Asset Insulators*

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Abstract

We propose that financial institutions can act as asset insulators, holding assets for the long run to protect their valuations from consequences of exposure to financial markets. We illustrate the empirical relevance of this theory for the balance sheet behavior of a large class of intermediaries, life insurance companies. The pass-through from assets to equity is an especially informative metric for distinguishing the asset insulator theory from Modigliani-Miller or other standard models. We estimate the pass-through using security-level data on insurers' holdings matched to corporate bond returns. Uniquely consistent with the insulator view, outside of the 2008-2009 crisis insurers lose as little as 10 cents in response to a dollar drop in asset values, while during the crisis the pass-through rises to roughly 1. The rise in pass-through highlights the fragility of insulation exactly when it is most valuable.

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1 Introduction

Financial intermediaries such as banks, life insurers, and pension funds hold tens of trillions of dollars of securities. Does the organization of ownership of financial assets matter? A long tradition tracing to Modigliani and Miller (1958) says no. Yet, a debate has erupted on the role of these institutions and whether alternative structures of the financial sector would affect the provision of financial intermediation. Addressing these issues requires understanding why these institutions exist and how they create value for their stakeholders, if at all.

In this paper, we propose that some financial intermediaries act as *asset insulators*. An asset insulator holds assets for the long run, protecting asset valuations from consequences of exposure to financial markets. This activity is the source of value creation and shapes the evolution of the intermediary's market equity. Viewing financial institutions as insulators makes prescriptions for their portfolio choice, liability structure, and trading behavior. To discriminate asset insulation from alternative theories of intermediation, we introduce the asset pass-through: the change in market equity in response to a dollar change in the market value of assets. For an insulator, the pass-through is typically below one, reflecting the insensitivity to some market fluctuations, but rises in periods of financial distress as the deterioration in the financial health of the intermediary threatens its ability to act as a long-lived investor.

We illustrate the empirical relevance of this theory in the context of a large class of intermediaries, the life insurance sector. The balance sheets of life insurers exemplify an asset insulation strategy. Insurers hold illiquid and risky assets for long intervals, an asset allocation that is complementary to their having relatively stable liabilities. This pattern is at odds with the common view of insurers making portfolio choices primarily to offset the interest rate risk of their policy liabilities. We then construct a data set of detailed regulatory data on insurers' security-level holdings matched with returns on those securities to measure the pass-through. A one dollar drop in asset values outside of the 2008-09 financial crisis results in a decline in equity of as little as 10 cents, while during the crisis the pass-through rises to approximately 1, uniquely consistent with the insulator view. Finally, the importance of asset insulation rises during the financial crisis, accounting for an increase in the franchise value of insurers of tens of billions of dollars.

We start our analysis by providing a model of an asset insulator. The model has two key ingredients. First, the value of assets on traded markets is affected by shocks that do not affect value if held inside the intermediary. We review a number of motivations for such a wedge. Second, because of leverage, the financial intermediary will have to liquidate its holdings on the open market if the value of assets deteriorates beyond a certain threshold. We solve the model to obtain an analytic expression for the firm's market equity. The wedge between the value of an asset held inside the firm and on the open market means that the Modigliani-Miller theorem does not apply in our setting. We define franchise value as the difference between the firm's market equity and the market value of financial assets minus liabilities. The franchise value fluctuates in response to both changes in the value of the asset insulation function and the ability of intermediaries to perform it.

Life insurers are a natural candidate to provide asset insulation. Life insurance and annuity policies have long contractual horizons. While policyholders may have the option to take an early surrender, the quantity of surrenders does not spike during periods of financial turmoil such as during the financial crisis. Thus, the long and predictable duration of liabilities makes insurers natural holders of assets which have transitory fluctuations in market prices. Our analysis of life insurers also takes advantage of the availability of detailed, security-level regulatory data.

Insulators should target assets which have a large wedge between their valuation on and off the market. Illiquid, risky assets provide such an opportunity. Indeed, Treasuries and agency bonds constitute only about 13% of insurers' assets, and the other assets on their balance sheet are not Treasury-like in their risk characteristics. The largest concentration of holdings is in corporate bonds. Even before the crisis in 2006, roughly half of these corporate bonds had a rating of BBB or below. Insurers hold securities for an average length of four years, a horizon long enough to allow the transitory fluctuations in market prices to dissipate. The portfolio concentration in illiquid, risky assets sharply contradicts the commonly held view that life insurance companies choose their assets solely to neutralize the interest rate risk of their liabilities (see, e.g., Briys and De Varenne, 1997).

The pass-through from a dollar of assets to equity provides a key moment to discriminate asset insulation from other theories of intermediation. Within our model, we derive an analytic expression for the pass-through and show how it varies with the asset value wedge and the distance to default of the firm. In normal times, the ability to insulate from transitory fluctuations in asset prices in the open market yields a pass-through into intermediary equity below 1. As the risk of liquidation increases, however, the ability to insulate diminishes and even transitory fluctuations affect equity. Moreover, each lost dollar of assets pushes the firm closer to liquidation, reducing the value of insulation on the entire balance sheet. Thus, the pass-through rises during a crisis.

We test these predictions empirically by constructing asset price shocks which affect some insurers and not others and comparing the responses of their equity prices. Specifically, we match daily cusip-level holdings of the assets on each publicly-traded insurer's balance sheet with the universe of corporate bond returns on each date. Our main empirical strategy exploits only corporate bonds experiencing large abnormal returns. We attribute the corresponding asset value change using the portfolio position of each insurer. We then regress the equity return on the asset value change in the cross-section of insurers. Focusing on tightly timed, large bond returns localized in a small subset of securities helps to ensure the asset value shocks are unrelated to other activities of affected insurers. Nonetheless, they are frequent and large enough to allow us to precisely estimate the pass-through. We further show that the shocks do not reflect only high-frequency variation in prices.

Consistent with the predictions of the model, pass-through estimates differ markedly in and out of the financial crisis of 2008-2009. Before or after the crisis, we find that a dollar lost on assets creates an approximately 10 cent loss to equity values, economically and statistically significantly much less than one. During the crisis, the point estimate of the pass-through rises. The data reject equality of the pass-through in and out of the crisis, but do not reject equality of the crisis pass-through and 1. The pass-through rises more during the crisis for insurers with larger overall declines in their stock price, providing further evidence of poor financial health during this period contributing to lower insulation from market movements.

Other common theories of financial intermediation cannot produce the pattern of pass-through we find in the data. With frictionless financial markets, asset values are equalized inside and outside the firm and the pass-through is 1. Any deviation of the pass-through from 1 must reflect a change in franchise value. In the presence of financial frictions such as costs of default, losing a dollar of assets deteriorates the financial health of the firm, further reducing firm value. Financial frictions can therefore only push the pass-through above 1. The existence of government guarantees can rationalize a pass-through lower than 1, as losing a dollar of assets increases the likelihood of receiving those guarantees, dampening the loss. However, the sensitivity of the value of guarantees to a dollar of assets rises closer to default, counterfactually implying a lower pass-through during the crisis.

Viewing insurers as asset insulators helps to resolve otherwise puzzling low frequency changes in the equity value of the life insurer sector during the 2008-09 financial crisis. During the year 2008, because of the sharp drop in interest rates, we estimate the value of policy liabilities of publicly-traded insurers to have increased by more than \$96 billion. At the same time, the risky assets held by these insurers lost at least \$30 billion. If the franchise value stayed constant, we would have observed a more than \$126 billion loss in the value of the equity. In practice, insurers' equity dropped by "only" \$80 billion: franchise value increased. If in the crisis fire sale discounts and increases in illiquidity caused market prices of assets to temporarily decline, then the resulting increase in comparative advantage to holding the assets inside an insulator can explain the rise in franchise value. The behavior of insurer equity during this period highlights a core tension in the provision of asset insulation. The crisis also coincided with a deterioration in the financial health of insurers, putting them closer to liquidation and threatening their ability to insulate assets from market movements. Thus, asset insulation may be most fragile exactly when it is most valuable.

While we use life insurance companies as our empirical laboratory, other related financial institutions may also provide asset insulation services. For example, commercial banks match illiquid assets and stable deposits (Hanson, Shleifer, Stein, and Vishny, 2015), while long-term asset managers such as pension funds match long and predictable liabilities with illiquid assets. We expect these institutions also derive some value from asset insulation.

To return to the questions we posed at the outset, our results paint a picture of a set of intermediaries which play a distinctive role in financial markets. Most important, we show the value of financial securities can differ if held inside an insulator or on the market. This difference suggests that these institutions provide useful financial intermediation through their asset management, facilitated by their liability structure. Proposals to tightly regulate asset holdings might impair this function. On the other hand, the fragility of insurers during the financial crisis suggests too much risk can also impair the insulation function.

The remainder of the paper proceeds as follows. We next situate our findings in the existing literature. We formalize our view of asset insulators in Section 2. Section 3 provides background on life insurers and describes our data. In Section 4, we document aggregate facts about insurers' balance sheets consistent with the insulator view. We derive and measure the asset pass-through in Section 5. Section 6 discusses implications of the insulator view for the behavior of franchise value during the financial crisis. Section 7 concludes.

Related literature. Our paper relates to a large body of work on the role of financial institutions.[1] Our assumption that financial intermediaries have an advantage in holding an asset relative to savers themselves is a common theme. Many theories (e.g., Leland and Pyle, 1977; Diamond, 1984; Holmstrom and Tirole, 1997) emphasize the role of intermediaries in mitigating problems of incomplete information through interacting directly with the entrepreur or consumer. We focus instead on the ability of certain intermediaries to avoid frictions in the market for securities. Our work can therefore explain why many intermediaries (insurers, pension funds, endowment funds, etc...) do little in the way of direct investing and rationalize the empirical relationship between asset and intermediary valuation.

Our focus on value creation from asset choice distinguishes our paper from theories based on liability creation.[2] However, particular liability structures naturally facilitate asset insulation activities. For example, Diamond and Dybvig (1983) show the inherent riskiness of pairing liquid liabilities with illiquid assets; this fragility gives institutions which can issue stable liabilities a comparative advantage in holding illiquid assets. Two papers related to ours illustrate this comparative advantage in the context of commercial banks and closed-end funds. In Hanson et al. (2015), commercial banks have "sleepy" liabilities because government deposit insurance makes depositors insensitive to the value of the bank's assets. In Cherkes, Sagi, and Stanton (2009), fully equity-financed closed end funds face no redemption risk. Our framework emphasizes that any institution with stable liabilities may adopt the role of an asset insulator. In the case of insurers, the long contractual horizon of policies and their issuance of equity make their liability holders "naturally sleepy."

Our work also relates to the literature on the limits to arbitrage.[3] Our paper adds to the evidence of multiple valuations of seemingly the same asset (e.g., Malkiel, 1977; Lamont and Thaler, 2003). We highlight how large financial institutions derive value from this difference in valuation and how it shapes the evolution of their market equity. Our approach most closely resembles a literature which tries to resolve the closed-end fund puzzle by valuing the comparative advantage of the institution (Lee, Shleifer, and Thaler, 1991; Berk and Stanton, 2007; Cherkes et al., 2009).

Finally, our empirical study of life insurers complements a growing body of work on this sector. We discuss this literature in more detail in the remainder of the paper.

[1] Gorton and Winton (2003) extensively survey this literature.

[2] See, e.g., Diamond and Dybvig (1983); Gorton and Pennacchi (1990); Calomiris and Kahn (1991).

[3] Shleifer and Vishny (1997) originate the term and provide the first formal model of it. Barberis and Thaler (2003) and Gromb and Vayanos (2010) provide surveys of the literature.

2 A Model of Asset Insulators

We begin by laying out a theory of asset insulators which will serve as a unifying framework for the remainder of the paper. The model contains two main elements. First, the value of an asset held inside an insulator can differ from the value when traded on the open market. Second, the risk of insolvency and liquidation counteracts value creation from asset insulation. Formally, we extend the model of Cherkes et al. (2009) to allow for firm leverage and liquidation.

2.1 Setup

Valuation inside and outside the firm. The starting point of the the asset insulator approach is that the value of an asset can differ when held inside the firm rather than when traded freely in the market. We assume a portfolio of assets with a continuous payout rate of c. The value of the assets while held inside the firm is A_t^{in}. This value follows a risk-neutral law of motion:

$$\frac{dA_t^{\text{in}}}{A_t^{\text{in}}} = (r - c)dt + \sigma_A dZ_t^A. \tag{1}$$

Asset value including payouts grows at the risk-free rate r and has volatility σ_A. The process $\{Z_t^A\}$ is a standard brownian motion.

The value of the assets when traded on the open market differs from the value inside the firm by a factor ω_t:

$$A_t^{\text{out}} = \omega_t A_t^{\text{in}}. \tag{2}$$

The quantity ω_t follows a mean-reverting process:

$$d\omega_t = -\kappa_\omega(\omega_t - \bar{\omega})dt + \sigma_\omega \sqrt{\omega_t} dZ_t^\omega. \tag{3}$$

The parameters $0 < \bar{\omega} < 1$ and σ_ω control the mean and volatility of ω_t, and κ_ω is the speed of reversion to the mean.[4] For clarity of exposition, we assume the standard brownian motion $\{Z_t^\omega\}$ is orthogonal to $\{Z_t^A\}$.

The process ω_t characterizes the wedge between asset values inside and outside the firm. Under the asset insulator view, assets typically have more value inside

[4]We assume that $2\kappa_\omega\bar{\omega} > \sigma_\omega^2$ to ensure that ω is always strictly positive.

than outside the firm, $\omega_t < 1$. A lower value of ω_t corresponds to a more important gain from holding the assets inside the firm. We review a number of theories of this comparative advantage.

Differences in transaction costs provide one source of the wedge ω. Many assets trade in over-the-counter (OTC) markets that are subject to search frictions. Duffie, Gârleanu, and Pedersen (2005) show that more sophisticated traders, such as large banks or insurers, will generally receive better bid-ask spreads in OTC markets. Moreover, if the market for equity of financial intermediaries has lower transaction costs than the markets in which the assets held by the intermediaries trade, then investors with short holding durations can gain exposure to the illiquid assets but economize on transaction costs by buying and selling the equity of the intermediary instead of the underlying assets.[5] Thus, a lower present value of transaction costs due to both lower costs per transaction and fewer transactions provide one source of the wedge ω.

Market prices can also reflect temporary factors such as fire sale discounts (Shleifer and Vishny, 2011) or the price impact from large trades. Fire sale discounts directly imply a low ω_t. Furthermore, holding assets directly risks having to sell at such inopportune moments, and this risk gets capitalized into the price of the asset in all periods (Duffie, Gârleanu, and Pedersen, 2007).

Differences in information or beliefs provide a third source of the wedge ω. For example, Lee et al. (1991) argue that closed-end funds select particular investors whose views of asset values differ from those prevalent on markets. In Berk and Stanton (2007), asset fund managers have a skill of choosing particular assets misvalued on markets.

All of these theories rely additionally on some characteristic of markets which allows a wedge in valuation to persist or prevents insulators from holding the entire supply of the asset. The presence of noise traders and risky arbitrage (De Long, Shleifer, Summers, and Waldmann, 1990), limited participation and segmented markets (Allen and Gale, 1994), and slow-moving capital (Duffie, 2010) have been suggested as forces which can work to sustain such a wedge. We need not take a stand here on the deep forces underlying ω, but instead proceed with how to value a firm when such a wedge exists.

