Insurance Companies and the Propagation of Liquidity Shocks to the Real Economy

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ABSTRACT

We study the role of insurance companies in propagating liquidity shocks to the real economy. We use natural disasters as our instrument to identify exogenous shifts in capital-market liquidity, and study whether capital-market liquidity affects regional-level fiscal conditions and output. Aggregate disaster-driven bonds sales of disaster-unaffected municipal bonds by exposed insurers cause low GDP growth and high unemployment. In micro data, natural disasters trigger large, unexpected redemptions of property-insurance contracts, causing: fire sales of municipal bonds; increased borrowing costs in primary markets; decreased muni issuance; lower investment in muni-reliant sectors. Therefore, insurance companies do propagate liquidity shocks to the real economy.

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The increasing globalization of insurance and financial markets provides important opportunities and advantages in terms of risk sharing and diversification, as evidenced by the fact that insurance companies as of 2020 hold in excess of $8 trillion in financial assets, which represents about 40% of the US GDP and is of a similar order of magnitude as the holdings of banks.[1] At the same time, these large insurers' portfolio holdings are concentrated in a few asset classes, i.e., treasuries, municipals, and corporate (Girardi et al. 2020), implying that any group of insurance companies collectively suffering financial difficulties may propagate them to the real economy through their asset sales.

Because insurance companies are also undercapitalized, several commentators have advanced concerns about the potential systemic effects of insurers' asset sales.[2] Yet the role of insurance companies in contributing to systemic risk is largely underexplored relative to that of other financial institutions such as banks,[3] for two main reasons. First, a large literature argues that insurance companies absorb—rather than amplify—systemic shocks (e.g., see Darpeix, 2015 and references therein). Insurers typically engage in extensive reinsurance activity, which is precisely designed to hedge the risks of large redemption demands at short notice. As a result, any large and unexpected shock may end up being fully absorbed by the insurers' balance sheets without propagating to the real economy.[4] On the other hand, while reinsurance may indeed successfully shield the insurers' financial and operating performance from the adverse consequences of large shocks, undercapitalized insurers may still need to sell their most liquid assets at short notice if the redemption demand they face is sudden and large enough. It is precisely these asset sales that may generate ripple effects in financial markets and potentially propagate to the real economy.

Second, a major challenge is the endogeneity of insurers' portfolio rebalancing to economic activity. The same earthquake that triggers insurance redemption demands also directly knocks down the local economy. As a result, a negative correlation between

[1] The aggregate holdings of investment banks is below $8 trillion; the aggregate holdings of commercial banks is about $14 trillion. Sources: Federal Reserve Economic Data (FRED), North American Industry Classification Systems (NAICS), Compustat, and authors' calculations.
[2] See, e.g., Acharya and Richardson (2014).
[3] E.g., see Peek and Rosengren (1997 and 2000) and many others. See our review later on.
[4] Accordingly, existing aggregate measures of systemic risk focusing on financial institutions' performance and capital shortfall, and on how they co-move with the market as a whole, attribute a large role to banks and a negligible one to insurance companies, e.g., see Acharya, Pedersen, Philippon, and Richardson (2017), Adrian and Brunnemeier (2016), and Engle, Jondeau, and Rockinger (2015). Chodorow-Reich, Ghent, and Haddad (2021) show how life insurers absorb shocks using the pass-through ratio.

aggregate insurers' sales and subsequent output growth could reflect the direct negative effects of the earthquake on the real economy rather than the causal effect of insurers' asset sales on economic activity.

In this paper, we examine the role of insurance companies in propagating large shocks to the real economy. We focus on the redemption demands faced by property insurers in connection with the natural disasters that occurred in the U.S. over 2000-2010. We examine the portfolio holdings and trades of property insurers, and we trace out the aggregate impact of all of the insurers' trades into financial markets. To the extent that these trades (1) affect securities issued by borrowers *not directly hit* by the natural disaster, and (2) are sizable enough to affect the cost of capital of these ultimate borrowers, we can use these disaster-driven trades by exposed insurers as our instrument to identify exogenous shifts in capital market liquidity. We then use this instrument to estimate the causal effect of insurers' sales on aggregate output and unemployment, and to trace out at the micro level the causal effect of insurers' sales on these same borrowers' financing and investment activity.

At the macro level, we use an aggregate index of disaster-driven net sales by disaster-exposed insurers. For each region i and year t pair, we compute the aggregate net trades by insurers of muni bonds i in year t, provided region i is not subject to a natural disaster in year t. We show that such aggregate index predicts low GDP growth and high unemployment in years t and $t+1$. The economic magnitude of our point estimates is large and indicates that insurance companies do transmit natural disaster shocks to the real economy. Quantitatively and across all disasters, they imply that \$1bn dollars of aggregate net sales by exposed insurers causes a cumulative 9.2% decrease in GDP growth and a 1.9% increase in unemployment over the subsequent two years. These are large effects, amounting to almost two standard deviations of the annual time series of GDP growth and unemployment growth in disaster-affected states.

In the remainder of the paper, we trace out these effects at the micro-level for each disaster. We illustrate our approach and results by examining insurers' response to Hurricane Katrina, which hit the coasts of Louisiana in August 2005 and was among the largest natural disasters ever (Groen and Polivka, 2008). While there were some warnings about Hurricane Katrina's landing several days in advance, the scale of the damage far exceeded insurers' estimates and as a result, insurance companies did not take the full measure of the warning (e.g., Casey (2015, CBS News)). It caused the tragic loss of many human lives and enormous damage to private properties (Knabb et al., 2005; Groen and Polivka, 2008; Towers Watson, 2005). Where people and private properties were insured, the insurance companies were hit with enormous unexpected redemption demands. To meet these redemption demands, insurance companies had to sell their most liquid assets at short notice.

We find that insurance companies exposed to Katrina disproportionately sold municipal bonds, and among muni bonds, they disproportionately sold those issued by the state of New York. Formally, we estimate the causal impact of Hurricane Katrina on the net sales of NY bonds in a 2SLS framework over the 2000-2010 period. In the first stage, a post-Katrina dummy interacted with the pre-Katrina exposure of insurance companies is our exogenous instrument. This instrument strongly explains the loss ratio of insurance companies, whereby the loss ratio measures the net redemption expenditure of insurers. In the second stage, we find that such instrumented loss ratio explains the net sales of NY municipal bonds by insurance companies.

Our findings are large in economic terms and strongly statistically significant. They indicate that insurance companies exposed to Hurricane Katrina suffered a 15.0% increase in their loss ratio, which in turn led to a large increase in the net sale of NY bonds by insurers. In the aggregate, the volume of such sales was so large as to constitute a "fire sale." In fact, we find the aggregate net sales of insurers amount in excess of 80% of the total excess supply of NY bonds, and the cumulative average abnormal return of NY municipal bonds almost reached –1.00% for the next several months.[5] Our findings are robust to many alternative definitions of ex ante exposure to Katrina and alternative ways to measure the loss ratio. We also find that the yield in the primary market on new issues of NY muni bonds went up, at the same time as the fire sale was taking place in the secondary market of NY bonds.

Interestingly, we find that insurers' financial and operating performance was largely unaffected, even when the insurers were ex ante more exposed to Katrina, thanks in large part to their reinsurance activity. Likewise, while Katrina did directly inflict large economic losses where it landed (mostly Louisiana and Mississippi, and to a smaller extent Alabama and Florida), by and large it did not have direct effects on New York State's economy. These findings support the notion that the fire sale of New York bonds subsequent to Katrina did

[5] Interestingly, media coverage after Katrina mentions concerns about massive sales of muni bonds by insurers. To give one example, see the WSJ on September 9, 2005, "Storm's Impact Could Prompt More Selling of Municipal Bonds" (Rosenberg, 2005).

not reflect fundamental difficulties of the exposed insurers or of the New York State economy, but represented an externality inflicted by property insurers on the rest of the economy.

Based on these findings, we use the fire sales of New York muni bonds by insurance companies affected by Katrina as our instrument to identify an exogenous supply shift in capital market liquidity, and thus trace out whether and how the insurance companies propagate the Katrina shock to the real economy, at both the micro and macro levels. At the micro level, we trace out the issuance of muni bonds to their ultimate users. Prominent users of municipal bond proceeds include public hospitals, universities, and various infrastructures. We observe data on the balance sheet of public hospitals. Public hospitals represent a large portion of health expenditures, which in turn amount to 41% of the NY State budget. Public hospitals rely prominently on municipal bonds to finance their capital expenditures (see, for example, Rossi and Yun, 2019).[6] We find that in the aftermath of these fire sales of NY bonds, the cost of capital for the state of New York went up, and as a result, the state of New York sharply decreased its issuance of muni bonds[7] and cut its expenditure on public hospitals. In a difference-in-differences framework, we find that public hospitals that relied on municipal bonds in the pre-Katrina period suffered a significant decline in municipal financing in the post-Katrina period and a significant decline in capital expenditures. The difference-in-differences estimate of capital expenditure (per total assets) for municipal bond reliant public hospitals in the post-Katrina period is large and statistically significant, averaging –1.5% of hospital assets. This decline in investments is more pronounced for investments in tangible assets, such as hospital buildings, than for those in liquid assets, such as equipment.

