Prices (CRSP) via Wharton Research Data Services (WRDS), Moody's Analytics: KMV, Federal Reserve Bank of St Louis, Federal Reserve Economic Data (FRED).

Table 3: Robustness of the IV Coefficient Estimate

This table investigates the robustness of the IV coefficient estimate in Table 2. The unit of observation is the election date t of an individual XFABN i issued by insurer j, and the sample extends from January 1, 2005 to December 31, 2010. The dependent variable D_{ijt} is the fraction of XFABN i issued by insurer j that is converted into a fixed maturity bond at election date t. The endogenous variable S_{ijt+1} is the fraction of all XFABN from insurer j that is converted between the current election date t and the next election date $t+1$. The variable Q_{ijt} is calculated as the fraction of XFABN from insurer j that were converted prior to election date t plus the fixed maturity FABN scheduled to mature between t and $t+1$. The baseline instrumental variable is RE_ex3m_{ijt+1}. Columns 1 and 2 include weekly time fixed effects. Columns 3 and 4 use the instrument measured as of June 1, 2007 (RE_Jun07_{ijt+1}). Columns 5 and 6 include the lagged dependent variable D_{ijt-1}. Columns 7 and 8 include the number of days until the next rollover date. Columns 9 and 10 restrict the sample to the run period extending from June 31, 2007 to December 31, 2008. Robust standard errors are reported in parentheses. ***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dependent variable: D_{ijt}	Week FE		RE_Jun07_{ijt+1}		D_{ijt-1}		Days to rollover		Run period	
	First stage	Second stage	First stage	Second stage	First stage	Second stage	First stage	Second stage	First stage	Second stage
S_{ijt+1} (endogenous)		1.606**		3.236***		2.029***		2.095***		2.657***
		(0.641)		(0.644)		(0.417)		(0.373)		(0.960)
RE_ex3m_{ijt+1}	0.0672***				0.124***		0.140***		0.131***	
	(0.0175)				(0.0176)		(0.0182)		(0.0319)	
RE_Jun07_{ijt+1}			0.0584***							
			(0.0101)							
Q_{ijt}	0.0616	0.519***	0.0541	0.315	0.103**	0.501***	0.152***	0.497***	0.0387	1.164**
	(0.0680)	(0.171)	(0.0409)	(0.195)	(0.0448)	(0.179)	(0.0507)	(0.185)	(0.0707)	(0.490)
D_{ijt-1}					0.0553	0.112				
					(0.0450)	(0.113)				
Days-to-rollover							-0.000474***	0.000118		
							(0.000168)	(0.000466)		
Observations	747	747	747	747	704	704	747	747	266	266
Adjusted R-squared	0.414	0.136	0.225	-0.735	0.278	-0.011	0.283	-0.075	0.435	-0.464
Insurer FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Weekly FE	Y	Y	N	N	N	N	N	N	N	N
Robust KP Wald F-stat		14.72		33.64		49.37		59.4		16.82
Stock-Yogo Critical Value 10%		16.38		16.38		16.38		16.38		16.38

Source: authors' calculations based on data collected from Bloomberg Finance LP, Markit and Center for Research in Security Prices (CRSP) via Wharton Research Data Services (WRDS), Moody's Analytics: KMV, Federal Reserve Bank of St Louis, Federal Reserve Economic Data (FRED).

Table 4: Correlations Between Alternative Instruments

This table explores the correlations between variables that are closely related to the instrumental variable RE_ex3m_{ijt+1} used in the main analysis of Table 2. The instrumental variable RE_ex3m_{ijt+1} is the maximum fraction of XFABN that can be converted into short-term fixed maturity bonds between an individual XFABN i's election dates t and $t+1$, removing any changes stemming conversion or new issue in the three months leading up to election date t; RE_ex3m_{ijt} is the same variable measued between election date $t-1$ and the current election date t; RE_{ijt+1} is the maximum fraction of XFABN that can be converted into short-term fixed maturity bonds between an individual XFABN i's election dates t and $t+1$; $RE@I_{ijt+1}$ is the anticipated fraction of XFABN that will be up for election between election date t and $t+1$ when the XFABN is issued; and Δ_3mVIX_t is three month change in VIX.