[5]Following Cherkes et al. (2009), if transaction costs result in losses at a rate of ρ at each instant, we obtain immediately $\omega_t = c/(c+\rho) < 1$. Larger transaction costs result in a lower ω and therefore more comparative advantage for the intermediary.

Firm financing structure. The assets of the firm finance payments to three sets of agents: debt holders, asset managers, and shareholders. The debt takes the form of a perpetual console bond, with payments ℓ due continuously. Asset managers receive payments proportional to the amount of assets they manage, a flow kA_t^{in} each period. These payments have a broader interpretation than the direct compensation of asset managers and represent any proportional costs linked with the management of the assets. Finally, shareholders are the residual claimants.

Our modeling of the financing structure reflects a general feature of asset insulators as having stable sources of financing as a counterpart to holding assets with volatile ω for the long run. A perpetual console bond takes this complementarity to the extreme. Of course, holding debt also raises the possibility of financial distress and forced liquidation of the firm's assets. We model such forced liquidation by a threshold A_0 for the inside value of the assets at which liquidation occurs. In this situation, the proceeds $\omega_t A_0$ first pay debt holders in full, with equity claimants receiving the remaining value. We assume a liquidation threshold A_0 high enough that debt holders can be paid in full in almost all states of the world.[6]

This view of the liquidation process is of course stylized. In practice, intermediaries face a combination of capital requirements and accounting rules, as well as more direct regulatory pressure. Liquidation of the portfolio is likely to happen progressively rather than as a discrete event. In the case of insurers, Ellul, Jotikasthira, and Lundblad (2011) provide evidence of capital-constrained insurers selling downgraded corporate bonds, Ellul, Jotikasthira, Lundblad, and Wang (2015) show how the interaction of accounting rules and asset downgrades led to early selling of assets, and Merrill, Nadauld, Stulz, and Sherlund (2014b) document liquidations of mortgage-backed securities by capital-constrained insurers in distressed markets. The single threshold A_0 captures in a parsimonious way the increased prospect of liquidation into the open market when an intermediary faces financial distress, as found in these studies.

[6]Because ω_t is not bounded below, no threshold can ensure full payment to debt holders. However, we assume that A_0 is high enough that most of the distribution of ω_t lies above it, and neglect the potential losses for debt holders in our calculations. In the case of insurers, recovery rates in insolvencies have typically exceeded 75%.

2.2 Market Equity

The value of the equity is

$$E_t = \mathbb{E}_t \left[\int_t^T e^{-r(\tau - t)} (c-k) A_\tau^{\text{in}} d\tau \quad + e^{-r(T-t)} \omega_T A_0 - \int_t^\infty e^{-r(\tau-t)} \ell d\tau \right], \tag{4}$$

where T denotes the first time the asset value reaches A_0. The first integral gives the asset payouts net of management fees before liquidation. The second term is the liquidation value of the assets. The last term is the cost of policy liabilities.

In appendix B.1 we derive a closed-form expression for the value of equity as a function of the state variables A_t^{in} and ω_t:

$$E_t = A_t^{\text{in}} \frac{c-k}{c} - \frac{\ell}{r} + A_0 \left(\frac{A_t^{\text{in}}}{A_0} \right)^{-f(r)} \left(\bar{\omega} - \frac{c-k}{c} \right) + A_0 \left(\frac{A_t^{\text{in}}}{A_0} \right)^{-f(r+\kappa_\omega)} (\omega_t - \bar{\omega}), \tag{5}$$

with $f(\alpha) = \frac{r-c-\frac{1}{2}\sigma_A^2 + \sqrt{\left(r-c-\frac{1}{2}\sigma_A^2\right)^2 + 2\sigma_A^2 \alpha}}{\sigma_A^2}$. To understand this expression, it helps to first consider the two polar cases of $A_t^{\text{in}} \gg A_0$ (far from liquidation) and $A_t \to A_0$ (at liquidation):

$$\text{Far from liquidation:} \qquad E_t \left(A_t^{\text{in}} \gg A_0, \omega_t \right) \approx A_t^{\text{in}} \frac{c-k}{c} - \frac{\ell}{r}, \tag{6}$$

$$\text{At liquidation:} \qquad E_t \left(A_t^{\text{in}} \to A_0, \omega_t \right) = \omega_t A_0 - \frac{\ell}{r}. \tag{7}$$

The first term of equation (6) gives the net-of-management-fees present value of assets inside the firm without default, and the second term subtracts the present value of policy liabilities. Notably, far from liquidation the value of equity does not depend on the wedge ω_t, as the firm uses its advantage as a long-hold investor to fully insulate equity holders from market fluctuations in the value of A_t which do not reflect future payouts. Conversely, at the liquidation boundary the value of equity simply equals the liquidation value of the assets on the open market, $A_0^{\text{out}} = \omega_t A_0$, less the value of liabilities. In the intermediate case, the third term of equation (5) gives the average change in value in liquidation if $\omega_t = \bar{\omega}$, $A_0 \left(\bar{\omega} - \frac{c-k}{c} \right)$, multiplied by the discounted time to liquidation, $\left(\frac{A_t^{\text{in}}}{A_0} \right)^{-f(r)} = \mathbb{E}_t \left[e^{-r(T-t)} \right]$, while the fourth term adjusts the discounted change in value in liquidation for transitory deviations in the liquidation value of the assets.

2.3 Franchise Value

We define the firm value under Modgliani-Miller, E_t^{MM}, as the market value of the assets minus that of liabilities:

$$E_t^{\mathrm{MM}} = \omega_t A_t^{\mathrm{in}} - \frac{\ell}{r}. \tag{8}$$

The deviation of the value of the equity to this benchmark, $E_t - E_t^{\mathrm{MM}}$, is the franchise value of the firm. The theory incorporates three determinants of franchise value. Most important, when $\omega_t < 1$, the value of assets inside the firm exceeds the value outside the firm, i.e., $A_t^{\mathrm{in}} > A_t^{\mathrm{out}}$. This ability of the intermediary to protect asset valuation from the wedge ω_t provides the main source of value creation. The other two forces mitigate this ability to create value. First, in bad states of the world, the firm must liquidate its assets, only collecting the market value. This effects prevents the structure from obtaining the full difference $(1 - \omega_t)A_t^{\mathrm{in}}$. Second, not all the benefits from keeping assets inside the fund accrue to shareholders. The proportional cost k captures the value paid to other stakeholders of the firm — asset managers and other employees — and the proportional operational costs of running the balance sheet. Depending on whether or not the present value of those costs exceeds the difference between asset valuations inside and outside the firm, the firm will trade at a premium or discount relative to net asset value. In the special case of no default, the firm trades at a premium if and only if $\omega_t < (c - k)/c$.

2.4 Comparison to Other Theories

We contrast the asset insulator approach with three standard theories of financial institutions.

Irrelevance. The simplest view of financial institutions is that they are irrelevant. Under the Modigliani-Miller theorem, a financial institution acts as a shell, raising capital — equity, debt, and policy liabilities in the case of life insurers — at market prices and investing it into securities at market prices as well. The firm itself creates no value – franchise value is zero – and asset choices are indeterminate. A variant of this view is that financial intermediaries make profits by issuing liabilities at a price higher than their fair market value, for example, selling life insurance policies at a markup. One justification is that households do not have direct access to competitive financial markets. This approach can rationalize positive franchise value, but with access to frictionless financial markets, asset choice remains irrelevant to value creation.

Financial frictions. A small cost of bankruptcy breaks this indeterminacy. This cost could involve the liquidation of assets, loss of expertise in pricing liabilities, or the destruction of reputation capital. Maximization of value therefore requires preserving the franchise value of the business by minimizing the risk of financial distress, for example by liability-matching.

Liability guarantees. Financial institutions may derive some private value from government guarantees of their liabilties. These guarantees may include explicit backing of liabilities, for example deposit insurance in the case of commercial banks and state guaranty funds in the case of life insurers, as well as an implicit expectation of bailouts following large shocks. The presence of guarantees allows intermediaries to extract private value by investing in risky assets.

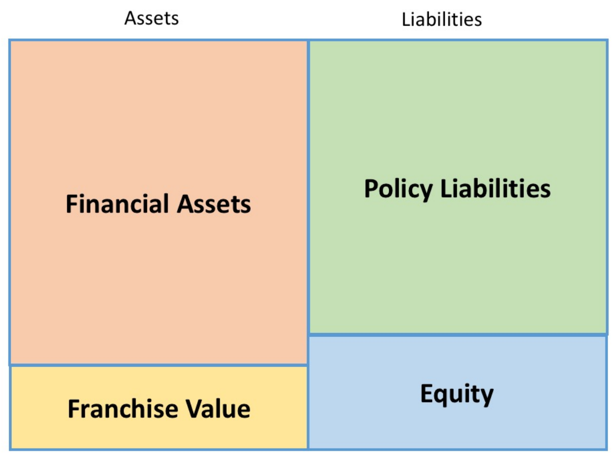
3 Background on Life Insurers and Data

In the remainder of the paper we consider specific implications of the asset insulator theory for the behavior of financial institutions, using the life insurance sector as our empirical laboratory. This sector is large, managing assets in excess of 20% of GDP, and we make use of detailed regulatory data on their asset holdings. We provide here a brief background on the life insurance sector and our data.

Figure 1 illustrates a simplified economic balance sheet of an insurer. Like all financial institutions, insurers issue liabilities and invest in assets. The type of liabilities issued, primarily life insurance contracts and annuities, defines what it means to be a life insurer for regulatory purposes. Insurers segregate their balance sheets into general account assets which back fixed rate liabilities and death benefits, and separate account assets linked to variable rate products. As their name suggests, gains and losses on separate account assets flow directly to the policyholder and hence do not directly affect the equity in the insurance company. We exclude separate accounts in all of our analysis hereafter. Insurers issue two broad types of liabilities against their general account assets: fixed rate (either annuities or life insurance contracts), and variable rate with minimum income guarantees.[7]

[7]See Paulson, Rosen, McMenamin, and Mohey-Deen (2012) and McMillan (2013) for an overview of the different products life insurers offer consumers. Koijen, Van Nieuwerburgh, and Yogo (2016) dis-

Figure 1: Economic Balance Sheet of a Life Insurer



State guaranty funds protect policyholders against the risk of insurer default up to a coverage cap. In exchange, insurers are subjected to regulation at the state level. Since the 1990s, such regulation has taken the form of a risk-based capital regime.

Our data on asset holdings come from mandatory statutory annual filings by insurance companies in operation in the United States to the National Association of Insurance Commissioners (NAIC). We use the version of these data provided by SNL Financial. Our main sample includes all publicly-traded U.S. life insurers that are substantively life insurers, and covers the period 2004-2014.[8] Table 1 reports the total quantity of general account assets under management in the life insurance industry as a fraction of GDP. The first column uses data from the Financial Accounts of the United States (FAUS, formerly known as the Flow of Funds). General ac-

cuss the demand for the various products. Koijen and Yogo (forthcoming) describe additional complications relating to how liabilities appear on the balance sheet or are ceded to reinsurance subsidiaries.

[8]The set of insurers (tickers) in our sample is: Aflac Inc. (AFL), Allstate Corp. (ALL), American Equity Investment (AEL), American National Insurance (ANAT), Citizens Inc. (CIA), CNO Financial Group Inc. (CNO), Farm Bureau Financial Services (FFG), Independence Holding (IHC), Kansas City Life Insurance Co. (KCLI), Lincoln Financial Group (LNC), MetLife Inc. (MET), Phoenix Companies Inc. (PNX), Prudential Financial Inc. (PRU), Protective Life (PL), and Torchmark Corp. (TMK). Our sample excludes financial conglomerates or foreign insurers that have a small fraction of their assets in U.S. life insurance companies, and reinsurers. Many insurance companies have multiple subsidiaries. To maximize the comprehensiveness of our data, we include holdings of Property and Causalty (P&C) subsidiaries as well. SNL aggregates the data up to the parent company level and applies inter-company adjustments to present historical balance sheet data on an "As-is" data. We convert to an "As-was" basis by subtracting balance sheet holdings for companies acquired after the filing date. Similarly, for major mergers and acquisitions, we add in holdings of insurance companies that were divested by the parent company after the reporting date but before 2014.

Table 1: Assets Under Management at Life Insurers

	FAUS	SNL	Traded
		(Percent of GDP)	
2006	21.2	21.3	5.6
2010	21.9	22.0	5.8
2014	21.6	21.8	5.2

Notes: The table shows total general account assets under management at life insurance companies as reported in the Financial Accounts of the United States table L.116.g (FAUS), for all life insurance companies in the SNL database (SNL), and for the 15 life insurers in our publicly-traded sample (Traded).

count assets exceed 20% of GDP. For comparison, in 2014 assets of commercial banks equaled 77% of GDP, assets of property and casualty insurers 9% of GDP, and assets of closed-end funds 2% of GDP. The second column reports general account assets for the universe of insurers in the SNL database. The FAUS and SNL track each other extremely closely; in fact, SNL provides the source data for the FAUS. The third column reports assets at the life insurers in our publicly-traded sample. This subset of insurers manages roughly one quarter of total insurer assets despite containing only 15 of the approximately 400 insurance companies in the SNL data.

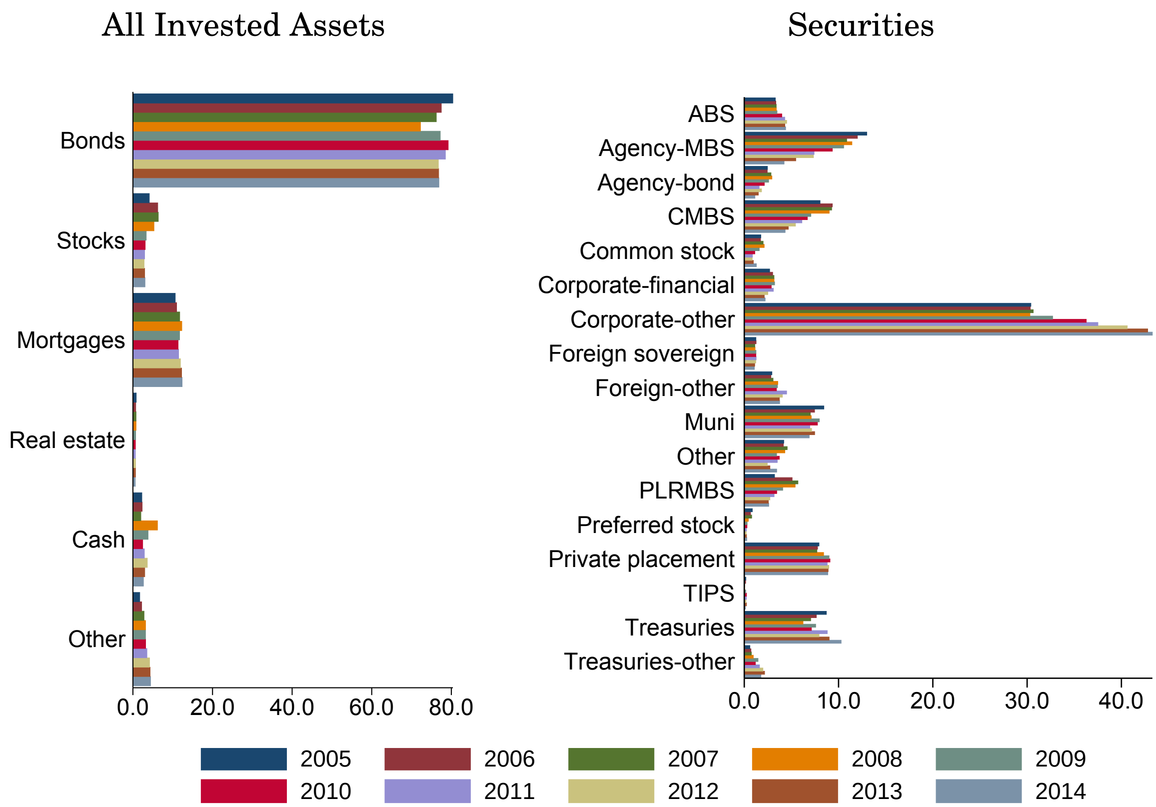
4 Balance Sheet Implications

In this section we study the salient features of the balance sheet of an asset insulator. We document key characteristics of life insurers consistent with this theory: insurers hold illiquid assets, exhibit low portfolio turnover, and have stable and predictable liabilities.