This large, negative effect of the insurers-driven fire sale of NY bonds on the financing and investment of public hospitals does already point to the possibility of a negative effect of insurers' sales on the aggregate output of NY State. However, in equilibrium the foregone

[6] In the case of hospitals, we are able to trace out the issuance and ultimate usage of funds raised by muni borrowers, and thus we are able to connect precisely the changes in the price and quantity of the muni bonds to the changes in the balance sheets of the hospitals who are the ultimate users of those funds. Other major users of muni bond financing include educational institutions such as universities; however, we do not have balance sheet data for them. Later we will estimate the aggregate effects of the Katrina-exposed property insurers' asset sales on the real economy.

[7] The muni bonds used to finance public hospitals are typically "project bonds" earmarked to a specific investment project explicitly mentioned in the bond indenture. As a result, we are able to trace out a direct link from the shift in the price of NY bonds in the secondary market, to the increase in the yield on newly issued NY bonds, to the decrease in the issuance of NY bonds used to finance public hospitals, to the actual decrease in capital investment in public hospitals themselves.

investment by public hospitals could in principle be undertaken by private hospitals if they are not subject to the same shock.

Therefore, we next examine the impact of Katrina on the investments of NY private hospitals. Private hospitals are direct competitors of public hospitals in the NY healthcare industry, and the cost for capital of private hospitals was unaffected by the fire sale of NY muni bonds, due to the private hospitals' reliance on more traditional financial structures. In a difference-in-differences framework, we find that New York private hospitals significantly increase their investment, and increase more the closer they are located to municipal bond reliant public hospitals; however, this increase in investment begins in the third year after Katrina, and quantitatively is not as large as the foregone investments by public hospitals. The difference-in-differences estimate of capital expenditure per total assets is 3.6% for private hospitals located near affected public hospitals in the post-Katrina period. The DD effect is stronger for investments in non-movable buildings (DD estimate of 2.8%) than movable equipment. Our findings are robust to alternative measures of closeness (the inverse of distance to a public hospital) and to examining shorter event windows (e.g., 2003-2009).

We find similar results for all disasters in the US from 2000-2010. Different hurricanes hit different states and different property insurers were exposed. These property insurers had different portfolio holdings at the time of the disaster, but all exposed insurers reached out to sell their most liquid municipal bonds, triggering fire sales.[8] In turn, these fire sales triggered a cut in financing and investment by affected public hospitals, and a subsequent increase in investment by unaffected neighboring private hospitals. Quantitatively and across all disasters, our results imply a substitution coefficient of private for public investment of about 0.9 across all disasters and over the ten years around the disasters, that is, from year -5 to year +5, but the increase of private investment occurs mostly from year +3. That is, the increase in investment by private hospitals is not large enough to fully make up for the prior decline by public hospitals, and occurs several years later. Our results further imply that the cost of public—relative to private—capital is a significant determinant of whether hospital assets are built under public or private ownership.

[8] Alison hit Texas and Missouri and prompted the fire sale of DC bonds; Charley, Frances, Ivan, and Jeanne hit Florida and Alabama and prompted the fire sale of PR bonds; Gustav and Ike hit Texas and Louisiana and prompted the fire sales of GA bonds.

At the broadest level, prior literature on the transmission of liquidity shocks to the real economy has focused on different intermediaries (e.g., firms, commercial banks, investment banks, hedge funds, mutual funds), different asset markets (e.g., corporate bonds, corporate stocks, securitized products), different transmission mechanisms (e.g., deleveraging by exposed intermediaries), and has not examined effects on aggregate output such as GDP and unemployment. Therefore, broadly speaking our paper makes two main contributions to the literature. First, we complement extant literature by examining a different intermediary, i.e., insurance companies, and a different financial market, i.e., the market for municipal bonds. We show that a liquidity shock to the balance sheet of insurance companies causes a dry-up of liquidity in the secondary market of (previously liquid) municipal bonds, and a higher yield in the primary market of such municipal bonds. We are able to isolate the mechanism at play, namely, the fire sales of those municipal bonds that happened to be collectively held by insurance companies at the time of the liquidity shock. Importantly, in our context insurance companies do not (need to) de-lever, because their performance does not take a direct hit from redemption demands due to reinsurance. As a result, we are able to isolate fire sales as the mechanism at play linking insurers' liability-side liquidity and capital market liquidity. Second, we add to this literature by showing that a tightening of capital market liquidity caused by fire sales has a causal effect on the fiscal situation in a region and, in turn, such a liquidity-driven fiscal shock has a causal effect on the real economy and on aggregate output.

In the next section we discuss in detail the various strands of the literature to which our paper contributes to. Section II discusses our data; Section III presents our results; and Section IV concludes.

I. LITERATURE

To begin, our paper belongs to a recent and growing literature on the role of insurance companies in financial stability, which so far has mostly examined life insurers, e.g., see Koijen and Yogo (2015, 2016, and 2021), Ellul et al. (2018), Ge (2021), and Chodorow-Reich, Ghent, and Haddad (2021) among others. Our results imply that, even if property insurers do not suffer poor performance as a direct result of a large natural disaster shock, it does not necessarily follow that they do not amplify such a shock and transmit its adverse effects to the real economy. In the conclusion, we discuss the implications of this observation for the measurement of systemic risk.

In this respect, our paper relates to a literature that studies how shocks, including but not limited to natural disasters, propagate to the real economy through firms' production networks and supply chains (Barrot and Sauvagnat, 2016; Carvalho, Nirei, Saito, and Tahbaz-Salehi, 2017; Hsu et al., 2018)[9] or through global banks' internal capital markets across regions, states, or countries (e.g., Peek and Rosengren, 1997 and 2000; Cetorelli and Goldberg, 2011; Kalemli-Özcan, Papaioannou, and Peydrò, 2013; Kalemli-Özcan, Papaioannou, and Perri, 2013; Baskaya, di Giovanni, Kalemli-Özcan, Peydrò, and Ulu, 2017; Cortés and Strahan, 2017). At the most basic level, our focus on insurance companies as a propagation mechanism is novel, due to the insurers' unique business model. In fact, unlike firms or banks who typically lose money as a direct result of the negative shocks to which they are exposed, as we show in our data insurance companies typically withstand even the largest shocks, thanks in large part to their reinsurance activity. However, reinsurance just shields the insurers' financial and operating performance from the shocks, and as such it does nothing to address the externalities that insurers' asset sales may inflict on financial markets and the real economy.

Our paper contributes also to the literature on fire sales in financial markets. Much of this literature has been concerned with documenting the existence of fire sales in corporate equity and bond markets associated with the bursting of financial bubbles (e.g., Coval and Stafford, 2007), or fire sales of real assets (e.g., Pulvino, 1998; Campbell, Giglio, and Pathak, 2011), particularly by mutual funds (e.g., Greenwood and Thesmar, 2011; Chernenko and Sunderam, 2020), and particularly during the financial crisis (e.g., see Shleifer and Vishny, 2011). Insurance companies play a role by reaching for yield in corporate bond markets (Becker and Ivashina, 2015) and by precipitating the fire sales of corporate bonds (Ellul, Jotikasthira, and Lundblad, 2011; Ellul, Jotikasthira, Lundblad, and Wang, 2015; Aslan and Kumar, 2018; Nanda, Wu, and Zhou, 2019), which sometimes occur in connection with natural disasters (e.g., see Massa and Zhang, 2011; Manconi, Massa, and Zhang, 2016; Liu, 2018). Our paper adds to this literature by showing that fire sales can also affect public (municipal) bonds,

[9] A related literature documents comovement in stock returns within production networks, e.g., Cohen and Frazzini (2008), Hertzel et al. (2008), Menzly and Ozbas (2010), Boone and Ivanov (2012), and Herscovic (2018), Herscovic, Kelly, Lustig, and Van Nieuwerburgh (2020).

and that such fire sales can have lasting effects on the real economy by determining which assets are built under private or public ownership and by affecting aggregate output and unemployment.[10] Furthermore, our results illustrate the "paradox of liquidity" for the asset side of financial institutions' balance sheets (Myers and Rajan, 1998): highly liquid assets—such as NY muni bonds—are highly pledgeable ex ante but they are also among the first to be sold in case of sudden funding needs, thereby increasing ex post the conflicts over the property rights of the assets.