	S_{ijt+1}	RE_ex3m_{ijt+1}	RE_{ijt+1}	RE_ex3m_{ijt}	$RE@I_{ijt+1}$	$\Delta_{3m}VIX_t$
S_{ijt+1}	1					
RE_ex3m_{ijt+1}	0.37	1				
RE_ijt+1	0.37	0.83	1			
RE_ex3m_{ijt}	0.10	0.57	0.57	1		
$RE@I_{ijt+1}$	0.15	0.54	0.56	0.52	1	
$\Delta_{3m}VIX_t$	0.04	0.03	-0.03	-0.04	0.00	1

Source: authors' calculations based on data collected from Bloomberg Finance LP.

Table 5: Further Robustness Tests

This table investigates the robustness of the results in Table 2 to alternative mechanisms. All regressions include the controls included in the baseline reduced form regression – column 4 of Table 2. Columns 3 and 4 instrument S_{ijt+1} with RE_ex3m_{ijt}, the fraction of XFABN that is up for election between election date $t-1$ and the current election date t. Columns 5 and 6 instrument S_{ijt+1} with $RE@I_{ijt+1}$, the anticipated fraction of XFABN that will be up for election between election date t and $t+1$ when the XFABN is issued. Column 7 includes RE_ex3m_{ijt+1} to the baseline reduced form regression (column 4 of Table 2). Columns 8 and 9 instrument S_{ijt+1} with Q_{ijt}, the fraction of XFABN from insurer j that were converted prior to election date t. Robust standard errors are reported in parentheses. ***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

	(1)	(2)	(3)	(4)	(5)
Dep. var.: D_{ijt}	Lagged IV		RE at issue		IV as a proxy
	First stage	Second stage	First stage	Second stage	
S_{ijt+1} (endogenous)		-0.274		1.842	0.549***
		(1.864)		(1.677)	(0.143)
RE_ex3m_{ijt+1}					0.197***
					(0.0429)
RE_ex3m_{ijt}	0.0116				
	(0.00761)				
$RE@I_{ijt+1}$			0.0173		
			(0.0118)		
Q_{ijt}	0.227***	1.152**	0.200***	0.698*	0.674***
	(0.0657)	(0.492)	(0.0698)	(0.389)	(0.158)
Observations	642	642	554	554	747
Adjusted R-squared	0.211	0.079	0.149	0.040	0.241
Insurer FE	Y	Y	Y	Y	Y
Robust KP Wald F-stat		2.32		2.15	
Stock-Yogo Critical Value 10%		16.38		16.38	

Source: authors' calculations based on data collected from Bloomberg Finance LP.

A Model appendix

The model in Section 1 discusses a new link between a firm's liability structure and the existence self-fulfilling runs. In this appendix, we specialize the model by making three additional assumptions to explore this link further. These assumptions are helpful to illustrate how concerns about bad fundamentals may trigger a self-fulfilling run when a large enough fraction of securities becomes puttable. These assumptions are also helpful to discuss the connection between this model and that of He & Xiong (2012).[36]

A1. $\rho + \theta < r < \rho + \phi$

A2. $0 \leq \pi_{bg} < \frac{\rho+\phi-r}{r-\rho} \cdot (\rho + \phi + \varepsilon\eta)$

A3. $\frac{r-(\rho+\theta)}{\rho+\phi+\theta-r} \cdot A < \pi_{gb} < \frac{r-\rho}{\rho+\phi-r} \cdot A$, where $A = \rho + \phi + \theta + \varepsilon + \delta + \pi_{bg}$.

We begin by establishing the basic properties of the *run* and *no run* equilibria. Assumption **A1** guarantees that *no run* is the unique symmetric equilibrium in the good fundamental state if the probability of switching from the good to bad state is zero. That is, if $\pi_{gb} = 0$ then $V^{g*}(e) \geq 1 \ \forall e \in [0, 1]$. To see this, note that if the good state is absorbing ($\pi_{gb} = 0$) and investors never withdraw in the good state, then the value of an extendible security is

$$V^{g*}(e) = \bar{\bar{V}}^g \equiv \frac{r + \phi + \varepsilon\eta}{\rho + \phi + \varepsilon\eta} \qquad \forall e \in [0, 1] \ .$$

Since investors' discount rate is $\rho < r$, it follows that $\bar{\bar{V}}^g > 1$ and it is optimal for investors to never exercise their put option. Moreover, with $\pi_{gb} = 0$, for all $e \in [0, 1]$ and $\bar{V}$

$$V^g(e; \bar{V}) \geq V^g(1; \bar{V}) = \frac{r + \phi + \varepsilon\eta}{\rho + \theta + \phi + \varepsilon\eta} > 1 \ ,$$

which implies that extending the security is the dominant strategy in the good fundamental state if $\pi_{gb} = 0$, and the *no run* is the unique equilibrium.