4.1 Asset Choice

Our model of insulators does not feature an explicit asset choice but nonetheless provides guidance for the types of assets insulators should buy. Insulators should target asset classes where the wedge ω between holding the asset inside the intermediary rather than on the open market is large and volatile. We discussed in section 2.1 possible sources of the wedge ω. Broadly, assets with high transaction costs, assets with high fire sale risk, perhaps due to infrequent trading or segmented markets, and assets subject to disagreement in their valuation constitute likely targets. In contrast,

Figure 2: Insurers' Asset Allocation by Year and Category



Notes: Agency-MBS refers to Mortgage-Backed Securities issued by the Government-Sponsored Entities (GSEs). Agency-bond refers to GSE bonds. CMBS refers to Commercial MBS. Muni refers to U.S. municipal, U.S. state, and U.S. public utility bonds. PLRMBS refers to private-label residential MBS. ABS represents Asset-Backed Securities not included in Agency-MBS, PLRMBS, or CMBS. Treasury-other comprises U.S. Treasury securities that do not have readily available pricing information (primarily STRIPs).

insulators should mostly avoid highly liquid, easily valued securities such as Treasuries. Aspects specific to certain intermediaries, including size, liability structure, managerial skill, or regulation determine the precise choice of assets within these guidelines.

What assets do insurers actually invest in? Figure 2 summarizes the holdings of our sample of life insurance companies across years and asset classes. The left panel shows all invested assets by broad asset category. There is little variation across years. Bonds, including passthroughs, constitute 70-75% of insurers assets, equities approximately 5%, and wholly owned mortgages (overwhelmingly on commercial property) roughly 15%. The remaining 5-10% of insurers' assets are divided between directly owned commercial real estate, other private equity investments, and cash.

The right panel of figure 2 reports the breakdown within the securities category. Bonds of non-financial corporations constitute the largest single category at more than 30% of securities, and bonds of financial corporations comprise another 5%. There is an upward trend in the share of non-financial corporate bonds, rising from 30% in 2005 to more than 40% in 2014. The increasing share of non-financial corporate bonds comes largely from decreases in the shares of Agency (Government-Sponsored Entities (GSEs)) MBS, Commercial MBS (CMBS), and private-label residential MBS (PLRMBS). The share in agency MBS falls from approximately 15% of security holdings to less than 5% of security holdings in 2014. Similarly, the share of CMBS falls from about 10% to 5% and the share of PLRMBS falls from over 8% to less than 5%. Municipal bonds, including US state and public utility bonds, constitute 7-8% of securities. Treasuries constitute only about 10% of insurers' assets and Agency (GSE) bonds constitute another approximately 3% of holdings.

The portfolio allocation of insurers reflects a targeting of illiquid, low ω assets. This fact follows immediately from visual inspection of figure 2, which shows the largest concentrations of holdings in corporate bonds and in directly held mortgages, with substantial holdings in municipal bonds and structured finance. These assets trade infrequently and are subject to large transactions costs. For example, Edwards, Harris, and Piwowar (2007) find median transactions costs for corporate bonds ranging from 60 basis points for small trades to 1 basis point for trades of more than $1,000,000. The finding of bid-ask spreads that are lower for larger trades is consistent with the prediction of Duffie et al. (2005) and gives large insurers additional comparative advantage in holding illiquid assets.[9] Overall, trade costs are even higher in the municipal bond market studied by Harris and Piwowar (2006) and Green et al. (2007) and in the MBS market that Bessembinder et al. (2013) study than in the corporate bond market. Hanson et al. (2015) assign liquidity weights to different asset classes and compare liquidity across several types of financial intermediaries. They conclude that commercial banks and life insurers have the most illiquid holdings. We extend their findings in Appendix A using our more granular data on insurer holdings and confirm their basic result.

Price dynamics further support the presence of a wedge ω for the main asset classes targeted by insurers. Fluctuations in ω require movements in the prices of assets traded in the open market unrelated to changes in their expected payoffs, which

[9] Bessembinder, Maxwell, and Venkataraman (2013) similarly find that trade costs decline with trade size in the structured finance market while Harris and Piwowar (2006) and Green, Hollifield, and Schürhoff (2007) confirm it in the muncipal bond market.

in turn means that asset returns must be predictable. Gilchrist and Zakrajšek (2012) construct a component of aggregate corporate bond prices that does not predict future defaults. Greenwood and Hanson (2013) show that cyclical declines in issuer quality predict low investor returns. More broadly, Nozawa (2014) documents important variation in expected returns in the cross-section and time series of bonds. Mortgage-backed securities also exhibit substantial predictability. Breeden (1994), Gabaix, Krishnamurthy, and Vigneron (2007) and Boyarchenko, Fuster, and Lucca (2015) document a predictive relation between spreads and returns of MBS.[10]

Comparison to other theories. A theory rooted in financial frictions would predict a very different asset allocation than what we have just described. In the case of insurers, such frictions may include fire sale prices on selling of assets, lost future business, and regulatory capital constraints.[11] Avoiding these costs requires an investment strategy which minimizes the risk of financial distress, which for insurers means neutralizing the risk from policy liabilities. Such a strategy is termed liability matching and has often been assumed to be the objective of insurance company asset managers (see for example Briys and De Varenne, 1997). Assuming diversified mortality risk, the liability risk for fixed rate contracts comes from changes in interest rates. A portfolio of Treasury securities with duration equal to the duration of liabilities perfectly hedges this interest rate risk. More specifically, because most life insurer liabilities have long duration, this view predicts insurers will hold long-dated Treasuries.[12] The low holdings of Treasuries therefore pose a challenge to the view that liability matching is the main driver of asset choices of life insurers. We provide three additional types of evidence to confirm that insurers actively choose to hold risky assets.

First, the small concentration of insurers' assets in U.S. Treasuries does not reflect constrained supply. To rule out this possibility, we match the insurer-cusip holdings of all Treasury securities in the SNL data (including of non-publicly traded insurers) with the total amount outstanding of each cusip reported in the Treasury Monthly Statement of the Public Debt and the fraction held by the Federal Reserve reported in the weekly statement of the System Open Market Account Holdings.[13] Figure 3 shows

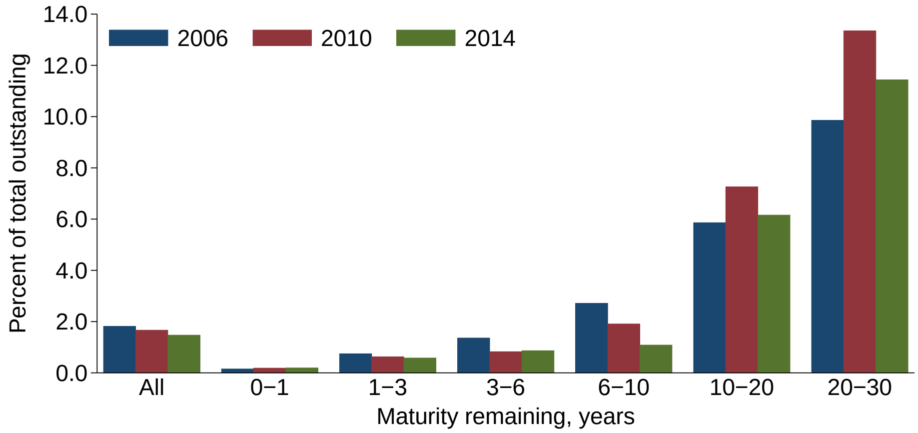
[10]More precisely, they focus on an option-adjusted spread (OAS) which adjusts for the possibility of prepayment and refinancing when rates drop.

[11]For example, Koijen and Yogo (2015) describe the sale of policy liabilities at a discount during the financial crisis to build regulatory capital.

[12]Similarly, insurers can hedge the risk of minimum income guarantees on variable rate annuities by buying put options on the underlying equity index.

[13]The data on total Treasuries outstanding and SOMA holdings come from `https://www.`

Figure 3: Insurers' Share of U.S. Treasury Securities



Notes: Each bar shows the percent of outstanding Treasuries with the maturity remaining indicated held by the life insurance sector. The definition of Treasuries outstanding used here excludes holdings of the Federal Reserve system.

the resulting share of Treasuries outstanding (excluding Federal Reserve holdings) held by life insurers, by maturity and calendar year. The life insurance sector holds less than 2% of all Treasuries outstanding. The fraction of Treasuries held by insurers increases with maturity, but even at the long end of 20 to 30 years remaining to maturity the share held by insurers does not exceed 14%. Notably, this share is less than the insurance sector share of the corporate bond market.

Second, the non-Treasury securities on insurers' balance sheets do not appear Treasury-like in their risk characteristics. Table 2 reports the value-weighted NAIC rating by asset class for the end of 2006. For example, roughly half of insurers' corporate bond holdings are rated BBB or below. Similarly, even prior to the European sovereign crisis, insurers' holdings concentrated in riskier sovereign bonds.

Third, insurers appear to choose risk even at the expense of duration-matching their liabilities. Table 3 provides one metric of this phenomenon by comparing the standard deviations of insurers' security portfolios with the standard deviations of insurers' security portfolios after subtracting for each asset the return on a U.S. Treasury of the same duration. The last column shows the share of the cross-sectional variation in insurers' aggregate security returns that can be explained by differences in the durations of their portfolio. Across all years, the standard deviation is actually

treasurydirect.gov/govt/reports/pd/mspd/mspd.htm and http://nyapps.newyorkfed.org/markets/soma/sysopen_accholdings.html, respectively.

Table 2: NAIC Risk Weights by Asset Category

	Value-weighted share with NAIC designation:						Value-weighted
	1	2	3	4	5	6	mean
Agency-MBS	100.0	0.0	0.0	0.0	0.0	0.0	1.0
Agency-bond	100.0	0.0	0.0	0.0	0.0	0.0	1.0
Treasuries	100.0	0.0	0.0	0.0	0.0	0.0	1.0
Treasuries-other	100.0	0.0	0.0	0.0	0.0	0.0	1.0
TIPS	100.0	0.0	0.0	0.0	0.0	0.0	1.0
PLRMBS	96.7	3.1	0.1	0.1	0.0	0.0	1.0
Other	92.7	6.2	0.5	0.2	0.0	0.3	1.1
Corporate-financial	91.4	7.2	1.4	0.0	0.0	0.0	1.1
CMBS	90.8	7.9	0.7	0.2	0.2	0.1	1.1
Muni	84.4	12.0	1.8	1.1	0.5	0.1	1.2
ABS	79.8	16.4	1.4	1.8	0.1	0.4	1.3
Corporate-other	42.9	44.9	7.6	4.1	0.3	0.1	1.7
Foreign sovereign	51.6	18.1	27.2	3.1	0.0	0.0	1.8
Foreign-other	28.2	61.0	8.6	1.4	0.7	0.2	1.9
Private placement	31.5	54.3	8.4	4.1	1.3	0.3	1.9

Notes: The table reports the dollar weighted percent of assets in each NAIC designation at the end of 2006 for the 15 insurers in our sample. The NAIC designations translate to bond ratings as: 1 = AAA/Aaa, AA/Aa, A/a ; 2 = BBB/Baa; 3 = BB/Ba; 4 = B/B; 5 = CCC/Caa; 6 = in or near default.

larger after we subtract off the duration matched Treasury.

If insurers' asset choices appear consistent with the predictions made by asset insulator theory and starkly inconsistent with liability matching, then what about other theories? The moral hazard from the protection of policyholders by state guaranty funds may also contribute to greater risk taking. Broad portfolio choices may also be affected by regulatory capital constraints (Becker and Opp, 2014; Hanley and Nikolova, 2014). Previous research has found evidence of insurers selecting higher yield assets within risk weight categories (Becker and Ivashina, 2015; Merrill, Nadauld, and Strahan, 2014a). The overlap between high yield and low ω assets makes it difficult to distinguish these theories on the basis of the portfolio allocation alone.

Table 3: Asset Risk and Duration Risk

	N	σ_R	σ_{XR}	$\frac{\sigma_R - \sigma_{XR}}{\sigma_R}$
All Years	165	5.6	9.5	-0.69
Ex Outlier CUSIPs	165	5.5	9.2	-0.69
2004	15	1.7	1.9	-0.10
2005	15	1.0	1.1	-0.10
2006	15	0.6	0.9	-0.33
2007	15	1.3	1.2	0.08
2008	15	3.4	4.0	-0.15
2009	15	4.3	4.0	0.07
2010	15	2.5	1.5	0.38
2011	15	3.0	2.6	0.15
2012	15	2.0	1.7	0.16
2013	15	1.7	1.0	0.40
2014	15	3.0	1.6	0.46

Notes: σ_R is the standard deviation of the return on the insurer's overall security portfolio (in %) aggregated from individual CUSIPs. σ_{XR} is the standard deviation of the return on the insurer's Treasury-hedged security portfolio where the return on a duration matched U.S. Treasury security for each security is substracted from the raw security return. Returns include income received during the year. "Ex Outlier CUSIPs" excludes cusips in the top and bottom 2% of each insurer-security class level before aggregating to the insurer level. The last column is the share of the standard deviation in security returns explained by differences in duration across insurers.

4.2 Asset Turnover

Unlike in our simple model, fixed income assets are not infinitely lived. Insulators must trade dynamically to renew their balance sheet. To reap the gains from insulation, however, the portfolio should exhibit relatively low turnover for individual securities.

The left panel of table 4 reports the remaining years to maturity for the value-weighted security held by an insurer in our traded sample. The mean maturity remaining is about 14 years, and the 10th percentile exceeds 2 years. The right panel reports the time elapsed since purchase. The mean holding period is about 4 years, and the 90th percentile between 7 and 10 years. The long holding period allows insurers to perform the asset insulation role.