Our results that a liquidity shock to insurers' liabilities drive capital market liquidity are consistent with an influential line of research studying how capital constraints drive market liquidity, see, for example, the theoretical models of Gromb and Vayanos (2002), Garleanu and Pedersen (2007), Brunnermeier and Pedersen (2009), and Geanakoplos (2010). Accordingly, a recent empirical literature has attempted to link intermediaries' capital constraints and funding liquidity to capital market liquidity using exogenous shocks to funding liquidity. For example, Comerton-Forde, Hendershott, Jones, Moulton, and Seasholes (2010) use a shock to the balance sheet of NYSE specialist liquidity providers; Aragon and Strahan (2012) use Lehman Brothers' bankruptcy as a shock to its hedge funds clients' ability to trade their positions; and Kahraman and Tookes (2017) exploit threshold rules that determine a stock's margin trading eligibility. These papers examine different intermediaries such as NYSE specialists, hedge funds, and other stock traders; and typically focus on stock markets. Furthermore, these papers typically focus on traders' deleveraging as the main mechanism linking funding liquidity and market liquidity, whereby the tightening of margin requirements during a downturn forces traders to de-lever, further amplifying the downturn itself.[11] By

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[10] Fire sales of municipal bonds differ from fire sales of corporate bonds in several important respects. To begin, firms issuing corporate bonds tend to be large and operating across regions at a national level, like Starbucks. There are two consequences of this. First, Starbucks bonds may be subject to a fire sale because investment opportunities of Starbucks are directly impaired by the natural disaster. Second, if the bonds of Starbucks and similar companies are subject to a fire sale, these companies may face lower sales and experience some layoffs. In turn, these layoffs are likely spread across the whole US, with small aggregate effects on output. By contrast, fire sales of municipal bonds affect a well defined region and are naturally concentrated in the region of the local issuer. We show that, when the muni bond issuer hit by the fire sale is not directly hit by the natural disaster, fire sales of municipal bonds have a large and causal negative impact on aggregate output in the local economy.

[11] A related literature provides an empirical connection between funding liquidity and market liquidity by using different proxies for aggregate shocks such as declines in market returns (Hameed, Kang, and Viswanathan, 2010), changes in monetary conditions (Jensen and Moorman, 2010), differences in the yields of on-the-run and off-the-run Treasury bonds (Fontaine and Garcia, 2012), and price deviations of U.S. Treasury bonds (Hu, Pan, and Wang, 2013). While the results of these papers suggest that funding liquidity drives market liquidity, the focus on aggregate shocks does not allow to isolate the mechanism at play, because aggregate shocks not only

contrast, in our setting insurance companies do not (need to) de-lever, because their performance does not take a direct hit from redemption demand due to their reinsurance activity. Therefore, in our context the transmission mechanism is fire sales by exposed insurers collectively hit by a natural disaster.

Our findings also contribute to the literature studying the interaction of finance and product market competition, e.g., Titman (1984), Brander and Lewis (1986), Maksimovic (1988), Titman and Wessels (1988), Chevalier and Scharfstein (1996), MacKay and Phillips (2005), Banerjee, Dasgupta, and Kim (2008), Ahern and Harford (2014), and Hoberg, Phillips, and Prabhala (2014). Our paper shows that in a competitive industry, when some firms experience an exogenous disruption in financing, their competitors may take advantage of it to gain market share, thereby leading to a shift in the industry equilibrium. The critical channel is the presence of financing constraints, which make the Modigliani and Miller theorem fail, as documented by a large empirical literature, e.g., Fazzari, Hubbard, and Petersen (1988), Kaplan and Zingales (1997), Whited and Wu (2006), and Hadlock and Pierce (2010). In this respect, our paper is closely related to Aslan and Kumar (2018), who show that firms exposed to a fire sale of their corporate bonds during the 2007-2009 financial crisis experience a subsequent decline in capital expenditures, R&D, acquisition activity, and also a decline in market share and price-cost margins.[12] One key issue in this literature is that (changes to) financing constraints may correlate with (changes to) investment opportunities. For example, in the context of Aslan and Kumar (2018) the fire sales of corporate bonds during the 2007-2009 financial crisis may reflect at least in part the anticipation of poor investment opportunities by the bond-issuing firms, so a remaining concern is that such omitted variables may drive at least in part the results. Our paper presents a setting where an exogenous shock to the cost of external financing generates financial constraints that are credibly orthogonal to investment opportunities (for examples of a similar logic used in other settings, see Lamont (1997) and Rauh (2006), among others). Ge (2021) studies a setting in which shocks to P&C divisions of insurance companies trigger a change in the pricing of weather and life insurance products to generate more liquid resources and overcome financial constraints (see also Ge

affect market liquidity directly but also bring about fire sales and information asymmetries, which also drive market liquidity.

[12] Aslan and Kumar (2018) do not examine whether exposed firms also suffer a decline in external financing; and do not examine whether firms' decline in capital expenditures have an impact on aggregate output.

and Weisbach 2021). Relative to this literature, our focus on hospitals has the additional advantage of holding the investment opportunity fixed. In our data, many private hospitals are located within a few blocks of the financially affected public hospitals, which implies that the investment opportunity we are considering is a new hospital building in a given block. Our experiment determines whether such new buildings are built by public or private hospitals as a function of the relative cost of external financing.[13]

Thus, our findings also inform a literature that has studied the determinants and implications of public versus private provision of goods and services. Hart, Shleifer, and Vishny (1997) point out that private contractors may have too strong an incentive to reduce costs because they do not internalize the adverse effects of cost reduction on non-contractible non-price terms such as quality of service.[14] In the discussion of public versus private health care, the pervasive concern is that private hospitals would find ways to save money by reducing the quality of care or turning away the very sick and expensive-to-treat patients. These concerns may extend to the differential availability of abortion procedures in public versus private hospitals, as documented, for example, by Hill, Slusky, and Ginther (2019). Our results imply that relatively transient financial market conditions and differences in the cost of public versus private capital may have lasting social effects and determine whether a given hospital asset ends up under private or public ownership.

Our estimate of a substitution coefficient of 0.9 between private and public investment is in line with the estimates reported in a recent macro literature on cross-sectional fiscal spending multipliers (e.g., Nakamura and Steinsson, 2014; see Chodorow-Reich, 2019 for a review), but the interpretation is very different. In macro models, increases in government spending g, $dg > 0$, make the interest rate, r, go up, which crowds out private spending. Crucially, in these papers the interest rate r is the same for both public and private borrowers.[15] By contrast, in our setting borrowers face different interest rates, and an

[13] Adelino, Lewellen, and Sundaram (2015) study how hospitals' investment responds to an exogenous shock to the hospitals' internally generated cash flow. Rossi and Yun (2019) study how municipal bankruptcy reform affects hospital investment. These papers do not examine how insurance companies' trading or fire sales of financial assets affect hospital investment. Conversely, Yi (2020) shows that shocks to the supply of municipal credit affect local public goods provision and resident migration.

[14] Consistent with this view, Karpoff (2001) shows that privately sponsored Arctic explorations had greater success through organizational efficiency of adapting to new information and better incentive structure than government-sponsored teams.

[15] Nakamura and Svensson (2014) and the other empirical macro papers referenced in Chodorow-Reich (2019) typically estimate a "fiscal multiplier," $m = dy/dg$, which in turn can reflect a substitution effect and/or a wealth

asymmetric shock makes the cost of capital go up for public borrowers but not for private borrowers. Furthermore, whereas macro papers are often interested in wealth effects, in our setting we are purely interested in the substitution effect of private for public investment, as put forward in models of product market competition and finance, and in models of public vs private asset ownership.

II. DATA

We compile our data from multiple sources. Section II.A discusses insurer-level data. Section II.B discusses municipal bond data. Section II.C discusses the Katrina disaster data, Section II.D discusses hospital data, Section II.E discusses aggregate data on output and unemployment, and Section II.F presents summary statistics.

A. Insurer-Level Data

We obtain quarterly balance sheet and financial information for insurance companies from the National Association of Insurance Commissioners (NAIC), the standard-setting and regulatory support organization for the U.S. insurance industry. We focus on individual stock/mutual type insurance companies and exclude other types of insurers, including reinsurers, Lloyd's, risk-retention groups, and pure insurance holding companies. We also eliminate insurance companies with a negative value for direct premium written, direct premium earned, total assets, policyholder surplus, or investment positions. Such insurance companies are not viable operating entities but are present in the NAIC database for regulatory purposes such as the resolution of insolvencies. We obtain the necessary information from NAIC and estimate two ratios for insurance companies: loss ratio and insurer liability ratio. Loss ratio is the ratio of change in loss incurred to direct premium

effect. Then, these papers test the hypotheses: (1) $m = 0$, as under Ricardian equivalence, e.g., Barro (1974); (2) $m > 0$ but "small," e.g., $m < 0.5$ as in simple versions of neoclassical models à la Baxter and King (1993); (3) $m > 0$ but "large," as for example in Neo-Keynesian models whereby at zero lower bounds the fiscal stimulus lowers real interest rates by raising inflation, as in Eggertsson (2010) and Christiano et al (2011); and (4) $m > 0$ entirely due to wealth effects, as in open economy models with fixed r, e.g., see Obstfeldt and Rogoff (1995). On a different note, Adelino et al. (2017) consider how an exogenous municipal credit rating upgrade determines a decrease in the cost of public (but not private) funds, triggering an increase in GDP and an improvement in local economic conditions.

written. Loss incurred includes actual claims and actuarial expected claims. Direct premium written is the income earned by an insurer. Insurer liability ratio is the ratio of total liability to total equity. The total liability of an insurer includes all unpaid losses claimed by policyholders and other short-term and long-term debt. We trim the loss ratio and insurer liability ratio at zero and one.