[36]It is straightforward to show that the set of parameters for which these assumptions hold is not empty.

Assumptions **A1** and **A2** yield a sufficient condition for a unique *run* equilibrium in the bad fundamental state, that is, $V^{b*}(e) < 1\ \forall e \in [0,1]$.[37] To see this, note that

$$V^b(e;\bar{V}) \leq V^b(e;\mathbf{1}) \leq \frac{r + \varepsilon\eta + \pi_{bg}\bar{\bar{V}}^g}{\rho + \phi + \varepsilon\eta + \pi_{bg}} \ ,$$

where

$$\bar{\bar{V}}^g = \frac{r + \phi + \varepsilon\eta}{\rho + \phi + \varepsilon\eta} \geq V^g(e;\bar{V}) \ ,$$

regardless of π_{gb} and $\bar{V}$. Thus, if assumptions **A1** and **A2** hold, $V^b(e;\bar{V}) < 1$ and withdrawing (exercising the put) is the dominant strategy in the bad state for a positive measure of investors.

For a low enough e, extending the maturity of a security is always the dominant strategy in the good fundamental state. This follows from the upper bound of π_{gb} in assumption **A3**, which guarantees that $V^g(0;\mathbf{0}) > 1$. Moreover, the lower bound of π_{gb} implies that $V^g(1;\mathbf{1}) < 1$. That is, investors run in the good state when e is high enough and the probability of switching to the bad state is sufficiently large.

To explore the differences between this model and the dynamic debt run model of He & Xiong (2012), it is instructive to fix the firm's liability structure by setting $\varepsilon = 0$. In this special case, switching between the good and the bad fundamental states in our model is similar to the fluctuating asset fundamental value in He & Xiong (2012). And although running is the dominant strategy in the bad state, the optimality of a run in the good state depends on the persistence of the good state. That is, investors run in the good state only when there is a high enough probability of switching to the bad state. In contrast, the analysis above and in Section 1 emphasized the link between variations in the firm's liability structure and self-fulfilling runs. In our model, a run occurs in the good state when the externality of asset liquidation due to investors' run is high. And the size of the liquidation cost depends on the amount of securities that is subject to rollover.

[37] Note that **A2** is feasible because of the upper bound of r in **A1**.

B FABS database

Our FABS database was compiled from multiple sources, covering the period beginning when FABS were first introduced in the mid-1990s to early 2014. To construct our dataset on FABS issuers, we combined information from various market observers and participants on FABS conduits and their issuance. We then collected data on contractual terms, outstanding amounts, and ratings for each FABS issue to obtain a complete picture of the supply of FABS at any point in time. Finally, we added data on individual conduits and insurance companies, as well as aggregate information about the insurance sector and the broader macroeconomy.

FABS are issued under various terms to cater to different investors demand. The most common type of FABS are funding agreement-backed notes (FABN), which account for more than 97 percent of all US FABS. We first identify all individual FABN issuance programs using market reports and other information from A.M. Best, Fitch, and Moody's. FABN conduits are used only to issue FABN. This FA originator-FABN conduit structure falls somewhere between the more familiar stand-alone trust and master trust structures used for traditional asset-backed securities, such as auto loan, credit card, and mortgage ABS.[38] Importantly, the FABS issuing SPVs are never fully bankruptcy remote as the FA remains a liability on the balance sheet of the insurer. A substantial fraction of FABN are issued with different types of embedded put options, including Puttable FABN and Extendible FABN. Extendible FABN gives investors the option to extend the maturity of their FABN at regular interval, and are designed to appeal to short-term investors such as MMFs subject to Rule 2a-7. A closely related type of short-term FABS are funding agreement backed commercial paper (FABCP). FABCP programs have an explicit liquidity guarantee from the sponsoring insurer or its holding company as the underlying FAs typically have a longer maturity than the associated CP.