4.3 Financing Structure

Asset insulation requires stable sources of financing as a counterpart to holding assets with volatile ω for the long run. Equity and long-term debt provide naturally

Table 4: Insurers are Long-hold Investors

	Years to maturity			Years since purchase		
	2006	2010	2014	2006	2010	2014
Statistic:						
Mean	14.9	13.7	14.6	3.2	4.1	4.6
SD	10.4	10.0	9.8	3.0	3.5	3.9
P(10)	2.7	2.3	2.8	0.5	0.4	0.6
P(50)	11.6	9.9	13.1	2.4	3.4	3.8
P(90)	29.1	28.1	28.1	7.1	8.4	10.1
Observations	65,754	60,922	55,148	65,754	60,922	55,148

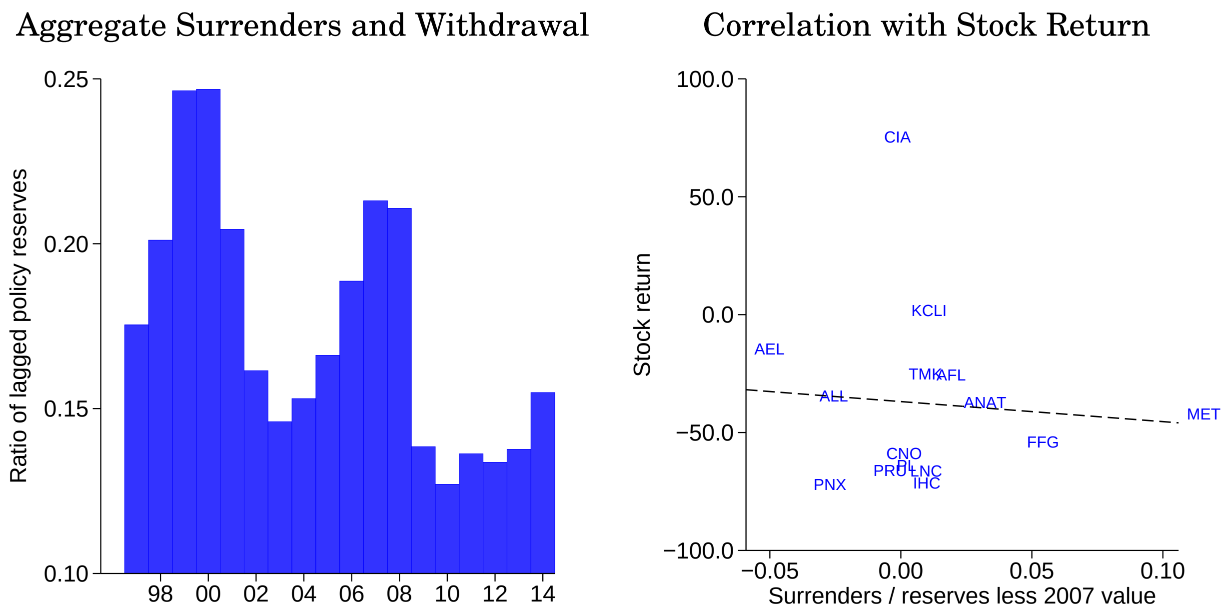
Notes: The sample includes Schedule D and BA holdings for the 15 publicly traded life insurers in our sample. Variables trimmed at 1st and 99th percentiles.

stable financing by generating predictable payouts and minimizing rollover risk. Alternatively, Hanson et al. (2015) discuss how government guarantees allow commercial banks to have stable financing by making liability holders "sleepy."

Life insurers obtain stable financing from the the long contractual horizon of life insurance policies and annuities and their ability to diversify mortality risk. Offsetting this, policy holders can request early termination of a policy in the form of a policy surrender and withdrawal. Surrender claims typically trigger a penalty if exercised in the first few years of a contract, but the penalty decays over the life of a contract and may eventually disappear. Aggregate surrenders increase when interest rates rise, as policy holders "refinance" at the more favorable rates or move their savings into higher yield vehicles, and during business cycle downturns, since surrenders constitute a form of dis-saving and may help to smooth consumption during unemployment spells (Russell, Fier, Carson, and Dumm, 2013). In addition, individual insurers may experience run-like dynamics if policy holders become concerned about solvency (DeAngelo, DeAngelo, and Gilson, 1994, 1996).

We assess for recent years the importance of surrenders in the aggregate and at the insurer level. The left panel of figure 4 shows the evolution of policy surrenders and withdrawals for our 15 insurers over time. While policy surrenders rise in 2007 and 2008, the increase appears part of a longer term trend, and surrenders in 2008 are not high by historic standards. For example, policy surrenders are higher in 1999 and 2000 and at about the same level in 1998 and 2001. Surrenders then fall substantially in 2009. While the increase in unemployment may have pushed up surrenders

Figure 4: Surrenders and Withdrawal



Notes: The left panel plots the ratio of surrenders and policy withdrawals to lagged policy reserves for the 15 insurers in our sample. The right panel shows a scatter plot of the change in surrenders in 2008 and the stock return.

for dis-saving purposes, the fall in interest rates likely reduced surrenders.[14]

The right panel of figure 4 shows a weak relation in the cross-section in 2008 between policy surrenders and stock returns. In particular, the insurers with the worst performance did not experience increases in surrenders. Insurers do not suffer large liability runs even during the market panic and insurance sector solvency crisis of 2008-09. Three features of the resolution process may explain the absence of runs. First, state laws allow regulators to intervene well before the event of default. Such interventions trigger automatically upon risk-based capital crossing certain thresholds and range from requiring an action plan to rebuild capital to taking operational control of the insurer through receivership. As such, policyholders may experience minimal operational disruption in the event of an insolvency. Second, many life insurers issue debt and such public debt is junior to policy liabilities, creating an additional buffer between asset losses and losses to policyholders. Third, policyholders

[14] In addition to surrenders, policies may lapse because of nonpayment of premiums. Whenever possible, a policyholder is strictly better off taking the surrender value or selling the policy on the secondary market than allowing the policy to lapse because of nonpayment. Nonetheless, some policies do lapse, providing a windfall to the issuer (Gottlieb and Smetters, 2014). Ho and Muise (2011) report a small increase in combined lapses and surrenders in the 2007-09 period relative to previous years, almost entirely driven by lapses on newly issued policies.

have the protection of their state guaranty funds. Most states have coverage caps of between \$100,000 and \$250,000, with policy claims in excess of these caps receiving a payout ratio equal to the value of total recovered assets divided by total policy claims. In actual insolvencies, we estimate a (dollar-weighted) average state guaranty share of roughly 80% of total policy claims, and a recovery rate on non-guaranteed claims of roughly \$0.75 on the dollar.[15] As with bank deposit insurance, the guaranty funds remove the incentive to run for most policyholders.[16]

From the lens of asset insulation theory, the long-term holdings of illiquid assets emerge as the natural counterpart to issuing long-term, predictable liabilities. The duration and predictability of liabilities allow insurers to hold illiquid assets without fearing sudden liquidation pressure. The low turnover of holdings also insulates insurers from transitory fluctuations in bond prices, a point to which we now turn.

5 Pass-through

We have described broad balance sheet predictions of the asset insulation view and showed how they fit the behavior of life insurers. We now introduce an especially informative metric to distinguish among alternative theories of intermediation: the pass-through of a dollar of assets to equity. In section 5.1, we use our theoretical framework to make predictions for the pass-through under the asset insulator view and contrast these predictions with those of other theories of financial institutions. In the remainder of the section, we design and implement an empirical methodology to measure the pass-through for life insurers. We estimate a low pass-through out of the financial crisis, a higher pass-through during the crisis, and higher crisis pass-through for more distressed insurers. Of the theories we have considered, only the asset insulator theory can rationalize these moments.

5.1 Theory

We formally define the pass-through PT as the change in the value of firm equity when the value of the asset on the open market changes by \$1. In the asset insulator

[15] These calculations correspond to multistate insolvencies over 1991-2009, and are based on the chart in National Organization of Life and Health Insurance Guaranty Associations (2011, p.11).

[16] Some evidence suggests the run risk for life insurer liabilities has increased modestly in recent years (Paulson, Plestis, Rosen, McMenamin, and Mohey-Deen, 2014). If this trend continues, it could affect the ability of life insurers to act as insulators in the future. What matters for the analysis here is that this run risk has remained low during our sample, as evidenced by figure 4.

model of section 2, this object corresponds to the coefficient of a regression of changes in firm value on changes in the outside value of the asset:

$$PT = \frac{\textbf{cov}\left(dE_t, dA_t^{\text{out}}\right)}{\textbf{var}\left(dA_t^{\text{out}}\right)}. \tag{9}$$

Variation in the outside value of the assets, dA_t^{out}, come from changes in the inside value, dA_t^{in}, and changes in the wedge, $d\omega_t$. Let V_A and V_ω denote the fraction of the variance var(dA_t^{out}) coming from each shock, so that $V_A + V_\omega = 1$. Using Ito's lemma on the expression for E_t, we derive the pass-through (see Appendix B.2):

$$\begin{aligned} PT = V_A & \left[\frac{\frac{c-k}{c}}{\omega_t} - \frac{f(r+\kappa_\omega)}{\omega_t A_t^{\text{in}}} \left(\frac{A_t^{\text{in}}}{A_0}\right)^{-f(r+\kappa_\omega)} A_0\left(\omega_t - \bar{\omega}\right) - \frac{f(r)}{\omega_t A_t^{\text{in}}} \left(\frac{A_t^{\text{in}}}{A_0}\right)^{-f(r)} A_0 \left(\bar{\omega} - \frac{c-k}{c}\right) \right] \\ & + V_\omega \left[\left(\frac{A_t^{\text{in}}}{A_0}\right)^{-f(r+\kappa_\omega)-1} \right]. \end{aligned} \tag{10}$$

The two bracketed terms characterize the response of firm value to changes in outside value coming from inside value dA_t^{in} and the wedge $d\omega_t$. These conditional responses are weighted by the relative contribution of each shock to the variation in outside value of the assets. We next derive simple empirical predictions for extreme cases of financial health.

Far from liquidation. Consider first the case when the firm is in good financial health and far from liquidation: $A_t^{\text{in}} \gg A_0$. Then, we have approximately:

$$PT_{\textsf{safe}} \equiv PT(A_t^{\text{in}} \gg A_0, \omega_t) \approx V_A \frac{\frac{c-k}{c}}{\omega_t}. \tag{11}$$

First, when the firm is in good financial health, it can completely fulfill its role of insulating the assets from the market. Therefore, shocks to the wedge ω_t do not impact firm value at all. This isolation reduces the unconditional pass-through. In the limiting case where $d\omega_t$ shocks account for all variation in market values, the pass-through converges to 0.

Second, the impact of shocks to inside value dA_t^{in} on the firm relative to the outside value depends on whether the firm trades at a premium or at a discount, defined by the term $\frac{c-k}{c}/\omega_t$ which multiplies the variance share. Higher values of ω_t due to, for example, more liquid markets, push the fund closer to trading at a discount, lowering the impact of valuation shocks on the firm value relative to market value.

Putting these two forces together, the asset insulator view can rationalize a low pass-through during episodes when insurers are in good financial health and markets are liquid.

At liquidation. Consider now the other extreme case when the firm is converging to liquidation, $A_t^{\text{in}} \to A_0$. In that case, we have:

$$PT_{\text{liquidation}} \equiv PT(A_t^{\text{in}} \to A_0) = PT_{\text{safe}} - V_A \left[\frac{f(r+\kappa_\omega)}{\omega_t A_t^{\text{in}}} (\omega_t - \bar{\omega}) + \frac{f(r)}{\omega_t A_t^{\text{in}}} \left(\bar{\omega} - \frac{c-k}{c} \right) \right] + V_\omega. \tag{12}$$

When the intermediary gets close to liquidation, two main differences arise. First, notice the last term V_ω. With liquidation imminent, changes in the liquidation value of the assets affect the value of the firm directly. Hence shocks to the wedge $d\omega_t$ now transmit one-to-one to firm value.

Second, as the financial health of the firm deteriorates, the value of the assets converges from its inside to its outside value. In particular, during episodes of low ω_t, this corresponds to an additional decrease in firm value; the term in brackets is negative. In illiquid times, the pass-through is therefore larger because of the convergence of the firm towards liquidation in response to declines in asset values. In appendix B.3, we show that the presence of other liquidation costs reinforces this effect, generating even higher pass-through.

In contrast to good conditions, the combination of low financial health and illiquidity pushes the pass-through to higher values, potentially larger than 1. This behavior illustrates the tension arising in periods of low asset valuation: while franchise value increases because of a low ω_t, the losses due to a potential liquidation also increase, generating a higher pass-through.

Intermediate situations. Between these two extreme cases, the weights in equation (10) with the form $\left(\frac{A_t^{\text{in}}}{A_0}\right)^x$ play an important role. These weights are cumulative discounted default probabilities. Two ingredients enter these quantities. First, forecasted default intensities during future dates. Second, the role of the wedge ω_t depends on the persistence κ_ω. More persistent shocks — lower κ_ω — are likely to still have an impact in future liquidations, and therefore have a larger impact on firm value. In contrast, extremely transitory shocks, for instance micro-structure noise, never impact firm value away from liquidation.

Putting these considerations together, we can summarize predictions on the behavior of the pass-through around the financial crisis of 2008-2009. To map various periods to the model, we consider insurers to be in good financial health ($A_t^{\text{in}} \gg A_0$) and assume a small wedge between the inside and outside value of assets (ω_t close to 1) before and after the crisis. In contrast, the crisis is a period of low financial wealth (A_t^{in} close to A_0, see figure 7) and a larger wedge (low ω_t). We can thus compare the pass-through in and out of the crisis.

Prediction 1. *The pass-through out of the crisis is less than* 1*, reflecting the ability to insulate assets from the market. The pass-through increases during the crisis. The pass-through during the crisis can be larger than* 1*, reflecting the possibility of losing the ability to insulate assets from the market.*

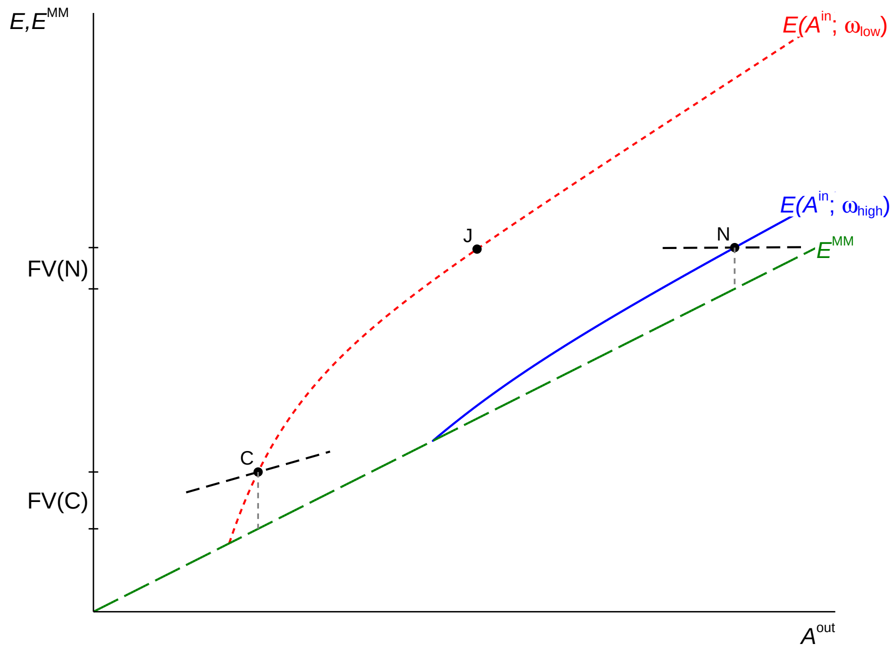
We can also compare the pass-through across insurers with different levels of financial distress during the crisis.

Prediction 2. *The pass-through is larger for more distressed insurers during the crisis as they are more likely to have to liquidate their assets.*

Figure 5 illustrates these predictions graphically. The figure plots equity valuations as a function of the outside value of the asset A^{out}. The figure contains three lines: the Modigliani-Miller benchmark (dashed green line), the equity for a fixed, high ω (the solid blue line), and the equity for a fixed, low ω (the dotted red line). The Modigliani-Miller benchmark has a slope of 1. The point N (for normal) corresponds to out of the crisis, with a high ω and high A^{in}. The point C (for crisis) corresponds to insurers during the crisis, with a low ω and low A^{in}. The slopes of the blue and red lines give the conditional pass-through with respect to a change in the outside asset value coming from a change in A^{in}, while the dashed black lines give the conditional pass-through with respect to a change in the outside asset value coming from a change in ω at the two points N and C. Both conditional pass-throughs rise at point C relative to point N, generating a higher unconditional pass-through at point C as well.