For each insurer-quarter, NAIC also reports how much insurance premium intake and incurred losses the insurer has in each of the 50 US states. This enables us to observe and estimate for a given insurance company its state-quarter loss incurred and direct insurance premium written. Taking advantage of this data, we estimate both geographical and monetary measures of Hurricane Katrina exposure. Over the six quarters following Hurricane Katrina (2005Q3-Q4 and 2006Q1-Q4), we estimate the quarterly state-level loss ratio for the states of Louisiana, Mississippi, and Alabama. The geographical measure KatrinaRegion equals one if the estimated loss ratio is greater than zero, and zero otherwise. To estimate the monetary measures RBCExposure and RBCDummy, we use the average state-quarter direct premium written in the affected states (i.e., Louisiana, Mississippi, and Alabama) before Hurricane Katrina (i.e., 2005Q1 and 2005Q2). RBCExposure is the estimated average state-quarter direct premium written. RBCDummy equals one when RBCExposure is greater than the median (zero) of RBCExposure, and zero otherwise. We winsorize the RBCExposure variable at the 1st and 99th percentiles.

From NAIC we also compile data on total reinsurance activity at the insurer-quarter level. We define reinsurance as the premiums ceded to reinsurers, computed as a percent of the sum of all of the insurer's premiums written or otherwise assumed. We winsorize these variables at the 1st and 99th percentiles.

B. Municipal Bond Data

We obtain municipal bond information from NAIC, the Municipal Securities Rulemaking Board (MSRB), and the Mergent Municipal Bond (BondViewer) database. NAIC classifies insurers' bond holdings into three general categories: government bonds, corporate bonds, and state bonds. The NAIC's definition of state bonds is potentially misleading because it includes asset-backed securities and other non-straight bonds, and also sometimes misclassifies bonds. To reliably identify municipal bonds, we supplement NAIC data with data from the Municipal Securities Rulemaking Board (MSRB). MSRB has overseen a mandatory transaction-reporting regime since 1997 and now it reports all dealer-to-dealer and dealer-to-customer municipal bond transaction information, including the date of each trade and the issuance date, maturity, and CUSIP codes of each security. We use the information from MSRB to cross check with NAIC to identify municipal bonds.

Once we have identified municipal bonds, we obtain from NAIC quarterly municipal bond holdings and all municipal bond transactions within a quarter for a given insurance company over 2001-2009. We observe the identity of buyers and sellers, the bonds traded, the transaction date and price, and trading volume (in $million par value). To clean the municipal bond transaction data, we first eliminate all data errors (negative/missing prices/par values) and all bonds with missing or incorrect CUSIPs. We then manually eliminate all transactions in which no counterparties are involved in the secondary municipal bond market (e.g., pay down, matured, called, canceled, put, redeemed, etc.). Finally, we estimate insurer-quarter net sales of municipal bonds by deducting total purchases from total sales volume (in $million par value). The net sale is then winsorized at the 1st and 99th percentiles. MSRB provides municipal bond characteristic information, including the state that issues the municipal bond, issuers' names, backers' names, bond description, bond identification, issue size, offer date, maturity date, and bond rating. We use the issue size and maturity date as control variables. We use the issuers' names and backers' name to identify the county of issuers and conduit bond issuers, respectively. Moreover, MSRB also provides municipal bond capital purposes and uses of proceeds, from which we can identify municipal bonds that are issued for hospital purposes only.

C. *Katrina Disaster Data*

We obtain information about Hurricane Katrina from the Spatial Hazard and Loss Database for the United States (SHELDUS) maintained by the University of South Carolina. The database provides county-level information on natural disasters, including hazard identification, hazard beginning and ending dates, hazard type (e.g., hurricane, flood, tornado), county code, county name, state code, and inflation-adjusted property damage. Figure 1 presents the map of disaster counties, indicating those requiring full federal assistance and distinguishing between individual and public assistance. We aggregate the county-level property damage to state-quarter level and confirm in Figure 2 that Louisiana, Mississippi, and Alabama are the three states affected by Hurricane Katrina, and heavily so.

D. *Hospital Data*

We obtain hospital data from the Centers for Medicare & Medicaid Services (CMS) through NBER's Healthcare Cost Report Information System (HCRIS). The CMS database provides hospital-year information, including hospital names, hospital addresses, hospital type (i.e., public/private), total capital expenditure, capital expenditure in building, capital expenditure in equipment, and total assets. Private hospitals may issue municipal conduit bonds to obtain access to municipal financing (this channel is studied in Rossi and Yun, (2019)). To identify and drop conduit bonds, we manually search private hospital names from the backers' names of municipal bonds in the Mergent Municipal Bond (BondViewer) database. We identify and drop 67 private hospitals that issued conduit bonds. We then estimate county-year municipal (non-conduit) bond issuance for hospital purposes. To identify counties that issued municipal bonds, we manually check issuers' names. For example, "Erie Cnty Indl Dev Agy Civic Fac Rev" is a bond issued by Erie County in New York state. If a public hospital is located in the county that has issued municipal (non-conduit) bonds for hospital purposes from 2000 to 2005, we assume that this hospital has relied on municipal financing and PubHMuni will equal one for such hospital and zero otherwise. To further increase our confidence in having credibly identified public hospitals that indeed issued municipal (non-conduit) bonds during 2000-2005, we also manually search public hospital names from news articles, hospital financial reports, and other related documents maintained by counties and states that explicitly state that the hospital has indeed relied on municipal financing. We identify seven such public hospitals in New York state. PubHMuni2 equals one for these seven hospitals and zero otherwise.

To measure public hospital financing, we consider three proxies: the county-hospital-year bond issuance, the county-hospital-year bond issuance scaled by hospital beginning-of-year assets, and the issuance scaled by total hospital capital expenditure in the previous year.

We match county-year issuance to hospitals by using the county where the hospital is located. Moreover, to measure hospital investment, we use capital expenditure scaled by beginning-of-year total assets. We further partition the hospital's investments into investment in buildings (i.e., capital expenditure on building scaled by beginning-of-year assets) and investment in equipment (i.e., capital expenditure on equipment scaled by beginning-of-year assets). We winsorize the investment variables at the 1st and 99th percentiles.

From the point of view of patients, a potentially immediate substitute for a public hospital is likely to be a private hospital located nearby. As a result, the inverse of the distance between two hospitals is likely to be a proxy for the substitutability of the two hospitals from the point of view of patients. To measure the geographical distance between private and public hospitals, we consider public hospitals located in a county that has issued municipal (non-conduit) bonds during 2000-2005, i.e., hospitals such that PubHMuni=1. To measure the distance between private and public hospitals, we use the addresses of the hospitals to search for longitude and latitude in Google Maps. Using these coordinates, we are then able to measure the distances (in miles) between a given private hospital and all qualified public hospitals (i.e., those in which PubHMuni=1). For a given private hospital, we record the shortest distance between it and a public hospital in which PubHMuni=1. Finally, we calculate the average of the shortest distances for all private hospitals. We define a given private hospital to be in the neighborhood of a qualified public hospital if its "shortest distance" is below that average. We then set PrvHNeibr equal to one for these neighbor private hospitals; it is zero otherwise. PrvHNeibr2 equals one if the private hospital is located in the neighborhood of a public hospital whose PubHMuni2 equals one, i.e., the public hospitals we believe have issued municipal (non-conduit) bonds during 2000-2005. As alternative measures to PrvHNeibr and PrvHNeibr2, we also estimate LogCloseness as the natural logarithm of one divided by the shortest distance measured for PrvhNeibr, and LogCloseness2 as the natural logarithm of one divided by the shortest distance measured for PrvhNeibr2.

E. Aggregate Data on Output and Unemployment

Our primary measure of state output is the GDP by state measure constructed by the US Bureau of Economic Analysis (BEA), which is available since 1963. We use the Bureau of Labor

Statistics (BLS) payroll survey from the Current Employment Statistics (CES) program to measure state-level employment.

F. Summary Statistics

Table A1 in the Appendix describe all variables used in our analysis and Table 1 provides summary statistics. At the insurer-quarter level, we have data on 1,068 insurers (who held more than 10% municipal bond holding at the end of 2004) over 40 quarters from 2001 to 2009, for a total of 34,438 insurer-quarter observations (denoted as the full sample). Given our focus on insurers' net sale of New York municipal bond, we also consider a subset of directly relevant insurers who actively held New York municipal bond prior to Katrina (denoted as the focused sample). There are 195 insurers who held more than 3% of New York municipal bond at the end of 2004: a total of 6,230 insurer-quarter observations in the focused sample. In the full sample, the average loss ratio is 3.28% (3.45% in the focused sample), reflecting a highly skewed distribution whereby the 75th percentile is zero and the maximum loss ratio is 79.10% (same in the focused sample). The average loss dummy is 0.14 (0.11 in the focused sample), implying that 14% of the observations have a positive loss ratio after 2005Q3. The average of KatrinaRegion is 0.17 (0.14 in the focused sample), implying that 17% of the observations in the sample of insurers have high ex-post exposure to Hurricane Katrina. The average RBCExposure, i.e., the average state-quarter direct insurance premium written for the states of Louisiana, Mississippi, and Alabama for 2005Q1 and 2005Q2, is $1.19 million ($0.7 million in the focused sample).[16] In turn, the average RBCDummy is 0.35 (0.32 in the focused sample), implying that about half of the observations of insurers have high ex-ante exposure to Hurricane Katrina.