We link these FABS programs to the insurance companies originating the FAs used as collateral. In total, as shown in Table 6, we find that FABS programs associated with over 130 conduits, backed by FAs from 30 life insurers in the United States. Of

[38]While a stand-alone trust issues a single ABS deal (with multiple classes) based on a fixed pool of receivables assigned to the SPV, the master trust allows the issuer/SPV to issue multiple securities and to alter the assigned pool of collateral. Although the FABN conduit may issue multiple securities, similar to a master trust, the terms of each security are shared with the unalterable FA backing the asset, similar to the fixed pool of collateral for a stand-alone trust.

these, there are four FABCP conduits (two of which are currently active) operated by two insurance conglomerates using FAs from five different insurers. We then use our list of FABS conduits to search Bloomberg and gather information on every FABN issue. For each FABN, we collected Bloomberg and prospectus data on contractual terms and amount outstanding to construct a complete panel of new FABN issuances and amount outstanding at a daily frequency.

We have records of 2,040 individual FABN issues, with the first issuance recorded in 1996 and about 70 new issues recorded in the first half of 2014. FABN issuance grew rapidly during the early 2000s, peaking at over $47 billion in 2006. We also collected data on FABCP, relying on end of quarter data from Moody's ABCP Program Review since individual security information is not available.[39] Total FABCP outstanding was less than $3 billion until 2008, growing to just under $10 billion at the end of 2013 after MetLife entered the market in late 2007. As described in the introduction, at its peak in 2007, the total outstanding value of the FABS market collateralized with FA from US based life insurers reached almost $150 billion, or more than 80 percent of the Auto ABS market (Figure 1).

Lastly, we match our data to a wide variety of firm-level, sector-level, and broader economic environment data. Since these data are usually available only at a quarterly frequency, we aggregate our data for most of the analysis in this paper. We include several data-series about the FA-sponsoring life insurers, including balance sheet and statutory filings information from SNL Financial and AM Best, CDS spreads from Markit, credit ratings from S&P, and expected default frequencies (EDF) from Moody's KMV.

[39] Individual issuance data on FABCP are available from DTCC but are confidential and unavailable to us.

Table 6: U.S. Issuers of Funding Agreement-Backed Securities (FABS)

This table shows the number and type of conduits used by U.S. life insurers to issue FABS and and their ultimate parent company.[a]

Funding agreement issuer name	Parent company name	No. of FABN conduits		No. of FABCP conduits
		Multiple issue	Single issue[b]	
AIG SunAmerica Life Insurance Company[c]	AIG/SunAmerica	3	15	
Monumental Life Insurance Company	Aegon	3	.	
Allstate Life Insurance Company	Allstate	5	.	
GE Capital Assurance Company	Ge Capital	.	10	
Genworth Life Insurance Company[d]	Genworth	2	40	
Hartford Life Insurance Company	Hartford	2	5	
ING USA Annuity and Life Insurance Company	Voya Financial[e]	1	.	
Security Life of Denver Insurance Company	Voya Financial[f]	1	.	
Jackson National Life Insurance Company	Jackson National	2	.	
John Hancock Life Insurance Company	John Hancock	2	.	
Massachusetts Mutual Life Insurance Company	MassMutual	2	.	
MetLife Insurance Company of Connecticut[g]	MetLife	4	.	1[h]
Metropolitan Life Insurance Company	MetLife	1	2	
Nationwide Life Insurance Company	Nationwide	2	.	
New York Life Insurance Company	New York Life	2	.	
Pacific Life Insurance Company	Pacific Life	2	1	
Principal Life Insurance Company	Principal Life	5	.	
Protective Life Insurance Company	Protective Life	3	2	
Prudential Insurance Company of America	Prudential	1	1	
Reliance Standard Life Insurance Company	Reliance	2	.	
Sun Life Assurance Company of Canada (USA)	Sun Life Financial	2	2	
Teachers Insurance and Annuity Association of America	TIAA	1	.	
Travelers Life and Annuity	Travelers	2	.	
Transamerica Life Insurance Company	Aegon	.	.	3[i]
Transamerica Occidental Life Insurance Company[j]	Aegon	.	.	
Other[k]		1	23	
Unknown[l]		.	31	
Total		51	132	4