Comparison to other theories. The Modigliani-Miller valuation provides a simple benchmark for the pass-through: $PT^{\text{MM}} = 1$. Thus, any deviation from 1 must come from changes in franchise value in response to changes in asset values. Financial frictions by themselves can only generate a pass-through above one, as losing a dollar of assets pushes the insurer closer to default and lowers franchise value. Policy guarantees can generate a pass-through less than one, since the value of the guarantee rises as the insurer moves closer to default. However, this effect is stronger in

Figure 5: Pass-through in the Asset Insulator Framework



Notes: The figure illustrates the relationship between equity and asset value in the asset insulator framework. The dashed green line is the Modigliani-Miller benchmark and has a slope of 1. The solid blue line plots equity as a function of the outside asset value for a fixed value ω_{high}, while the dotted red line plots equity as a function of the outside asset value for a fixed value ω_{low}. The slopes of the blue and red lines give the conditional pass-through with respect to a change in the outside asset value coming from a change in A^{in}. The dashed black lines give the conditional pass-through with respect to a change in the outside asset value coming from a change in ω at the two points N (for normal) and C (for crisis). Point J shows the equity value holding A^{in} fixed at its value at point N but for ω_{low}. The distance between the equity value and the Modigliani-Miller benchmark gives the franchise value (FV) and is shown on the vertical axis for the two points N and C.

periods of high financial distress, implying a smaller pass-through during the crisis and for more distressed insurers.

5.2 Empirical Framework

We use the rich data available on security-level holdings to estimate the pass-through in and out of the crisis. We generalize notation in a straightforward way to accommodate multiple insurers and a more complicated liability structure. Let $E_{i,t}$ denote the market value of equity of insurer i at date t, $A^{\text{out}}_{i,t}$ the open market gross asset value, and $L_{i,t}$ the present value of liabilities. We write the value of an insurer's equity as:

$$E_{i,t} = A^{\text{out}}_{i,t} - L_{i,t} + [\text{Franchise value}]_{i,t}\,. \tag{13}$$

Taking the total derivative of equation (13) and dividing through by lagged market equity,

$$R^E_{i,t} = \rho^A_t R^A_{i,t} - \rho^L_t R^L_{i,t} + R^{OB}_{i,t}, \tag{14}$$

where $R^E_{i,t}$ denotes the return on market equity, $R^m_{i,t}$ the scaled change in value of assets ($m = A$, and we drop the out superscript to ease notation) or liabilities ($m = L$), $\rho^A_t = 1 + \frac{\partial[\text{Franchise value}]_{i,t}}{\partial A^{\text{out}}_{i,t}}$ the pass-through with respect to assets, $\rho^L_t = 1 + \frac{\partial[\text{Franchise value}]_{i,t}}{\partial L_{i,t}}$ the pass-through with respect to liabilities, and $R^{OB}_{i,t}$ the scaled return to franchise value with respect to other variables. We seek to consistently estimate ρ^A_t.

An identification challenge arises because the return on the assets we observe may be correlated with the return on liabilities and the value of future business. For example, a decrease in the risk free rate might raise the value of both assets and liabilities. We proceed in two directions. Our main result uses abnormal bond returns at a daily frequency to isolate a part of $R^A_{i,t}$ plausibly uncorrelated with the other determinants of equity. We complement this approach by using the fair value reporting requirements at the end of December of each year to confirm the basic patterns also hold at an annual frequency for a broader part of the balance sheet.

5.3 Main Results

We measure the pass-through of a dollar of assets on 2,600 trading days before, during, and after the financial crisis using our data set of insurer corporate bond holdings matched to the actual returns on bonds in the over-the-counter market. The data on bond returns come from the FINRA TRACE data set. TRACE reports the date, time, and transaction price of all over-the-counter trades of corporate bonds in the U.S. We form a daily price series for each bond using the last trade on each date.[17]

Our econometric procedure focuses on corporate bonds with returns which deviate substantially from their benchmark index. We first partition $R^A_{i,t}$ into the part coming from corporate bonds for which we can construct a return, $R^A_{i,t}(T)$ (T for "traded"), and the remaining assets for which we do not know the return, $R^A_{i,t}(NT)$. Let $R^{A,x}_{i,t}$ denote the rescaled excess return. We further partition $R^{A,x}_{i,t}(T)$ into the part coming from bonds with large excess (unscaled) returns $R^{A,x}_{i,t}(b)$, $b \subseteq T$ (b for "big"), and the part coming from bonds with small excess returns $R^{A,x}_{i,t}(b^c)$, $b^c \subseteq T \setminus b$. Our main

[17] In order to have a current market value of each bond position, we require that the bond transact at least once on a date when an insurer reports the fair value price in a regulatory filing.

specification takes the form:

$$R^E_{i,t} = \rho^A_{\text{crisis}}\mathbf{I}\{t \subseteq \textbf{crisis}\}R^{A,x}_{i,t}(b) + \rho^A_{\text{noncrisis}}\mathbf{I}\{t \nsubseteq \textbf{crisis}\}R^{A,x}_{i,t}(b) + \alpha_t + \gamma_i' X_t + \epsilon_{i,t}, \tag{15}$$

where crisis denotes the period from January 2008 to December 2009.

In writing equation (15), we have replaced the non-idiosyncratic part of asset returns, the returns on non-traded assets, the return on liabilities, and the return on other business with the fixed effect α_t, the loading $\gamma_i' X_t$, and the regression residual $\epsilon_{i,t}$. The fixed effect α_t absorbs aggregate shocks to the value of the insurance business which affect all insurers equally. In our baseline specification, we include the return on the 10 year Treasury bond in X_t to control for differences in duration mismatch across insurers, and in robustness we also include the Fama-French factors. Thus, our identifying assumption to estimate pass-through is that $R^{A,x}_{i,t}(b)$ is uncorrelated with the returns on other parts of the insurer's balance sheet and with changes in the value of other business not captured by time fixed effects or the insurer-specific loadings. Intuitively, if large excess returns reflect idiosyncratic news about the particular bond rather than systematic characteristics targeted by the insurer for its portfolio, then they will likely be uncorrelated with other parts of the balance sheet or aspects of its business.

We construct $R^{A,x}_{i,t}(b)$ as follows. On each date, we start with the universe of corporate bonds held by at least one insurer on that date and reported in the FINRA TRACE data set with at least one transaction on each of the current and previous trading day. Let $P_{j,t}$ denote the (open market TRACE) price of bond j and $\tilde{R}^A_{j,t} = \frac{P_{j,t}-P_{j,t-1}}{P_{j,t-1}}$ the raw unscaled return. Using the NAIC ratings reported in the insurance regulatory filings, we match each bond to the BAML index of the same rating and compute the excess return as the residual in a pooled regression of the bond returns $\tilde{R}^A_{j,t}$ on the index return. A bond belongs to the large excess return set b if the excess return exceeds 6 percentage points in absolute value. We then aggregate the large excess returns for each insurer to generate an insurer-level excess return on its corporate bond portfolio: $R^{A,x}_{i,t}(b) = \sum_{j\in b}\frac{Q_{i,j,t-1}(P_{j,t}-P_{j,t-1})}{V_{i,t-1}}$, where $Q_{i,j,t-1}$ denotes the quantity of bond j held by insurer i.[18]

[18]Importantly, market participants could have constructed these portfolio returns in real time. The NAIC end-of-year filings of security holdings become public about two months after the end of the calendar year, and quarterly filings of transactions a few months after the end of the quarter. If insurers engaged in frequent turnover of their portfolios, then equity analysts and traders might not know which insurers experienced large excess portfolio returns on a particular date. However, in our data, the fraction of large excess bond returns occurring in positions which insurers' had established before the previous regulatory filing exceeds 98% both in and out of the crisis.

Table 5: High Frequency Portfolio Return Statistics

	Dependent variable:	
	$\tilde{R}^{A,x}_{i,t}(b^c)$	$R^{A,x}_{i,t}(T)$
	(1)	(2)
Right hand side variable:		
$\tilde{R}^{A,x}_{i,t}(b) \times$ Not crisis	0.0036	
	(0.0037)	
$\tilde{R}^{A,x}_{i,t}(b) \times$ Crisis	0.0038	
	(0.018)	
$R^{A,x}_{i,t}(b) \times$ Not crisis		1.23^{**}
		(0.071)
$R^{A,x}_{i,t}(b) \times$ Crisis		1.21^{**}
		(0.16)
Date FE	Yes	Yes
Treasury factor	Yes	Yes
Number small excess returns	11,304,897	11,304,897
Number large excess returns	152,220	152,220
Dollar share of large excess returns	0.009	0.009
R^2	0.25	0.65
Observations	36,810	36,810

Notes: In column 1, $\tilde{R}^{A,x}_{i,t}(b^c)$ is the unscaled excess return on corporate bonds with small excess returns and $\tilde{R}^{A,x}_{i,t}(b)$ is the unscaled excess return on corporate bonds with large (6 p.p. or more) excess returns. Both variables are demeaned on each date and normalized to have unit variance in and out of the crisis such that the reported coefficients are correlations. In column 2, $R^{A,x}_{i,t}(T)$ is the excess return on all traded bonds, and $R^{A,x}_{i,t}(b)$ is the excess return on bonds with large excess returns. Both variables are rescaled by the ratio of the holdings to market equity. The crisis is defined as January 2008-December 2009. Standard errors clustered by date in parentheses. ** denotes statistical significance at the 1% level. The data cover the period 2004 - 2014.

The bonds with large excess returns constitute only a small share of total bonds which transact on consecutive dates. Our sample contains more than 11 million insurer-date-cusip observations between 2004 and 2014 of a bond held by a particular insurer for which we can construct a return on a particular date; of these, less than 1.5% meet our threshold for a large excess return. The share by dollar value is less than 1%.[19] The rarity of such large returns gives *a priori* plausibility to the

[19] In fact, we choose the 6 p.p. threshold to ensure a ratio of large excess returns to total holdings of under 1%. We have experimented with other thresholds and obtain similar results.

assumption that they do not reflect systematic variation in insurers' holdings.

We obtain further support for our identifying assumption by comparing the large excess returns to the rest of the transacted portfolio. Column 1 of table 5 performs this comparison by reporting the correlation coefficients of the (demeaned daily) unscaled returns $\tilde{R}^{A,x}_{i,t}(b)$ and $\tilde{R}^{A,x}_{i,t}(b^c)$ in and out of the crisis period. Both correlations are less than 0.005 in absolute value. Column 2 compares the total scaled excess return $R^{A,x}_{i,t}(T)$ to the part coming from the large excess returns $R^{A,x}_{i,t}(b)$. Here we find coefficients close to albeit slightly above one, again consistent with idiosyncracy of the large excess returns. Furthermore, the similarity of coefficients in and out of the crisis period suggests that differential correlation of large excess returns and the rest of the portfolio cannot explain a higher pass-through in the crisis.

Table 6 presents our main findings. Column 1 reports our baseline specification of the equity return on the scaled excess bond return $R^{A,x}_{i,t}(b)$ controlling only for the date fixed effects and the general movement in interest rates by including in X_t the return on the 10-year Treasury and allowing the coefficient to vary across insurers. We obtain a pass-through of 0.10 out of the crisis and 1.13 during the crisis. The table reports standard errors clustered by date to allow for arbitrary correlation across insurers on each date. We can reject equality of the pass-through coefficients and equality of the pass-through out of the crisis and unity at the 1 percent level. We cannot reject equality of pass-through during the crisis and unity at any conventional confidence level. In words, an additional dollar of assets translates into an additional \$0.10 of equity out of the crisis, but slightly more than \$1 of equity during the crisis.

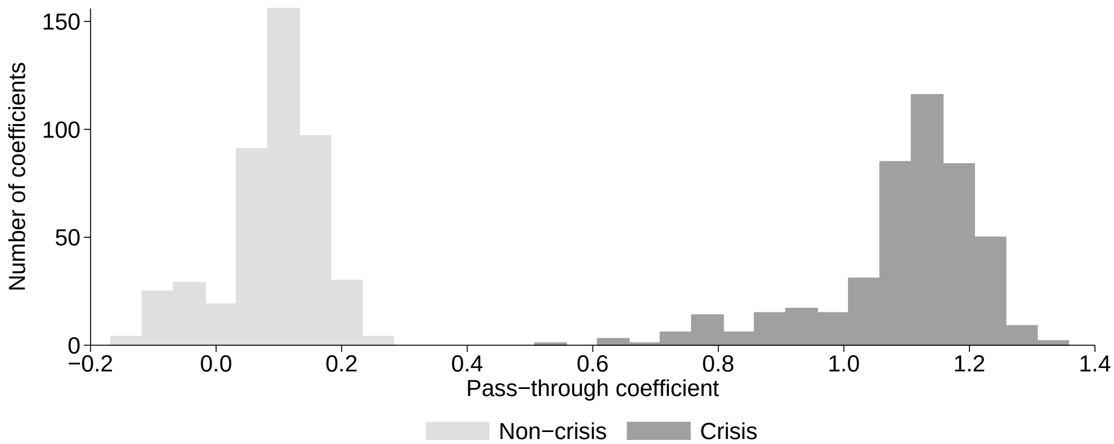
The remaining columns explore robustness. In column 2, we run the regression without controlling for the movement in Treasuries and find similar results to those from our benchmark specification. In column 3, we allow the non-crisis coefficient to differ before and after the crisis. We do not find evidence of a permanent structural break at the start of the crisis, but rather that pass-through is high during the crisis and low before and after. Column 4 reports the baseline regression without winsorizing the dependent variable; the few large equity returns cause the standard errors to rise, but the same pattern remains. Columns 5 and 6 explore sensitivity to the large declines in equity during the crisis for some insurers, in column 5 by scaling the changes in equity and bond holdings by the sample mean of market capitalization for each insurer rather than the $t-1$ market capitalization, and in column 6 by including the interaction of the inverse of market capitalization and a date fixed effect. In column 7, we define the crisis period more narrowly as the one year period from September 2008 to August 2009. In column 8, we include insurer-specific loadings

Table 6: High Frequency Portfolio Return Pass-through

	Dependent variable:								
	Equity								Debt
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Large excess bond returns interacted with:									
Not crisis	0.10	0.10		0.07	0.04	-0.03	0.10	0.03	-0.01
	(0.20)	(0.21)		(0.34)	(0.20)	(0.20)	(0.19)	(0.17)	(0.03)
Crisis	1.13^{**}	1.06^{**}	1.13^{**}	1.69^{**}	0.86^{*}	1.08^{**}	1.14^{**}	1.02^{**}	0.32^{*}
	(0.34)	(0.34)	(0.34)	(0.60)	(0.40)	(0.38)	(0.34)	(0.36)	(0.16)
Pre-crisis			0.08						
			(0.48)						
Post-crisis			0.10						
			(0.22)						
Date FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dep. var. winsorized	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Crisis period	2Y	2Y	2Y	2Y	2Y	2Y	1Y	2Y	2Y
Denom.	1	1	1	1	Mean	1	1	1	1
Size control	No	No	No	No	No	Yes	No	No	No
Treasury factor	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
FF factors	No	No	No	No	No	No	No	Yes	No
R^2	0.56	0.56	0.56	0.50	0.53	0.62	0.56	0.61	0.59
p(Homog. effect)	0.010	0.016	0.034	0.019	0.065	0.010	0.008	0.013	0.043
Observations	36,810	37,365	36,810	36,810	36,795	36,795	36,810	36,810	13,149

Notes: The estimating equation is: $R^E_{i,t} = \rho^A_{\text{crisis}}\mathbf{I}\{t \subseteq \text{crisis}\}R^{A,x}_{i,t}(b) + \rho^A_{\text{noncrisis}}\mathbf{I}\{t \nsubseteq \text{crisis}\}R^{A,x}_{i,t}(b) + \alpha_t + \gamma_i' X_t + \epsilon_{i,t}$, where $R^E_{i,t}$ denotes the equity return and $R^{A,x}_{i,t}(b)$ the market-capitalization scaled return on the insurer's holdings of corporate bonds with abnormal returns greater than 6 p.p. In all columns, the benchmark index is the BAML index of the same rating, and standard errors clustered by date are reported in parentheses. In columns 1 and 3-9, X_t includes the return on the 10 year Treasury bond and we allow γ_i to vary by calendar year. In column 2, X_t is empty. In column 8, X_t additionally includes the three Fama-French factors. In column 5, $R^E_{i,t}$ and $R^{A,x}_{i,t}(b)$ are rescaled by the ratio of one-day lagged market capitalization to the insurer's sample mean market capitalization. In column 6, we interact a date fixed effect with the inverse of insurer market capitalization. If indicated, the dependent variable is winsorized each month at the median $\pm$ 2.5 standard deviations. The 2Y crisis period is January 2008-December 2009. The 1Y crisis period is September 2008-August 2009. Standard errors clustered by date in parentheses. ** and * denote statistical at the 1 and 5% levels. The data cover the period 2004 - 2014.