Reinsurance activity is widespread. On average, property insurers reinsure 40% of all premiums directly written or otherwise assumed. More than 80% of all property insurers

[16] While this might seem a small number, it should be noted that it is measured as the average across the over 1000 insurers in our sample. In the population of 2500 insurers, the average direct premium written is around $1.8 million (see https://www.iii.org/table-archive/21113). Consistent with our data, it implies a total insurance premium written for the P/C sector of about $430 billion annually. In turn, $430 billion annually imply an average quarterly premium across insurers of about $0.78 million, which is close to the estimate in our sample.

engage in reinsurance. Average reinsurance is about 3% of assets, and the median insurer reinsures about 30% of all their premiums.

Average trading volume for New York municipal bonds is $10.84 million with $1.243 billion as the maximum. Average time-to-maturity is 1.95 years with a maximum of 40.17 years. The insurer liability ratio is 1.72% with a maximum of 49.66%. This is consistent with prior insurance literature, e.g., Elango et al. (2008) and He and Sommer (2011).

At the public-hospital-year level, we have data on 37 public hospitals over 1999-2012, for a total of 406 observations for capital expenditures and 417 observations for financing. The average PubHMuni is 0.52, implying that 52% of the hospital-year observations pertain to those public hospitals that relied on municipal bond financing (affected public hospital henceforth) over 2000-2005. The corresponding figure for PubHMuni2, i.e., the more restrictive definition of muni-bond-financed public hospitals, is 0.34. Average investment is 7% of lagged assets, which decomposes into 6% for building expenditures and 1% for equipment expenditures.

At the private hospital-year level, we have data on 171 private hospitals over the period of 1999-2012, for a total of 1,890 observations. The averages of PrvHNeibr and PrvHNeibr2 are 0.47 and 0.48 respectively, implying that about half of the private-hospital-year observations relate to private hospitals located in the neighborhood of an affected public hospital. The average investment for private hospitals is 22% of lagged assets, which decomposes into 15% for hospital building and 7% for hospital equipment.

In terms of distance, the averages for Closeness and Closeness2 are 0.20 and 0.18 respectively, which imply distances of 5.00 miles and 5.56 miles respectively. In economic terms, the minimum distance is 0.13 miles, which is less than one block in Manhattan.

In terms of macro variables, we report our three aggregate variables of insurers' trades. Our first variable, disaster-driven aggregate sales of disaster-unaffected bonds by exposed insurers (our $\text{Sales}_{i,s\neq i,t}$ index, discussed more formally below) has a median (and 85th percentile) of zero, as well as an average of $0.01 billion with relatively large standard deviation ($0.05 billion). Our second variable, disaster-driven aggregate purchases of disaster-unaffected bonds by exposed insurers (our $\text{Purchases}_{i,s\neq i,t}$ index, discussed more formally below) has similar statistics to the prior sales variable with an average of $0.01 billion and a large standard deviation of $0.06 billion. Finally, disaster-driven aggregate trades of disaster-affected bonds by exposed insurers (our $\mathrm{AT}_{i,s=i,t}$ index, discussed more formally below) has an average of –$0.02 billion with a standard deviation of $0.15 billion.

Furthermore, average GDP growth rate is 2.24% with a standard deviation of 3.17%, while average unemployment growth rate is 0.41% with a standard deviation of 1.15%.

Panel B shows portfolio holdings (percent) and dollar amount ($billion) by major asset types for insurers affected by Hurricane Katrina at the end of 2004. Prior to Hurricane Katrina (end of 2004), affected insurers had $145.4 billion, among which only $21.2 billion (14.57%) was held in cash and was not sufficiently large to meet redemption demand due to Hurricane Katrina ($40 billion). As a result, affected insurers also sold non-cash assets, in particular, municipal bonds (19.56% or $28.4 billion), to meet redemption demands. Panel C shows net sales activities of municipal bond for top and bottom five states around Hurricane Katrina. Prior to Hurricane Katrina, the net sales amount of municipal bond by affected insurers are similar to those of unaffected insurers. In contrast, the largest net sales of municipal bond (NY) by affected insurers are substantially larger ($1,529.54) than the next largest state ($569.97 for CA) by affected insurers, as well as those by unaffected insurers (top state of net sales by unaffected insurer is LA with $171.43). Overall, Panels B and C show that insurers affected by Hurricane Katrina held large amounts of municipal bonds and sold disproportionately large amounts of NY bond to meet redemption demand after Hurricane Katrina. The choice of which asset class to sell (i.e., whether munis, treasuries, or corporate), and of which assets to sell in a given class (i.e., whether NY, GA, or other bonds) likely reflects a trade-off between a desire to sell liquid, high quality bonds on the one hand and regulatory constraints to hold a given fraction of safe assets at all times on the other hand. In fact, NAIC regulations on the riskiness and quality of insurers portfolio (e.g., MDL-283, Investments of Insurers Model Act) requires insurers to retain at all times a sufficient portion of liquid assets such as treasuries, which likely influences the insurers' choice of which assets to dispose of in a fire sale.[17]

[17] The ratings of the muni bonds subject to fire sales are in general very high and stable during the periods around natural disasters, e.g., GA bonds have been AAA rated and NY bonds have been AA rated throughout our sample period, and if anything DC bonds have been steadily upgraded throughout our sample period all the way up to AA–.

III. RESULTS

In Section III.A we examine the aggregate effects of disaster-driven net sales by exposed insurers on GDP growth and unemployment. In the following sections, we decompose the aggregate effects into its components, and we illustrate the channels at play by focusing first on the largest disaster, the Katrina hurricane. In Section III.B we report results on insurance companies' losses following Katrina and on the net sales of NY municipal bonds by insurance companies. In Section III.C we document the fire sales of NY municipal bonds following Katrina. In Section III.D we examine public hospital financing, and in Section III.E we examine public hospital investment around Katrina by affected and unaffected public hospitals. In Section III.F we examine private hospital investment. In Section III.G we re-examine public and private hospital investment using predicted Katrina-driven net sales by exposed insurers as our instrument. In Section III.H we examine results on all natural disasters in the US over 2000-2010.

A. Effects of Disaster-Driven Insurers' Sales on Aggregate Output and Unemployment

We begin by establishing whether the insurers' sales of municipal bonds around natural disasters have a causal effect on aggregate output and unemployment. First, for all insurers j we define the aggregate trades $\mathrm{AT}_{i,s\neq i,t}$ of a bond of region i, with $s \neq i$, in year t as

$$\mathrm{AT}_{i,s\neq i,t} = \sum_j \left(X_{i,j,t} - X_{i,j,t+1}\right) \cdot \mathbf{1}_{j,s\neq i,t}$$

where $X_{i,j,t}$ is the holding by insurer j of a bond of region i in year t, s indicates a disaster region, and $\mathbf{1}_{j,s\neq i,t}$ is an indicator variable that equals 1 if insurer j was exposed to a natural disaster in region $s \neq i$ in year t. Next, we decompose this index into its components, $\mathrm{Sales}_{i,s,t}$ and $\mathrm{Purchases}_{i,s,t}$, as follows

$$\left|AT_{i,s\neq i,t}\right| = \mathrm{Sales}_{i,s\neq i,t} + \mathrm{Purchases}_{i,s\neq i,t}$$

where

$$\mathrm{Sales}_{i,s\neq i,t} = \mathrm{AT}_{i,s\neq i,t} \cdot \mathbf{1}_{\mathrm{AT}_{i,s\neq i,t}<0}$$

$$\mathrm{Purchases}_{i,s\neq i,t} = \mathrm{AT}_{i,s\neq i,t} \cdot \mathbf{1}_{\mathrm{AT}_{i,s\neq i,t}\geq 0}$$

where $\mathbf{1}_{\mathrm{AT}_{i,s\neq i,t}<0}$ (re., $\mathbf{1}_{\mathrm{AT}_{i,s\neq i,t}\geq 0}$) is an indicator variable that equals 1 if $\mathrm{AT}_{i,s\neq i,t} < 0$, i.e., it is an aggregate sale (re., $\mathrm{AT}_{i,s\neq i,t} \geq 0$, i.e., it is an aggregate purchase) and 0 otherwise.