[a]Source: numerous industry reports from Moody's Analytics, A.M. Best Company, ©2015 Standard & Poor's Financial Services LLC ("S&P"), Fitch Research.
[b]Includes *Premium Asset Trust Series* and *Structured Repackaged Asset Trust Series* issuing structures.
[c]Merged with General American Life in 2013, which is part of AIG Life and Retirement Group.
[d]Formerly GE Capital Assurance Company; IPO-ed as Genworth on May 24, 2004.
[e]Formelry ING U.S.; IPO-ed in 2013, renamed Voya Financial on April 11, 2014.
[f]Formelry ING U.S.; IPO-ed in 2013, renamed Voya Financial on April 11, 2014.
[g]Formerly Travelers Life and Annuity; aquired by MetLife on July 1, 2005.
[h]FABCP collaterized by FA from Metropolitan Life Insurance Company and MetLife Insurance Company of Connecticut.
[i]FABCP collaterized by FA from Transamerica Life Insurance Company and Transamerica Occidental Life Insurance Company.
[j]Merged with Transamerica Life Insurance Company on October 1, 2008.
[k]Includes Beneficial Life, Federal Kemper, Hanover Insurance Group, MBIA, Mutual of Omaha, Scottish Annuity & Life Insurance Co., and XL Life.
[l]Unmatched series issued under Premium Asset Trust and Structured Repackaged Asset Trust structure.

C XFABN Prospectus (first three pages)

FINAL TERMS

Final Terms No. 2011-5 dated June 7, 2011

Metropolitan Life Global Funding I

Issue of $800,000,000 Extendible Notes due 2017
secured by a Funding Agreement FA-32515S issued by

Metropolitan Life Insurance Company

under the $25,000,000,000 Global Note Issuance Program

This Final Terms should be read in conjunction with the accompanying Offering Circular dated September 8, 2010 as supplemented by (i) a first base prospectus supplement dated as of November 24, 2010 (the "**First Base Prospectus Supplement**"), (ii) a second base prospectus supplement dated as of April 5, 2011 (the "**Second Base Prospectus Supplement**") and (iii) a third base prospectus supplement dated as of May 27, 2011 (the "**Third Base Prospectus Supplement**") (as so supplemented, the "**Offering Circular**") relating to the $25,000,000,000 Global Note Issuance Program of Metropolitan Life Global Funding I (the "**Issuer**").

PART A — CONTRACTUAL TERMS

Terms used herein and not otherwise defined herein shall have the meanings ascribed in the Offering Circular, which constitutes a base prospectus for the purposes of the Prospectus Directive (Directive 2003/71/EC) (the "**Prospectus Directive**"). This document constitutes the Final Terms of the Notes described herein for the purposes of Article 5.4 of the Prospectus Directive and must be read in conjunction with the Offering Circular. Full information regarding the Issuer and the offer of the Notes is only available on the basis of the combination of these Final Terms and the Offering Circular. The Offering Circular is available for viewing in physical format during normal business hours at the registered office of the Issuer located at c/o U.S. Bank Trust National Association, 300 Delaware Avenue, 9th Floor, Wilmington, DE 19801. In addition, copies of the Offering Circular and these Final Terms will be available in physical format free of charge from the principal office of the Irish Paying Agent for Notes listed on the Irish Stock Exchange and from the Paying Agent with respect to Notes not listed on any securities exchange. In addition, the Offering Circular is published on the website of the Central Bank of Ireland at www.centralbank.ie.

1.	(i) Issuer:	Metropolitan Life Global Funding I
	(ii) Funding Agreement Provider:	Metropolitan Life Insurance Company ("**Metropolitan Life**")
2.	Series Number:	2011-5
3.	Tranche Number:	1
4.	Specified Currency or Currencies:	U.S. Dollar ("**$**" or "**USD**")
5.	Aggregate Principal Amount:	$800,000,000
6.	(i) Issue Price:	100.00% of the Aggregate Principal Amount
	(ii) Net proceeds:	$798,400,000 (after payment of underwriting commissions and before payment of certain expenses)
	(iii) Estimated Expenses of the Issuer:	$55,000
7.	Specified Denominations:	$100,000 and integral multiples of $1,000 in excess thereof
8.	(i) Issue Date:	June 14, 2011