Figure 6: Pass-through Coefficients Sample Robustness



Notes: The figure reports the histogram of coefficients of pass-through in and out of the crisis from the regression specification in column (1) of table 6 when we exclude three insurers at a time from the sample. The crisis period is January 2008-December 2009. The data cover the period 2004 - 2014.

on the three Fama-French factors. We consistently find results similar to the baseline specification. Finally, column 9 measures the pass-through to public debt for the subsample of insurers with liquid CDS on their outstanding public debt throughout our sample period.[20] We find some evidence of a higher crisis pass-through on public debt as well, but caution that equity pass-through is lower for this subgroup so that pass-through on the total value of the firm is not higher.

The evidence of differential pass-through in and out of the crisis does not depend on the asset price behavior of only a few insurers. To make this point, we selectively drop three insurers at a time, or 20% of our sample, and re-estimate the baseline regression in column 1 of table 6. Figure 6 reports the histogram of coefficients from these $\frac{15!}{12!3!} = 455$ regressions. Most coefficients cluster around the level estimated in the baseline specification in the full sample, and the two distributions of coefficients in and out of the crisis do not overlap. The gap between the crisis and out of crisis coefficients estimated for each sample ranges between 0.5 and 1.4.

Table 7 explores the sensitivity of our results to the window over which we measure excess returns. We reproduce our benchmark specification, in which we measure returns over a 1-day horizon, in column 1. In column 2, we measure excess returns over a 3-day horizon, and in column 3 we measure returns over a 7-day horizion.

[20]The tickers of these insurers are: AFL, ALL, LNC, MET, PRU, TMK. To compute the return on public debt, we first use Compustat and Mergent FISD to construct the maturity structure of public debt for each company. We then use the CDS yield curve from Markit to price the debt using a no-arbitrage condition.

Table 7: High Frequency Portfolio Return Pass-through, Longer Horizons

	Dependent variable: equity		
	Return horizon:		
	1 day	3 day	7 day
	(1)	(2)	(3)
Large excess bond returns interacted with:			
Not crisis	0.10	0.10	0.23
	(0.20)	(0.35)	(0.43)
Crisis	1.13**	1.30**	1.93**
	(0.34)	(0.33)	(0.74)
Date FE	Yes	Yes	Yes
Dep. var. winsorized	Yes	Yes	Yes
Treasury return	Yes	Yes	Yes
R^2	0.56	0.56	0.55
p(Homog. effect)	0.010	0.012	0.047
Observations	36,810	36,757	36,854

Notes: The estimating equation is: $R^E_{i,t} = \rho^A_{\text{crisis}}\mathbf{I}\{t \subseteq \text{crisis}\}R^{A,x}_{i,t}(b) + \rho^A_{\text{noncrisis}}\mathbf{I}\{t \not\subseteq \text{crisis}\}R^{A,x}_{i,t}(b) + \alpha_t + \gamma_i' X_t + \epsilon_{i,t}$. In column 1, $R^{A,x}_{i,t}(b)$ comprises daily returns which exceed their benchmark by 6 p.p., in column 2 3-day returns which exceed their benchmark by 8 p.p., and in column 3 7-day returns which exceed their benchmark by 10 p.p. The crisis period is January 2008-December 2009. Standard errors clustered by date in parentheses. ** denotes statistical significance at the 1% level. The data cover the period 2004 - 2014.

Since the variance of returns may increase with horizon, we raise the threshold for inclusion in the idiosyncratic component b to 8 p.p. for the 3-day horizon and to 10 p.p. for the 7-day horizon. The pass-through of the crisis remains low as the horizon increases, while the pass-through in the crisis remains above 1.

5.4 Further Evidence

Heterogeneity. The asset insulator theory explains the higher pass-through during the crisis as reflecting the heightened risk of liquidation. We find additional evidence of this channel by splitting the sample according to the level of financial distress. Specifically, we form two subgroups of insurers based on each insurer's stock return during the period September 12, 2008 to October 10, 2008. This four-week period begins with the day of the Lehman bankruptcy and contains the most acute drop in insurer stock prices in our sample. To avoid a mechanical correlation between stock

Table 8: Pass-through by Insurer Distress

	Dependent variable: equity return	
Sample:	Equity return 09/12/08-10/10/08 < Median	Equity return 09/12/08-10/10/08 > Median
	(1)	(2)
Large excess bond returns interacted with:		
Not crisis	0.15	0.15
	(0.27)	(0.22)
Crisis	1.13**	0.51
	(0.41)	(0.41)
Date FE	Yes	Yes
Drop 09/15/08-10/10/08	Yes	Yes
Dep. var. winsorized	Yes	Yes
Treasury factor	Yes	Yes
P(Crisis pass-through equal)	0.358	0.358
R^2	0.62	0.59
Observations	17,161	19,346

Notes: The table shows the extent to which pass-through differs by how much the insurer's stock fell in the period September 12, 2008 - October 10, 2008. The crisis period is January 2008-December 2009. Standard errors clustered by date in parentheses. ** denotes statistical significance at the 1% level. The data cover the period 2004 - 2014 excluding the period September 12, 2008 - October 10, 2008.

price decline and crisis pass-through from sorting based on decline, we then drop this four-week period from the sample. Table 8 reports the results from estimating equation (15) separately for each subsample. The pass-through coefficient rises during the crisis in both groups, consistent with the increase in the comparative advantage of an asset on the balance sheet playing a role, as well as reflecting a heightened level of distress even among the healthier insurers. However, the pass-through coefficient for the healthier subgroup rises by only half as much as for the more distressed subgroup. The limited sample size generates too little power to formally reject equality of the crisis pass-through coefficients at conventional levels, but the difference of 0.6 is economically significant and consistent with liquidation risk substantially raising the pass-through.

Annual pass-through. An exercise based on regulatory data reported at the end of each calendar year complements the previous results. These data have the advantage of much fuller coverage of assets, but at the cost of limited power as we have only one observation per insurer-year. The annual data do allow us to exploit variation by insurer in broad asset class allocation as well as within asset class idiosyncratic returns. Indeed, as we document in figure A.1, insurers differ substantially in their broad asset class allocation with some heavily exposed to ABS and PLRMBS before the crisis and others with virtually no exposure.

We construct annual portfolio returns from the NAIC regulatory data. NAIC Schedules BA and D require insurers to report a fair value per unit for all securities held on their balance sheet on December 31st of each year, regardless of whether valuation of the assets occurs at fair value or historical cost for accounting and regulatory purposes. These schedules also list the value of dividends received during the year, pre-payments, and purchases and sales. We use this information to construct for each asset a total dollar gain equal to the sum of mark-to-market capital gains and net dividends. Summing over assets then gives the total dollar value of investment gains and losses in a year. We obtain information on derivatives holdings from Schedule DB. Like bonds, insurers must include a fair value of each derivative position in their filing, but depending on the hedging classification may not include unrealized gains and losses in their accounting totals. We use a string matching algorithm to match open derivatives positions across consecutive filing years and the fair value reported in each year to construct mark-to-market gains and losses on the derivatives portfolio.[21] Our measure differs, sometimes substantially, from the investment gains and losses reported by insurers in their statutory filings because it attributes gains and losses to the period in which the underlying investments change value rather than the year in which they are recognized for accounting purposes.

Table 9 reports regressions of the same form as equation (15) but using the NAIC data at the annual frequency. The specification in column 1 includes no controls other than the year fixed effects and reports pass-through with respect to the scaled return on the portfolio assets. We obtain a coefficient of 0.72 for the year 2008 and of essentially zero for all other years. In columns 2 and 3 we construct excess portfolio returns by first demeaning each asset class return with respect to its yearly mean across all insurers (column 2) or as the residual after extracting one asset-class specific factor

[21]The annual filings also contain detailed data on wholly owned mortgages (Schedule B) and directly held real estate (Schedule A), but value these assets only at historical cost. We exclude these assets in our calculations.

Table 9: Annual Portfolio Return Pass-through

	Dependent variable: stock return			
	Portfolio capital gains measured as:			
		Excess return w.r.t.:		
	Actual	Asset-class year mean	1 factor	Actual incl. derivatives
	(1)	(2)	(3)	(4)
Right hand side variables: scaled portfolio return in:				
Not crisis	-0.047	-0.33^{**}	-0.48^{**}	-0.029
	(0.036)	(0.11)	(0.15)	(0.042)
2008	0.72^{*}	0.77^{*}	0.71	0.87^{+}
	(0.29)	(0.33)	(0.50)	(0.51)
2009	0.022	0.31	0.86	0.022
	(0.052)	(0.42)	(0.93)	(0.050)
Year FE	Yes	Yes	Yes	Yes
R^2	0.55	0.55	0.56	0.54
Observations	150	150	150	150

Notes: The table presents the coefficients from regressions of the insurance company's total stock return on the change in the value of its asset holdings. The right hand side variable is the total return on the insurer's asset portfolio. In column (2), we adjust the portfolio capital gains by removing the asset-class mean in each year before aggregating to the individual insurer level. Our asset classes are defined as shown in the right hand panel of figure 2. In column (3), we control for differences across insurers in initial holdings by extracting the first principal component for each asset class before aggregating to the individual insurer level. In column (4), we include derivative positions in addition to the securities held. Heteroskedasticity-robust standard errors in parentheses. **, *, and + denote statistically significant at the 1, 5, and 10% levels. The data cover the period 2004 - 2014.

as chosen by the Bai (2009) interactive effects factor model (column 3). The 2008 pass-through changes little, while the non-crisis pass-through falls to be a bit negative.[22] The 2009 pass-through increases in these specifications. In column 4 we augment the Schedule D and BA holdings with the mark-to-market capital gain/loss on each insurer's derivatives portfolio. The pass-through coefficients change little, in part because the gains and losses on the non-derivatives holdings dwarf those from the derivatives portfolio. In sum, while less powerful and well-identified than the results

[22] While more comprehensive than the set of corporate bonds which transact on consecutive days, the annual filings nonetheless lack mark-to-market prices of directly held mortgages, real estate, assets held outside the insurance company, and especially liabilities.

based on daily returns, annual data confirm the basic result of a low pass-through out of the crisis and a higher pass-through during the crisis.

5.5 Discussion

The finding of a pass-through coefficient significantly below one out of the crisis poses a challenge to a Modigliani-Miller theory of the firm and to the other standard theories of financial institutions. The asset insulator view of insurers can explain both the low pass-through out of the crisis and the increase in pass-through during the crisis. In normal conditions, as asset prices fluctuate on the market, the value inside the firm is preserved and the pass-through is low. When the crisis occurs, asset prices on the market drop. This results in a larger comparative advantage to holding the assets on the balance sheet, so franchise value increases. However, this effect is mitigated by the deterioration in the financial health of insurers, putting them closer to liquidation. Assets are less likely to be held for a long time, and therefore less well insulated from market movements, which results in a higher pass-through. Further, while high, the value creation from the asset insulation activity is precarious. Adverse price changes can precipitate liquidation, further increasing the pass-through.

While the asset insulator theory predicts a pass-through in normal times below one, point estimates in the range of \$0.10 to \$0.20 may strike some readers as quite low. We offer four comments in this regard.

First, the crucial predictions of the insulator theory are that the pass-through in normal times is below one and that it rises during the crisis. In almost all specifications, the data reject both equality of the out-of-crisis pass-through and one, and equality of the coefficients in and out of the crisis at conventional confidence levels, confirming the predictions of the theory. However, the confidence interval in our baseline specification does not reject a pass-through out of the crisis of as high as \$0.50.

Second, our identification strategy of exploiting only large abnormal returns may affect the type of variation in bond returns we consider. Through the lens of equation (10), the pass-through we measure is a weighted average of the pass-through with respect to A^{in} shocks and ω shocks, with the pass-through decreasing in the overall variance share of ω shocks, V_ω. V_ω for large abnormal bond returns may exceed V_ω for all bond returns. This difference in and of itself would not affect the interpretation of our results, as long as V_ω for the bond returns we consider does not differ too much in and out of the crisis.

We find supportive evidence for this condition from similarity in the mean rever-

Table 10: High Frequency Bond Return Serial Correlation

	Dependent variable: excess return over next:			
	7 days		28 days	
	(1)	(2)	(3)	(4)
Large excess bond returns interacted with:				
Not crisis	-0.29^{**}	-0.35^{**}	-0.30^{**}	-0.34^{**}
	(0.03)	(0.03)	(0.03)	(0.03)
Crisis	-0.29^{**}	-0.34^{**}	-0.27^{**}	-0.31^{**}
	(0.02)	(0.02)	(0.03)	(0.02)
Date FE	Yes	Yes	Yes	Yes
Impute 0?	Yes	No	Yes	No
R^2	0.172	0.193	0.139	0.148
Observations	70,042	67,137	70,042	69,185

Notes: The table shows the extent of mean-reversion in excess bond returns in and out of the crisis. The sample includes one oberservation per cusip-date with an excess return above 6 p.p. Columns 1 and 3 impute a value of 0 for the subsequent 7 or 28 day return if the cusip does not transact again in that horizon, while columns 2 and 4 exclude such observations from the regression. The crisis period is January 2008-December 2009. Standard errors two-way clustered by date and cusip in parentheses. ** denotes statistical significance at the 1% level. The data cover the period 2004 - 2014.

sion of abnormal bond returns. Specifically, table 10 reports for the sample of cusip-dates which contribute to $R^{A,x}_{i,t}(b)$ in our baseline specification the coefficients from regressions of the excess return over the subsequent 7 or 28 days on the contemporaneous excess return. Roughly one-third of the excess return has dissipated after 7 days, and this reversion is of similar magnitude in and out of the crisis. The amount of reversion after 28 days almost exactly equals the 7 day reversion, suggesting two-thirds of the excess returns persist over a longer period, again of similar magnitude in and out of the crisis. Thus, while only very temporary price dislocations may partly explain the low pass through, many of the abnormal bond returns do not quickly dissipate, and differences in the characteristics of abnormal bond returns do not appear able to explain the increase in pass-through during the crisis. These results echo the findings in table 5 regarding the similarity of shocks in and out of the crisis.