For completeness, for all insurers j we also define the aggregate trades $\mathrm{AT}_{i,s=i,t}$ of a bond of region i affected by disaster s, with $s = i$, in year t as

$$\mathrm{AT}_{i,s=i,t} = \sum_{j} \left(X_{i,j,t} - X_{i,j,t+1} \right) \cdot \mathbf{1}_{j,s=i,t}$$

Then, we run a regression:

$$\frac{Y_{i,t+k} - Y_{i,t}}{Y_{i,t}} = \alpha_i + \beta_t + \gamma \cdot \mathrm{Sales}_{i,s\neq i,t} + \delta \cdot \mathrm{Purchases}_{i,s\neq i,t} + \theta \cdot \mathrm{AT}_{i,s=i,t} + \varepsilon_{i,t}$$

where $Y_{i,t}$ is the real GDP (re. aggregate unemployment) in region i in year t, $x_{i,t}$ is a disaster-driven insurance fire sale of region i's muni bonds, and α_i is region i's fixed effect, β_t is year t's fixed effect, and $k \in \{1,2\}$. Region fixed effects control for all time-invariant differences among regions that may be spuriously associated with aggregate insurers' sales. Year fixed effects control for all region-invariant, nationwide macroeconomic shocks.

To illustrate how our identification works, consider the case of insurers trades before and after Katrina hit Louisiana, as described in the statistics reported in Table 1C. Table 1C shows that insurers not exposed to Katrina sold disproportionately Louisiana bonds. These sales are likely a reflection of Katrina hitting Louisiana and directly knocking down the local economy, impairing its investment opportunities. These sales of Louisiana bonds following Katrina are thus endogenous to the disaster, and are picked up by our index $\mathrm{AT}_{i,s=i,t}$. On the other hand, insurers exposed to Katrina also sold New York bonds, California bonds, Iowa bonds, Virginia bonds, Florida bonds, among others. All these sales in unaffected states are picked up in the computation of our $\mathrm{Sales}_{i,s\neq i,t}$ index. Additionally, in the process of rebalancing their portfolio, we also observe some aggregate purchases (although usually smaller than the previously described sales in absolute value) by insurers exposed to Katrina who purchase bonds of Georgia, Massachusetts, Michigan, Arizona, and Wisconsin bonds. These purchases are picked up in our $\mathrm{Purchases}_{i,s\neq i,t}$ index. This same procedure is then repeated for all insurers' trades around all natural disasters. Interestingly, there are different exposed insurers at each disasters, and aggregate sales (and purchases) of different bonds.

For example, after Gustav and Ike disasters the largest sales by exposed insurers involve Georgia bonds, and so on.

As a result, our $\text{Sales}_{i,s\neq i,t}$ index allows us to estimate the causal effect of insurers' sales on aggregate output to the extent that these disasters (and the subsequent disaster-driven bond sales) are orthogonal to the future investment opportunities of the issuer of the bonds. That is, our exclusion restriction is that the Katrina hurricane affects the NY state economy only through the aggregate sales of NY bonds by Katrina-exposed insurers; the Katrina hurricane affects the California state economy only through the aggregate sales of California bonds by Katrina-exposed insurers; the Gustav and Ike hurricanes affect the Georgia economy only through the aggregate sales of Georgia bonds by Gustav- and Ike-exposed insurers; and so on and so forth. This restriction is plausible, most naturally due to the geographic location of these states.

Therefore, our main coefficient of interest, γ, picks up the causal effect of insurers' aggregate sales and not any direct macroeconomic effects of the natural disasters that apply equally to all regions at the same time. Furthermore, coefficient δ picks up the (causal) effect of aggregate net purchases of exposed insurers to a disaster in region $s \neq i$, because it is in principle possible that a "fire purchase" of bonds of some region i may trigger a positive shock to the cost of capital of the bond of region i, leading to increases in bond issuance and increases in aggregate output in region i. Finally, coefficient θ picks ups the (endogenous) effect of aggregate trades of bonds of disaster-hit regions, such as aggregate trades of Louisiana bonds following Katrina, and so on.

We report our results in Table 2. We find that a $1bn of $\text{Sales}_{i,s\neq i,t}$, the aggregate sales driven by a disaster in region s in a given year of a bond issued by region i, with $s \neq i$, results in a 9.2% lower GDP growth and a 1.9% higher unemployment rate over the following two years in that same state i. Our R-squared are between 53% and 58% in GDP growth regressions, and between 74% and 80% in unemployment regressions. We conclude that disaster-driven bond sales by exposed insurers have large adverse effects on the local economy by causing a large decrease in aggregate output and a large increase in unemployment.

We also document the negative and significant (endogenous) correlation between sales of bonds of region i, with $s = i$, and subsequent aggregate output. Insurers exposed to a disaster also sell bonds issued by the same region, and that same region experiences a decrease in aggregate output, likely driven by the disaster itself. While such decrease in output is also large, interestingly, its magnitude is much smaller than that found above on exogenous fire sales of bonds issued by unaffected regions. Finally, we find that aggregate purchases of bonds have zero effect on subsequent output.

In the following sections, we decompose these aggregate results into their components, by examining each disaster in isolation and by documenting whether the aggregate sales following each disaster are indeed fire sales, and whether they have real effects on local investment using micro data. For illustration, we begin by examining the Katrina disaster, the NY bond sales, and the NY state economy following Katrina in detail. In the Online Appendix C, we report our analysis on each of the other disasters in isolation. We then conclude the paper by examining all disaster together using micro data.

B. Katrina, Insurers' Losses, and Insurers' Net Sales of NY Bonds

We now examine the quarterly trades in NY muni bonds by insurers exposed to Katrina relative to other insurers, where Katrina exposure is defined as conducting business in Mississippi, Louisiana, or Alabama by the end of June 2005. Our data shows that insurers sell a lot of municipal bonds following natural disasters.[18] Figure 3 presents our basic finding. Prior to Katrina (t=0), both exposed and unexposed insurers behave very similarly, starting from two years prior to Katrina, i.e., quarter t-8. There is some cyclical rebalancing, involving small net sales in quarters t-7, t-3, and t-4, and larger net purchases in the other quarters, and these rebalancing cycles are almost identical for exposed and not exposed insurers. Then, in the quarter right after Katrina there is a large spike in net sales of NY bonds by exposed insurers, while not exposed insurers make a small net purchase of NY bonds, and these net sales by exposed insurers last for about three quarters. After that, exposed and unexposed insurers restart behaving very similarly with respect to the net sales/purchases of NY bonds.

[18] Ge and Weisbach (2021) show an example of insurers' portfolio decision based on their financial conditions.

We move next to a regression framework to examine more formally whether Katrina was indeed the exogenous shock prompting exposed insurers to suffer unexpected losses, which in turn triggered the sale of NY bonds. First, we examine the extent to which the Katrina disaster caused unexpected losses to exposed insurance companies. We estimate:

$$\begin{aligned}\text{Loss}_{i,t} = \beta_0 &+ \beta_1 \text{Katrina Exposure}_i * \text{Post-Katrina}_t + \beta_2 \text{Katrina Exposure}_i \\ &+ \beta_3 \text{Post-Katrina}_t + \beta_4 \text{X}_{i,t} + \beta_5 \text{X}_{i,t} * \text{Post-Katrina}_t + \beta_6 \text{X}_{i,t} \\ &* \text{Katrina Exposure}_i + \sum_i \text{Insurer}_i + \sum_t \text{Year Quarter}_t + \epsilon_{i,t} \quad (1)\end{aligned}$$

We begin by examining as a dependent variable the loss ratio, direct loss incurred divided by direct premium written, and by using a geographic definition of Katrina Exposure, that is, whether insurers had exposure to property located in the states of Louisiana, Mississippi, and Alabama. In Appendix B, we also show results (Table 2A) using an alternative measure, loss dummy, which is one if an insurer incurred losses due to Katrina and zero otherwise. The coefficient of interest is β_1, which we expect to take on positive values under the hypothesis that the Katrina disaster increased the losses of affected insurers relative to unaffected insurers. We report the results in Table 3, Panel A. We find that affected insurance companies experience a 14.8% (full sample) to 15.0% (focused sample) increase in their loss ratio (which is 1.35 to 1.37 times the full/focused sample standard deviation) relative to unaffected insurers. In the baseline regression of column (1) without fixed effects, the F-statistic is 205.69, and the p-values of our instrument is 0.00, which indicates that our instrument is unlikely to be weak.[19] We perform a large number of robustness tests. We add insurer and time fixed effects, and we control for reinsurance activity, issuer size and liability ratio. Strikingly, our point estimates are not affected by the inclusion of these controls, supporting the notion that ex ante exposure to Katrina is ‘as good as randomly assigned’. We find similar results also if we study an indicator dummy for positive losses as the dependent variable (Table B1 of Appendix B).

[19] This is true both relative to the critical values provided by Stock and Yogo (2005), as well as for the much more stringent ones provided recently by Lee, McCrary, Moreira, and Porter (2020).