	(ii) Interest Commencement Date (if different from the Issue Date):	Not Applicable
	Maturity Date:	
	— Initial Maturity Date:	July 6, 2012, or, if such day is not a Business Day, the immediately preceding Business Day, except for those Extendible Notes the maturity of which is extended on the initial Election Date in accordance with the procedures described under "Extendible Notes" below.
	— Extended Maturity Dates:	If a holder of any Extendible Notes does not make an election to extend the maturity of all or any portion of the principal amount of such holder's Extendible Notes during the notice period for any Election Date, the principal amount of the Extendible Notes for which such holder has failed to make such an election will become due and payable on any later date to which the maturity of such holder's Extendible Notes has been extended as of the immediately preceding Election Date, or if such later date is not a Business Day, the immediately preceding Business Day.
	— Final Maturity Date:	July 6, 2017, or, if such day is not a Business Day, the immediately preceding Business Day.
9.	Election Dates:	The 6th calendar day of each month, from July 6, 2011, through, and including, June 6, 2016, whether or not any such day is a Business Day.
10.	Closing Date:	June 14, 2011
11.	Interest Basis:	Floating Rate
12.	Redemption/Payment Basis:	Redemption at par
13.	Change of Interest or Redemption/Payment Basis:	Not Applicable
14.	Put/Call Options:	Not Applicable
15.	Place(s) of Payment of Principal and Interest:	So long as the Notes are represented by one or more Global Certificates, through the facilities of The Depositary Trust Company ("**DTC**") or Euroclear System ("**Euroclear**") and Clearstream Luxembourg, *société anonyme* ("**Clearstream**")
16.	Status of the Notes:	Secured Limited Recourse Notes
17.	Method of distribution:	Syndicated
Provisions Relating to Interest (If Any) Payable		
18.	Fixed Rate Notes Provisions:	Not Applicable
19.	Floating Rate Note Provisions:	Applicable

(i)	Interest Accrual Period(s)/Interest Payment Dates:	Interest Accrual Periods will be successive periods beginning on, and including, an Interest Payment Date and ending on, but excluding, the next succeeding Interest Payment Date; *provided*, that the first Interest Accrual Period will commence on, and include, June 14, 2011, and the final Interest Accrual Period of any Extendible Notes will end on, but exclude, the Maturity Date of such Extendible Notes. Interest Payment Dates will be the 6th day of each January, April, July and October beginning on October 6, 2011; subject to adjustment in accordance with the Modified Following Business Day Convention, provided that the final Interest Payment Date for any Extendible Notes will be the Maturity Date of such Extendible Notes and interest for the final Interest Accrual Period will accrue from, and including, the Interest Payment Date immediately preceding such Maturity Date to, but excluding, such Maturity Date.
(ii)	Business Day Convention:	Modified Following Business Day Convention, except as otherwise specified herein
(iii)	Interest Rate Determination:	Condition 7.03 will be applicable
	— Base Rate:	USD 3-Month LIBOR, which means that, for purposes of Condition 7.03(i), on the Interest Determination Date for an Interest Accrual Period, the Calculation Agent will determine the offered rate for deposits in USD for the Specified Duration which appears on the Relevant Screen Page as of the Relevant Time on such Interest Determination Date; *provided* that the fall back provisions and the rounding provisions of the Terms and Conditions will be applicable. The Base Rate for the first Interest Accrual Period will be interpolated between USD 3-Month LIBOR and USD 4-Month LIBOR.
	— Relevant Margin(s):	Plus 0.125% from and including the Issue Date to but excluding July 6, 2012 Plus 0.18% from and including July 6, 2012 to but excluding July 6, 2013 Plus 0.20% from and including July 6, 2013 to but excluding July 6, 2014 Plus 0.25% from and including July 6, 2014 to but excluding July 6, 2015 Plus 0.25% from and including July 6, 2015 to but excluding July 6, 2016 Plus 0.25% from and including July 6, 2016 to but excluding July 6, 2017 (if any such day is not a Business Day the new Relevant Margin will be effective in accordance with the Modified Following Business Day Convention)
	— Initial Interest Rate:	The Base Rate plus 0.125%, to be determined two Banking Days in London prior to the Issue Date