Third, anecdotal evidence of the valuation convention of equity analysts of insurance companies conforms with a low pass-through in normal times. According to Nissim (2013), most equity analysts value insurance companies using a price-book ratio which excludes accumulated other comprehensive income (AOCI) from the book valuation. Our own conversations with market participants confirm the popularity of this approach. The category AOCI includes all of the unrealized gains and losses from the asset portfolio. Nissim (2013, p. 326) describes the rationale for excluding AOCI as stemming from a desire to smooth the high volatility of investment gains and losses, consistent with the asset insulator view. For our purposes, the industry practice of ignoring AOCI when doing valuation amounts to a target pass-through of close to zero in normal conditions.

Fourth, our theory abstracts from other frictions which might amplify the asset insulation function in non-crisis periods. Monitoring costs, rational inattention, and heuristics provide possible candidates. For example, if equity market participants must pay a cost to monitor developments on insurers' portfolios, they will do so only if the mis-valuation from not paying the cost exceeds the cost itself. With a target pass-through absent information costs already low, the gains from monitoring are small, and participants will not pay the cost, pushing the realized pass-through even lower. Similarly, with low target pass-through, valuing assets strictly at book value may be preferred to valuing strictly at market value. We leave further investigation of these channels to future research.

In sum, the pass-through evidence in and out of the crisis, and the cross-sectional differences in pass-through during the crisis, accord well with the asset insulator view of life insurers. In contrast, the financial friction view cannot explain the low pass-through out of the crisis, while the policy guarantee view counterfactually predicts a smaller pass-through during the crisis and for more distressed insurers. We conclude that only the asset insulator view can fit the empirical pass-through moments.[23]

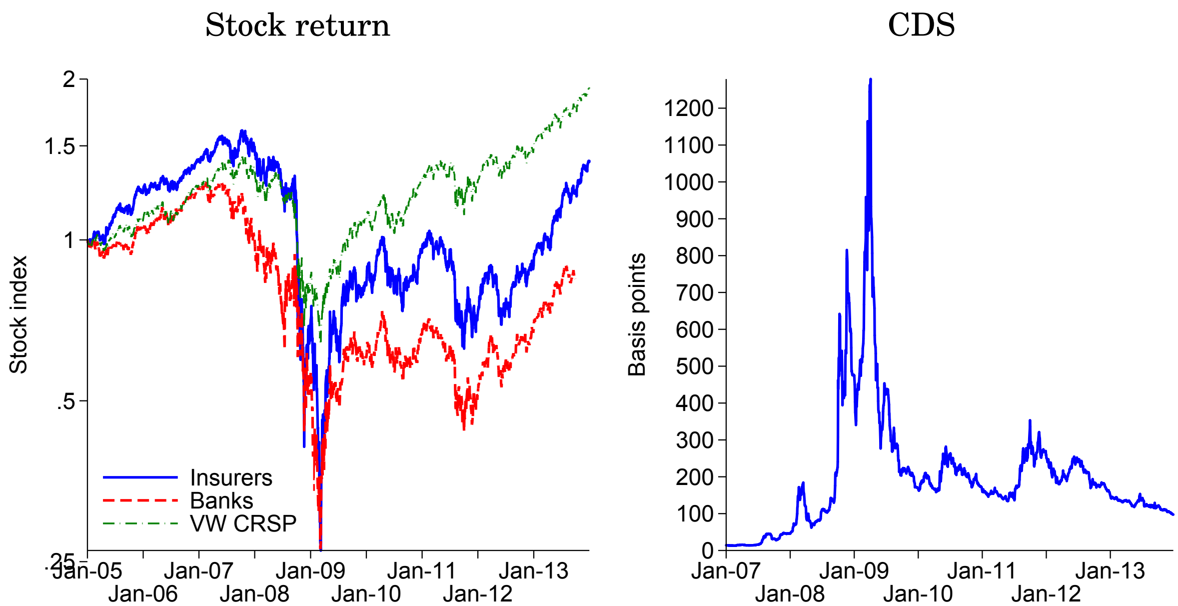
6 Franchise Value

We have shown how the asset insulator view can rationalize the balance sheet choices of life insurers and explain the behavior of pass-through in and out of the crisis. We now demonstrate that it also helps to resolve otherwise puzzling low frequency movements in the equity value of the life insurance sector during the financial crisis.

As a starting point, figure 7 illustrates the financial distress of the life insurance sector during the financial crisis. The left panel shows the stock return index for pub-

[23] We have discussed already the inconsistency of the liability matching view with insurers' portfolio choices. The pass-through evidence here also helps to reconcile the evidence in Chodorow-Reich (2014) that life insurers' stock prices rose sharply during the crisis on dates when the Federal Reserve took actions to lower interest rates, a result at odds with the duration mismatch of insurers but consistent with the sharp rise in the value of portfolio holdings passing through into the equity at a high rate.

Figure 7: Insurer Distress During Crisis



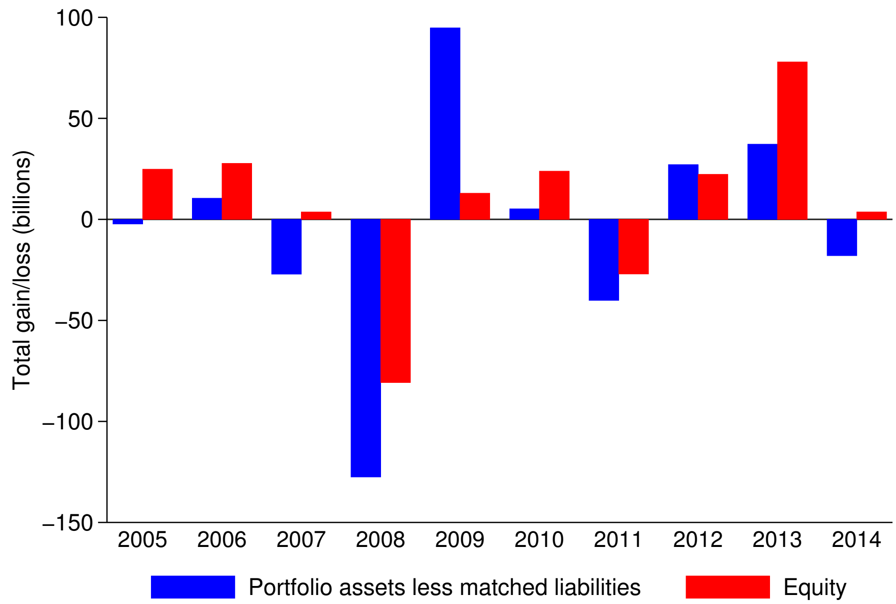
Notes: The left panel plots the value-weighted total return index for publicly traded insurers, banks, and the entire CRSP value-weighted index. The right panel plots the equity value-weighted annual premium to insure $10,000 of debt for a period of 5 years for AFL, ALL, LNC, MET, PRU, and TMK.

licly traded life insurers plotted against commercial banks and the value-weighted CRSP index for comparison. The insurance sector has the largest peak-to-trough decline of the three sectors. The right panel shows the equity value-weighted average CDS spread for the six insurers with liquid CDS throughout the period. From a low of essentially zero before the crisis, the spread rises beginning in 2008 and peaks above 1200 basis points in March 2009 before declining to a "new normal" range in the latter part of that year. The distress evident in figure 7 is why we treated the 2008-09 period as one of heightened liquidation risk in the previous section.

Remarkably, the aggregate dollar change in insurers' assets net of liabilities during the crisis exceeds the substantial drop in equity. Figure 8 shows this result. The figure requires two caveats. First, we do not have mark-to-market data on the value of liabilities. Instead, we use the effective duration of each security on the balance sheet and the Treasury yield curve to construct a matched-Treasury capital gain/loss as the buy-and-hold return for a Treasury security of the same effective duration.[24] We use this matched-Treasury capital gain/loss as a lower bound for the change in

[24] When the holding changes due to purchases, sales, dividends, or pre-payments, we adjust the matched Treasury holding accordingly.

Figure 8: Aggregate Changes in Assets, Liabilities, and Market Equity



Notes: The blue bars show the fair value capital gain/loss on assets reported in NAIC schedule BA and D minus the gain/loss on a portfolio of Treasuries constructed by matching each cusip to a U.S. Treasury of the same duration. The red bars show the total change in market equity.

liabilities under the assumption that insurers tend to hold assets of shorter duration than their liabilities. For example, this bound leads us to understate the increase in the value of liabilities due to the sharp drop in interest rates in 2008. Second, our calculation does not include balance sheet losses resulting from guaranteed income annuities, direct holdings of mortgages or real estate, or assets held outside of the insurance subsidiary. Omitting these factors results in a conservative estimate of the loss in portfolio assets net of liabilities in 2008.[25]

Even with these conservative assumptions, we estimate the decline in the interest rate in 2008 to have increased the value of policy liabilities by at least \$96 billion, while the assets held by insurers lost at least \$30 billion. If the franchise value stayed constant, we would have observed more than a \$126 billion loss in the value

[25]The figure does not include the changes in the value of public debt since we do not have CDS prices for most of our sample. However, this omission does not affect the result much. For example, in 2008 total equity at the 6 insurers for which we do have CDS prices declined by \$75 billion. Applying the CDS curve and Treasury yield curve to the maturity structure of public debt outstanding for these insurers, we estimate a decline in the value of debt of \$2 billion for these insurers, the result of an increase in value of \$6 billion from the decrease in interest rates and a fall in value of \$8 billion from the higher default risk.

of the equity in 2008. In fact, insurers' equity dropped by "only" \$80 billion: franchise value increased. This result runs counter to Modigliani-Miller, and is even more at odds with the financial friction view that a deteriorating financial situation destroys firm value.[26]

We can illustrate these dynamics formally in the context of our model using figure 5. We represent an increase in market illiquidity as a decline in the wedge ω. This change lowers directly the value of the assets in the market and hence the Modigliani-Miller value of the firm. However, far from default, a change in ω has a small effect on firm equity. As a result, franchise value rises. In the figure, the two points N and J derive from the same value of A^{in} but different values of ω. The increase in vertical distance from the Modigliani-Miller line when moving from point N to point J reveals the increase in franchise value. Of course, life insurers also became financially distressed during the 2008-09 crisis. We represent this distress as a decline in A^{in}, or a movement from point J to point C. As they approach default, insurers lose the ability to insulate assets from the market. Indeed, a large enough decrease in A^{in} could reverse the increase in value creation coming from the lower ω; in the extreme case of $A^{\text{in}} \to A_0$, value creation from insulation ceases. Which of the two effects dominate is an empirical question. In the figure, as in the data, the overall change in franchise value when moving from N to C is positive.

These results highlight a core tension in both the theory and the data. Periods of financial turmoil and market dislocation represent prime opportunities for asset insulators. However, such periods may also coincide with insulators becoming financially distressed, jeapordizing their ability to insulate. Thus, asset insulation may be most fragile exactly when it is most valuable. The combination of high pass-through and high franchise value during the financial crisis demonstrates this tension for life insurers.

7 Conclusion

We have proposed a theory of financial intermediaries as asset insulators, institutions which hold assets for the long run to protect valuations from consequences of exposure to financial markets. The balance sheets of life insurers exemplify an asset insulation

[26] These results may also bear on issues of systemic risk. Acharya, Philippon, and Richardson (2016) define a firm's systemic risk as its contribution to an aggregate capital shortfall in the financial sector. While the comovement of stock prices in figure 7 indicates a strong correlation of life insurer distress and the overall market, figure 8 suggests the capital shortfall would be even worse if the assets were not insulated inside the life insurance sector.

strategy. Insurers hold illiquid and risky assets for long intervals, in contrast to the classic duration-matching of liabilities view of their portfolio choice. Asset insulation is especially valuable during periods of market turmoil, as evidenced by the franchise value of insurers increasing in 2008 and 2009.

The pass-through of the value of assets into market equity is a useful metric to discriminate asset insulation from other theories. Using detailed security-level holdings data matched to trading data on corporate bonds, we estimate that insurers' equity value decreases by as little as 10 cents in response to a one dollar drop in asset values outside of the 2008-09 financial crisis. During the crisis, the pass-through rises to approximately 1. Our theory interprets the higher pass-through during the crisis as resulting from the deterioration in the financial health of insurers, which threatens their ability to act as long-lived investors.

Our results depict a set of institutions which create private value through their ability to hold risky, illiquid assets for long intervals. Ascertaining whether these institutions create social value requires answering additional questions. On the one hand, the asset insulation view suggests a stabilizing role for these institutions, rather than the amplifying role sometimes attributed to them. On the other, the correlation between market illiquidity and the health of the financial sector makes the asset insulation function most fragile exactly when it is most valuable. Finally, we do not consider the social benefits of having a large share of assets trade on financial markets, such as price discovery and liquidity. We leave these questions to future work.

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A Additional Data Information

We assess the accuracy of insurers' self-reported valuations of their assets in two ways. First, we collect prices for as many assets as possible from external sources such as TRACE, CRSP, and Bloomberg terminals. We are able to obtain external prices for approximately 38% of insurers' securities by value in any given year. The primary difficulty in obtaining external prices is that many of the assets they hold are highly illiquid.[27] Table A.1 summarizes the difference in prices from what the insurers themselves report and third-party prices. In general, there is very little variation in asset prices reported in NAICs and external quotes. When we include outliers, insurers appear to slightly underreport the values of some securities as the mean raw price difference is -1.2%. However, after excluding outliers, the mean raw price difference is 0.2%. The absolute price differences with and without outliers are 3.6% and 1.8%. We thus feel confident using that insurers are reporting their asset values without significant bias to NAICs.

Table A.1: Differences Between Insurer-Reported and Third-Party Log Prices

	All Cusips	Excluding Outliers
N	328,230	326,684
Mean Absolute	0.036	0.018
Median Absolute	0.006	0.006
Mean Raw	-0.012	0.002
Median Raw	0.000	0.000
Mean Squared	0.082	0.002
Standard Deviation	0.286	0.050
P75 Absolute	0.018	0.017
P90 Absolute	0.043	0.042
P95 Absolute	0.073	0.070
P99 Absolute	0.283	0.187
Maximum Absolute	13.816	0.999

Notes: All values as of Q4. Count (N) refers to number of CUSIPS for which external prices are available. Fair value per unit used for insurer-reported price. Raw difference calculated as log of insurer-reported less third-party value. Outliers are CUSIPS for which the insurer-reported value deviates by more than 100% from that reported by third-parties.

The second way we assess the accuracy of insurers' self-reported valuations is by comparing the prices reported by multiple insurers in our sample that hold the

[27]Edwards et al. (2007) report that about half of corporate bonds trade very infrequently. Bessembinder et al. (2013) find that only 20% of structured finance securities trade at all in a 20-month period.

same asset. Approximately 55% of insurers' securities by value are held in securities that multiple insurers hold. Table A.2 details the deviations in prices reported across insurers. The mean and median standard deviations are 4.3% and 0.0%. After excluding outliers, these statistics fall to just 0.9% and 0.0%.