Next, we wish to establish whether the Katrina-caused losses of exposed insurers led those insurers to sell their holdings of NY municipal bonds. Therefore, in the second stage we estimate:

$$\text{Net Sales}_{i,t} = \beta_0 + \beta_1 \widehat{\text{Loss}}_{i,t} + \beta_2 \text{X}_{i,t} + +\beta_3 \text{X}_{i,t} * \text{Post-Katrina}_t + \beta_4 \text{X}_{i,t} * \text{Katrina Exposure}_i + \sum_i \text{Insurer}_i + \sum_t \text{Year Quarter}_t + \epsilon_{i,t} \quad (2)$$

We report the results in Table 3, Panel B. We find that the instrumented loss ratio is strongly positively correlated with net sales in NY municipal bonds. The first stage regression indicates that insurance companies exposed to Hurricane Katrina suffered a 14.91% (15.23% for the focused sample) increase in their loss ratio. In the second stage, the increase in the loss ratio translates into a 0.072 (0.465 in the focused sample) increase in net sales per insurer per quarter. Over the 1068 insurers in the full sample (re. 195 insurers in the focused sample) and the four quarters post-disaster over which the fire sale takes place (as we document in Figures 3 and 4), these estimates imply an aggregate net sale in excess of \$3.1 billion (\$3.7 billion for the focused sample). These are large effects. Interestingly, the magnitude of these effects accounts almost entirely for the \$1.6 billion net sales of NY bonds documented over the two quarters after Katrina in Table 1 Panel C. We perform a large set of robustness tests; we add insurer and time fixed effects, and we control for the insurers' variables, such as reinsurance, size, and liability ratio, as well as for bonds' characteristics, such as time-to-maturity, and our main estimated coefficient of interest remains stable and strongly significant.

For comparison purposes, we report the OLS estimate of equation (2) in Panel C of Table 3. Relative to the OLS estimates, the IV estimates are more than three times (3.79 times for the full sample, and 3.35 times for the focused sample) as large and indicate that the impact of hurricane Katrina on the net sales of New York bond is much larger when accounting for the endogeneity of asset sales to the natural disaster.

Next, we perform a robustness test using a different, dollar-based measure of Katrina exposure: the average state-quarter insurance premium (in \$million) written for the states of Louisiana, Mississippi, and Alabama in the two quarters prior to Katrina. We report the results in Table 4 (and Table B2 in Appendix B using an alternative insurer loss measure, loss dummy). In Panel A we report estimates of equation (1), in Panel B we report 2SLS estimates of equation (2), and in Panel C we report OLS estimates of equation (2) for comparison. We find very similar results to those reported in Table 3. If anything, our results are stronger using these dollar-based measures of Katrina exposure, and the F-statistics of 356.99 (Table 4, Panel A, column1) indicates that also this IV is unlikely to be weak.

C. The Fire Sale of NY Municipal Bonds

In the previous section we documented that the Katrina disaster triggered massive net sales of NY municipal bonds by insurance companies. Now we examine whether these sales by property insurers in the aggregate caused price pressure in the market for NY municipal bonds.

To do so, we compute monthly percent Cumulative Average Abnormal Returns for NY municipal bonds over a t-8 to t+8 window around the date of Hurricane Katrina. We use the five-factor bond model developed by Fama and French (1993) to estimate abnormal bond returns. This model includes the commonly used three factors (i.e., market risk premium, small minus big factor, and high minus low factor) and two additional factors, Term and Def. Term represents the slope of the Treasury yield curve, and Def the default premium measured as the difference between the returns on long-term corporate bond indices and long-term Treasuries. The intercept is the estimate of the abnormal bond return. We first estimate bond-level abnormal weekly returns using weekly Fama-French five factors, and then aggregate the weekly returns to get monthly abnormal returns.

Figure 4 and Table 5 report our results. The results show a large negative abnormal return of -0.92% following Katrina, which is very large for municipal bonds and indicates that a fire sale was taking place. Note that our estimates use bond returns based on daily trades to capture the most liquid segment of the NY State bond market. Other NY bonds trade less frequently (weekly or monthly).[20] Our fire sale estimate based on the most liquid muni bonds is thus likely conservative and shows that even highly liquid bonds, in principle less subject to fire sales risk, were long depressed after disaster-exposed insurers massively sold NY bonds.

[20] See Cornaggia, Hund, Nguyen (2020) on how to compute muni bond returns including illiquid bonds.

Critically, when aggregating the trades of all insurers in our sample, we find that the trades of property insurers add up to an aggregate net sale exceeding 80% of the excess supply of NY muni bonds in the two months after Katrina. Therefore, the fire sale of NY municipal bonds that we document in Figure 4 and Table 5 was overwhelmingly driven by the trades of property insurers.[21] In addition, Figure 5 shows that also the yield on the newly issued NY muni bonds in the primary market went up significantly after Katrina, at the same time as the fire sale in the secondary market we document in Figure 4 is taking place.

Interestingly, we also find that the stock price performance of insurers around Katrina is largely unaffected. Figure 6 Panel A reports daily Cumulative Average Abnormal Returns in the [-50,+50] event window around Katrina for all property insurers with at least 70 valid returns over the even window. Figure 6 Panel A shows negative but statistically insignificant CAARs for just about 15 trading days after the event; furthermore, the CAARs fully recovered shortly thereafter. To dig deeper on how the property insurers were able to withstand such a large shock, we split the sample of insurers by the extent of their reinsurance activity. Figure 6 Panel B reports our results in the high (above-median) reinsurance sample, where we find the CAAR is essentially zero even in the immediate aftermath of Katrina. Figure 6 Panel C reports our results in the low (below-median) reinsurance sample, where we find that low reinsurance insurers had negative CAARs in excess of -6% after Katrina, and they had yet to recover several months afterwards. We find similar results concerning changes in operating performance (ROA) around Katrina.

Our results indicate that reinsurance activity plays a large role in shielding the insurers' financial and operating performance from large negative shocks,[22] and further indicate that most property insurers were able to withstand even a massive shock such as Katrina.[23] At the same time, their massive portfolio rebalancing—needed to meet the

[21] We also find that the credit rating of NY municipal bonds were very stable in the two years around Katrina, again consistent with the notion that Katrina did not have direct adverse effects on the NY State economy, and in addition suggesting that no other material adverse event was taking place concurrently in NY State economy.
[22] See Koijen and Yogo (2016) for a view that (shadow) reinsurance could reduce risk-based capital and increase expected loss for the life insurance industry.
[23] To be sure, not all insurers came out equally unscathed. For example, AMBAC reported a persistent cumulative abnormal return in excess of –6% following Katrina, and was downgraded shortly thereafter. Nevertheless, our data shows that the industry as a whole did withstand the huge Katrina losses fairly well. As yet another illustration, between 2004 and 2009 only Florida-based Southern Family Insurance went bankrupt, and not because of Katrina.

unexpected redemption demands—generated ripple effects in financial markets by causing the fire sale of NY municipal bonds. In the next section we trace out the financing and investment activity of a large class of NY municipal borrowers.

D. Public Hospitals' Financing

Results from the previous sections show that there was an exogenous liquidity shock in the New York municipal bond market driven by the redemption demands faced by insurance companies exposed to the Katrina disaster.

In this section, we examine the impact of this liquidity shock on financing activities by borrowers relying on New York municipal bonds. We observe balance sheet data of public hospitals, which are major users of municipal bonds (e.g., see Rossi and Yun (2019)) and represent a large portion of NY State budget.[24] In a difference-in-differences framework, we compare relative changes in municipal bond financing around Hurricane Katrina by municipal bond reliant and non-reliant public hospitals in New York state. We estimate:

$$\begin{aligned}
\text{Public Hospital Financing}_{i,t} &= \beta_0 + \beta_1 \text{PubHMuni}_i * \text{Post Katrina}_t + \beta_2 \text{PubHMuni}_i * +\beta_3 \text{Post Katrina}_t \\
&+ \beta_4 \text{X}_{i,t} + \beta_5 \text{X}_{i,t} * \text{Post Katrina}_t + \beta_6 \text{X}_{i,t} * \text{PubHMuni}_i + \sum_i \text{Hospital}_i \\
&+ \sum_t \text{Year}_t + \epsilon_{i,t}
\end{aligned}$$

The dependent variable is the amount of public hospital financing, measured in three different ways. We identify the county of a given public hospital and estimate the dollar amount at the county-year level of total municipal (non-conduit) bond issuance for hospital purposes. We then take the natural logarithm of the dollar issuance. In Appendix B (Table B3), we also report results using alternative measures: in Panel A we scale the county-hospital

[24] We do not observe balance sheet data on other muni borrowers such as universities, so it is likely that our micro-level results understate the extent to which insurance companies propagate natural disaster shocks to the real economy. In fact, Table 2 documents large aggregate effects of disaster-driven bond sales by exposed insurers on aggregate output and unemployment.

issuance by beginning-of-year total assets, and in Panel B we scale it by beginning-of-year total capital expenditures.

To identify a public hospital's ex ante reliance on municipal bond issuance, we construct an indicator (PubHMuni), which equals one if the public hospital was financed with municipal bonds prior to Hurricane Karina, i.e., over 2000-2005. Equivalently, the indicator PubHMuni equals one if the hospital's municipality has issued municipal bonds *for the purpose of financing the corresponding public hospital* over the same period, 2000-2005. PubHMuni equals zero otherwise. We examine the results using PubHMuni in Columns 1 to 4 of Table 6. In Columns 5 to 8, we use an alternative indicator, PubHMuni2, which equals one if we can manually confirm, through Factiva and other news searches, that the public hospitals for which PubHMuni equals one indeed issued municipal (non-conduit) bonds over 2000-2005. This procedure is arguably very conservative, as issuing municipal (non-conduit) bonds is a common event for public hospitals, and as such wouldn't necessarily be reported by news outlets. Therefore, to the extent that we obtain similar results with PubHMuni and PubHMuni2, we are a lot more confident that we are indeed picking up public hospitals' reliance on municipal bonds for financing.