Table A.2: Cross-Insurer Standard Deviations for Insurer-Reported Log Prices by CUSIP

	All CUSIPS	Excluding Outliers
N	287,903	285,774
Mean	0.043	0.009
Median	0.000	0.000
Standard Deviation	0.277	0.036
P75	0.004	0.004
P90	0.017	0.016
P95	0.043	0.035
P99	1.687	0.190
Maximum	11.209	1.354

Notes: Q4 fair values used to calculate standard deviations. Count (N) refers to number of CUSIPS held by multiple insurers. Outliers are CUSIPS for which the differences in prices across insurers exceed 100%.

We next provide further detail on holdings by insurer and asset illiquidity. Figure A.1 reports the asset class allocation for each insurer for the years 2005, 2009, and 2013.

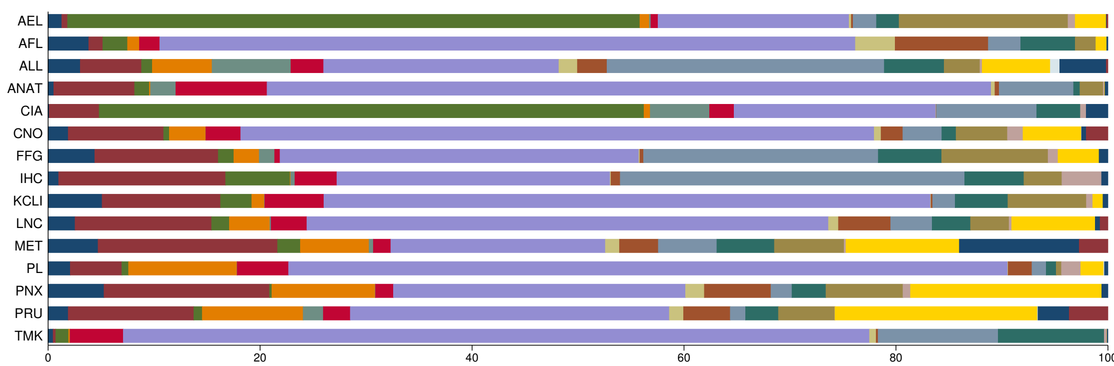
We use the Hanson et al. (2015, Appendix Table AII) liquidity weights summarized in table A.3 below to assign liquidity weights at the year-insurer-asset class level.[28] Table A.4 shows the illiquidity of our insurers by year. Despite our use of much more disaggregated data than Hanson et al., we obtain a very similar estimate of the illiquidity of our insurers of 60%. By comparison, Hanson et al. find that banks' assets have an illiquidity measure of slightly above 60%.

[28] Hanson et al. (2015) assign an illiquidity weight of 50% to corporate bonds under the assumption that the corporate bonds are rated A- or higher. We maintain this weighting scheme despite most corporate bonds held by insurers having a rating below AA (see Table 2). Because lower rated corporate bonds are generally less liquid (see, for example, Edwards et al. (2007)), this assumption likely biases our measure of the illiquidity of insurers' holdings downwards.

Figure A.1: Portfolio Allocation by Insurer

Panel A: 2005

Panel B: 2009



Panel C: 2013

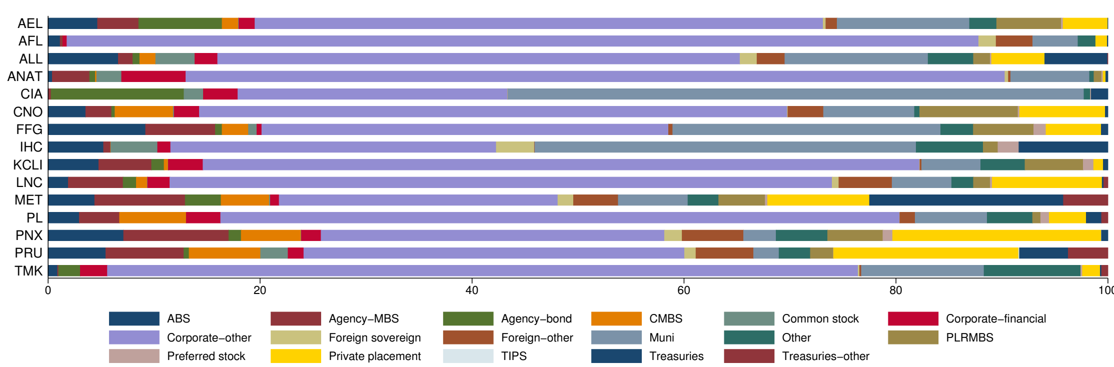


Table A.3: Illiquidity Weights by Asset Class

Asset Class	Illiquidity Weight (%)
ABS	100
Agency-MBS	15
Agency-Bond	15
Cash	0
CMBS	100
Common Stock	50
Corporate-financial	50
Corporate-other	50
Foreign sovereign	50
Foreign-other	50
Mortgages	100
Muni	50
Other	100
PLRMBS	100
Preferred Stock	50
Private Placement	100
Real Estate	100
TIPS	0
Treasuries	0
Treasuries-other	0

Notes: Weights based on Hanson et al. (2015). We assume a weight of 100% for mortgages because the overwhelming majority of insurers' mortgages are commercial rather than residential mortgages.

Table A.4: Illiquidity of Insurers' Total Portfolios by Year

Year	Illiquidity Measure
2005	58.3
2006	60.4
2007	61.2
2008	59.2
2009	60.0
2010	60.7
2011	60.5
2012	59.8
2013	60.1
2014	59.3
Average	60.0

Notes: See Table A.3 for weights assigned to individual asset classes. Summary is value-weighted by individual insurers' assets. 0=Completely liquid, 100=Completely illiquid.

B Solving the Model

B.1 Value of equity

The exogenous laws of motions are

$$\frac{dA_t^{\text{in}}}{A_t^{\text{in}}} = (r-c)dt + \sigma_A dZ_t^A, \tag{A.1}$$

$$d\omega_t = -\kappa_\omega(\omega_t - \bar{\omega})dt + \sigma_\omega\sqrt{\omega_t}dZ_t^\omega. \tag{A.2}$$

The liquidation stopping time T is the hitting time of the threshold A_0.

The value of the equity is

$$E_t = \mathbb{E}_t\left[\int_t^T e^{-r(\tau-t)}(c-k)A_\tau^{\text{in}}d\tau + e^{-r(T-t)}\omega_T A_0 - \int_t^\infty e^{-r(\tau-t)}\ell d\tau\right]. \tag{A.3}$$

We drop the "in" superscript for simplicity and reorganize the equation:

$$E_t = \mathbb{E}_t\left[\int_t^T e^{-r(\tau-t)}(c-k)A_\tau d\tau + e^{-r(T-t)}\omega_T A_0 - \int_t^\infty e^{-r(\tau-t)}\ell d\tau\right] \tag{A.4}$$

$$= \underbrace{\mathbb{E}_t\left[\int_t^\infty e^{-r(\tau-t)}(c-k)A_\tau d\tau\right]}_{\text{no-liquidation asset value}} + \underbrace{\mathbb{E}_t\left[e^{-r(T-t)}\omega_T A_0 - \int_T^\infty e^{-r(\tau-t)}\left(c-k\right)A_\tau d\tau\right]}_{\text{liquidation adjustment}}$$

$$- \underbrace{\mathbb{E}_t\left[\int_t^\infty e^{-r(\tau-t)}\ell d\tau\right]}_{\text{liabilities}}. \tag{A.5}$$

The present value of liabilities is

$$\int_t^\infty e^{-r(\tau-t)}\ell d\tau = \frac{\ell}{r}. \tag{A.6}$$

Note that $\mathbb{E}_t\left[A_\tau|A_t\right] = A_t \exp\left(r-c\right)\left(\tau-t\right)$. Therefore,

$$\mathbb{E}_t\left[\int_t^\infty e^{-r(\tau-t)}(c-k)A_\tau d\tau\right] = A_t\int_t^\infty \left(c-k\right)\exp\left(-c\left(\tau-t\right)\right)d\tau \tag{A.7}$$

$$= A_t\frac{c-k}{c}, \tag{A.8}$$

and

$$\mathbb{E}_T\left[\int_T^\infty e^{-r(\tau-t)}\left(c-k\right)A_\tau d\tau\right]=\mathbb{E}_T\left[\int_T^\infty e^{-r(\tau-t)}\left(c-k\right)e^{(r-c)(\tau-T)}A_T d\tau\right] \tag{A.9}$$

$$=e^{-r(T-t)}\frac{c-k}{c}A_{T.} \tag{A.10}$$

We can also compute expectations of ω_τ for various values of τ. For this remember the conditional mean of a CIR process is

$$\mathbb{E}_t\left[\omega_\tau|\omega_t\right]=\omega_t e^{-\kappa_\omega(\tau-t)}+\bar{\omega}\left(1-e^{-\kappa_\omega(\tau-t)}\right). \tag{A.11}$$

Plugging these results in the liquidation adjustment, and using the fact that, by definition, $A_T=A_0$, we have

$$\mathbb{E}_t\left[e^{-r(T-t)}\omega_T A_0-\int_T^\infty e^{-r(\tau-t)}\left(c-k\right)A_\tau d\tau\right]=A_0\mathbb{E}_t\left[e^{-r(T-t)}\left[\left(\omega_t-\bar{\omega}\right)e^{-\kappa_\omega(T-t)}+\bar{\omega}-\frac{c-k}{c}\right]\right] \tag{A.12}$$

We are left with computing $\mathbb{E}_t\left[e^{-r(T-t)}\right]$ and $\mathbb{E}_t\left[e^{-(r+\kappa_\omega)(T-t)}\right]$. The following lemma gives a general expression for this type of expectations.

Lemma 1. *For any* $\alpha\geq 0$ *, we have*

$$\mathbb{E}_t\left[e^{-\alpha(T-t)}\right]=\left(\frac{A_t}{A_0}\right)^{-f(\alpha)}, \tag{A.13}$$

with

$$f(\alpha)=\frac{r-c-\frac{1}{2}\sigma_A^2+\sqrt{\left(r-c-\frac{1}{2}\sigma_A^2\right)^2+2\sigma_A^2\alpha}}{\sigma_A^2}. \tag{A.14}$$

The function f *is positive and increasing.*

Proof. Define $M_t=e^{-\alpha t}\left[\frac{A_t}{A_0}\right]^{-\tilde{\gamma}_1}$. Applying Ito's lemma gives

$$dM_t=M_t\left[-\alpha-\tilde{\gamma}_1(r-c)+\frac{1}{2}\sigma_A^2\tilde{\gamma}_1\left(1+\tilde{\gamma}_1\right)\right]dt-\tilde{\gamma}_1\sigma_A M_t dZ_t^A. \tag{A.15}$$

Hence M_t is a martingale if $\tilde{\gamma}_1$ solves

$$0 = \left[\frac{1}{2}\sigma_A^2\right]\tilde{\gamma}_1^2 + \left[-(r-c) + \frac{1}{2}\sigma_A^2\right]\tilde{\gamma}_1 + [-\alpha] \tag{A.16}$$

$$\tilde{\gamma}_1 = \frac{(r-c) - \frac{1}{2}\sigma_A^2 \pm \sqrt{\left((r-c) - \frac{1}{2}\sigma_A^2\right)^2 + 2\sigma_A^2\alpha}}{\sigma_A^2}. \tag{A.17}$$

Let us consider the positive root, calling it γ_1. In this case M_t is uniformly bounded before the stopping time T. Doob's optional stopping theorem applies: $M_t = E_t[M_T]$. Hence, substituting the definition of M_t,

$$e^{-\alpha t}\left[\frac{A_t}{A_0}\right]^{-\gamma_1} = E_t\left[e^{-\alpha T}\right], \tag{A.18}$$

$$E_t\left[e^{-\alpha(T-t)}\right] = \left[\frac{A_t}{A_0}\right]^{-\gamma_1}. \tag{A.19}$$

This last expression coincides with our lemma. ■

Using this lemma, we obtain the value of equity:

$$E_t = A_t\frac{c-k}{c} + A_0\left(\frac{A_t}{A_0}\right)^{-f(r+\kappa_\omega)}(\omega_t - \bar{\omega}) + A_0\left(\frac{A_t}{A_0}\right)^{-f(r)}\left(\bar{\omega} - \frac{c-k}{c}\right) - \frac{\ell}{r}. \tag{A.20}$$

B.2 Pass-through

We can compute the laws of motion for E_t and A_t^{out} using Ito's lemma. We drop the dt terms as they do not enter the pass-through calculation, and ignore the "in" superscript. For the equity value, we obtain:

$$\begin{aligned} dE_t = {} & \left(\frac{c-k}{c} - \frac{f(r+\kappa_\omega)}{A_t}\left(\frac{A_t}{A_0}\right)^{-f(r+\kappa_\omega)} A_0(\omega_t - \bar{\omega}) - \frac{f(r)}{A_t}\left(\frac{A_t}{A_0}\right)^{-f(r)} A_0\left(\bar{\omega} - \frac{c-k}{c}\right)\right) dA_t \\ & + A_0\left(\frac{A_t}{A_0}\right)^{-f(r+\kappa_\omega)} d\omega_t \end{aligned} \tag{A.21}$$

For the outside value of the assets, we obtain:

$$dA_t^{\text{out}} = \omega_t dA_t + A_t d\omega_t \tag{A.22}$$

We can then compute the pass-through, remembering that cov $(dA_t, d\omega_t) = 0$:

$$PT = \frac{< dE_t, dA_t^{\text{out}} >}{(dA_t^{\text{out}})^2} \tag{A.23}$$

$$= \frac{\omega_t^2 dA_t^2}{\omega_t^2 dA_t^2 + A_t^2 d\omega_t^2} \left[\frac{\frac{c-k}{c}}{\omega_t} - \frac{f(r+\kappa_\omega)}{\omega_t A_t} \left(\frac{A_t}{A_0}\right)^{-f(r+\kappa_\omega)} A_0 \left(\omega_t - \bar{\omega}\right) - \frac{f(r)}{\omega_t A_t} \left(\frac{A_t}{A_0}\right)^{-f(r)} A_0 \left(\bar{\omega} - \frac{c-k}{c}\right) \right]$$

$$+ \frac{A_t^2 d\omega_t^2}{\omega_t^2 dA_t^2 + A_t^2 d\omega_t^2} \left[\left(\frac{A_t}{A_0}\right)^{-f(r+\kappa_\omega)-1} \right]. \tag{A.24}$$

We define the fractions of variance of dA_t^{out} coming from the two shocks

$$V_A = \frac{\omega_t^2 dA_t^2}{\omega_t^2 dA_t^2 + A_t^2 d\omega_t^2}, \tag{A.25}$$

$$V_\omega = \frac{A_t^2 d\omega_t^2}{\omega_t^2 dA_t^2 + A_t^2 d\omega_t^2}. \tag{A.26}$$

B.3 Extension: costs of financial distress

Consider the same setup as before, except that an additional cost K is paid at liquidation. This cost can for instance represent the lower sales of policies because consumers are worried about the continued existence of the insurer or the cost of operating under higher regulatory scrutiny if constraints are not respected. It could also be generated by the direct fire sale discount when liquidating large positions on short notice. Noting E_t^K the value of the equity and still E_t the value in our standard model, we have:

$$E_t^K = E_t - \mathbb{E}_t\left[e^{-rT} K\right] \tag{A.27}$$

$$= E_t - \left(\frac{A_t}{A_0}\right)^{-f(r)} K. \tag{A.28}$$

Default costs lower the value of the equity, more so when the firm is close to liquidation. Similarly, we can immediately obtain the pass-through:

$$PT^K = PT + V_A \frac{f(r)}{\omega_t A_t} \left(\frac{A_t}{A_0}\right)^{-f(r)} K. \tag{A.29}$$

The costs of financial distress increase the pass-through.