The key independent variable of interest is the interaction between the post-Katrina indicator (post-Katrina) and the municipal bond reliant public hospital indicator (PubHMuni or PubHMuni2), which captures the difference-in-differences effect of the Katrina disaster on NY state public hospitals' muni bond financing. In the full specification (Columns 3, 4, 7, and 8), we control for insurer fixed effects (Insurer FE) and year-quarter fixed effects (Time FE). Standard errors are clustered at the hospital level and are reported in parentheses.

Table 6 reports the results. In Column 1 we show that the first stage OLS-based estimate is significantly negative, and it is large in economic terms: -3.96. That is, the incremental amount of municipal bond issuance is negative for municipal bond reliant NY public hospitals relative to the non-reliant ones after Katrina. The estimate is almost identical when we control for asset growth (-3.84 in Column 2). Column 3 shows the DD estimate when including hospital and year-quarter fixed effects. Again, the DD estimate is large and significantly negative (-4.63). The implication is that the difference in municipal bond issuance between muni bond reliant and non-reliant public hospitals decreased after Hurricane Katrina. The DD estimates are similar when we control for asset growth (-4.50 in Column 4).

These effects are even stronger when we measure muni bond reliance with PubHMuni2 (-5.07 in Column 5 and -5.12 in Column 6 with asset growth control; -4.76 in Column 7 and -4.73 in Column 8 with insurer and time fixed effects), suggesting that municipal bond issuances reported in news outlets are presumably larger and as a result public hospitals where PubHMuni2 equals one are those particularly reliant on muni bond financing. Our results are stronger when we scale our dependent variable by beginning-of-period hospital assets (Panel A of Table B3 in Appendix B), and similar to Table 6, when we scale our dependent variable by lagged hospital capital expenditures (Panel B of Table B3 in Appendix B).

Overall, the impact of Katrina on the external financing of municipal-bond-reliant NY public hospitals is negative, because we find that the disaster led to a significant decrease in borrowing through NY municipal bonds.

E. Public Hospitals' Investments

In the previous section, we showed that public hospitals relying on NY municipal bonds decreased their municipal bond financing after Hurricane Katrina. While it is possible that this result is due to an increase in the cost of capital, it could also be that these public hospitals reduced municipal financing due to greater reliance on alternative financing sources. If that was the case, then we should not find an effect of Katrina on the capital expenditures of public hospitals.

To address this possibility, we examine the capital expenditure of public hospitals in the aftermath of Katrina. If the affected public hospitals were able to access alternative financing sources, we would expect them not to change their investments after Katrina. However, if their reduction in municipal financing is driven by supply side reasons, such as an increase in the costs of capital, and they were not able to access alternative financing sources, we would expect to see also a reduction in capital expenditures by these affected public hospitals.

In Table 7, we compare investments by New York public and private hospitals. Panel A shows univariate comparison for disaster affected and unaffected hospitals. For each New

York muni bond reliant public hospital (PubHMuni=1), we match the closest private hospital and compute average capex/asset six years before and five years after hurricane Katrina. Numbers are in percentage. Katrina adversely impacted investments of hospitals relying on public funds (i.e., New York municipal bonds) and led to 1.59 percent reduction in investments. In contrast, investments by matched New York private hospitals increased by 2.3 percent. Panel B shows change in investments (capital expenditures divided by total assets) relative to six-year average prior to the Hurricane Katrina.

The investment relative to pre-Katrina levels immediately decreased for New York public hospitals (e.g., 1.16% decrease in the first year, 1.34% decrease in the second year, and 1.58% decrease in the third year after the Hurricane Katrina). In contrast, investments by matched New York private hospitals increased with a significant delay (e.g., 3.14% increase in the third year, 2.68% increase in the fourth year, and 2.76% increase in the firth year after the Hurricane Katrina). Results from Panel B suggest that investments by New York public hospitals rapidly declined after their financing sources were adversely impacted by the Hurricane Katrina, whereas the investments by matched New York private hospitals increased with significant delay. In terms of aggregate economic magnitude, the increase in investment by private NY hospitals is not as large as the decline in investment public NY hospitals. [25] In what follows we examine these patterns more formally to account for potential pre-trends and for potential confounders in a regression framework.

In Figure 7 we zero in on the capital expenditures of public hospitals and examine differences in trends between affected (i.e., muni-bond-reliant) and unaffected (non-muni-bond-reliant) public hospitals, and we find no differences in trends before Katrina, and after Katrina we find that affected public hospitals cut their investment, relative to unaffected public hospitals.

Moving on to a regression framework, we use difference-in-differences (DD) estimations in a panel setting to examine the impact of Katrina on investments by public hospitals. We estimate:

[25] This is true, even if the point estimate is larger in absolute value for private hospitals relative to public hospitals, because on average NY public hospitals are much larger than private ones.

$$\text{Public Hospital Investment}_{i,t} = \beta_0 + \beta_1 \text{PubHMuni}_i * \text{Post Katrina}_t + \beta_2 \text{PubHMuni}_i * +\beta_3 \text{Post Katrina}_t + \beta_4 \text{X}_{i,t} + \beta_5 \text{X}_{i,t} * \text{Post Katrina}_t + \beta_6 \text{X}_{i,t} * \text{PubHMuni}_i + \sum_i \text{Hospital}_i + \sum_t \text{Year}_t + \epsilon_{i,t}$$

The dependent variable is capital expenditures divided by total assets for each public hospital in each year. The key independent variable is the interaction between post-Katrina and PubHMuni, which measure the difference-in-differences effect of Katrina on muni-reliant public hospitals. We control for insurer fixed effects (Insurer FE) and year-quarter fixed effects (Time FE) for model specifications (Columns 3, 4, 7, and 8). Standard errors are clustered at the hospital level.

In Panel A of Table 8, the dependent variable is total investment, i.e., hospital total capital expenditures divided by lagged assets. Column 1 shows the OLS specification, where the estimated coefficient on our key variable, the interaction of post-Katrina and PubHMuni, is -0.015 and strongly statistically significant. The estimates are similar when we control for asset growth (Column 2) and when hospital and time fixed effects are included (Columns 3 and 4). For example, the DD estimate in Column 3 is -0.015, which implies the decrease in investments (scaled by total assets) after Hurricane Katrina is 1.5% larger for public hospitals that relied on muni bonds in the pre-Katrina period than for those that did not rely on muni bonds. The DD estimates are similar when we use PubHMuni2 in Columns 5 to 8.

These findings demonstrate that the Katrina disaster did indeed represent an exogenous increase to the cost of capital for muni-reliant public hospitals, which as a result suffered a large decrease in investment.

Next, we examine whether the effect of Katrina on public hospitals' investments differs by investment type. Panel B considers investments in tangible vs. non-movable assets (hospital capex in hospital building/lag asset) and Panel C considers investments in movable assets (hospital capex in hospital equipment/lag asset). The results in Panel B show that the DD estimate for investments in non-movable assets are similar to those in Panel A (total investments). In contrast, the DD estimate for investments in movable assets such as equipment is not significantly different from zero, as shown in Panel C. That is, the adverse effect of the Katrina-driven shock to the cost of capital for affected public hospitals is concentrated in investments in tangible and non-movable assets such as buildings, whereas there are no discernible effects on movable assets such as hospital equipment.

Our identifying assumption in this section builds on our earlier results in Tables 3 and 4 showing that insurers' large net sales of NY bonds following Katrina are strongly driven by redemption demand from the Katrina-affected area. That is, property insurers with many insurance contracts in disaster areas (LA, MS, AL) prior to Katrina faced a large and unexpected redemption demand for insurance payouts, which is orthogonal to the fundamentals of the property insurers themselves, or of the NY State economy. In turn, such redemption demand leads these insurers to sell some of their liquid bond holdings, which turn out to be NY bonds. In contrast, unaffected insurers not facing such demand continue their usual portfolio rebalancing activity and buy or sell some "normal" or "average" amount of any bond, resulting in net sales (or purchases) close to zero on average, not only for NY bonds but also for all other bonds, as we document in Panel C of Table 1.

A potential concern underlying our identification strategy is the possibility that swings in the redistribution of federal funding, such as Medicare and Medicaid, away from non-disaster areas (e.g., NY) and toward disaster areas (e.g., LA) might help explain the large decrease in capital expenditures by NY public hospitals that we document, thereby violating our exclusion restriction. To address this possibility, we examine data on the federal portion of Medicare/Medicaid funding and we find it remained remarkably stable throughout the 1990s and 2000s, staying at around 50% until at least 2008 where, if anything, it increased to 60%. Furthermore, as we later show, across all non-disaster states that could potentially suffer from an adverse redistribution of federal funding, only those states affected by large disaster-driven net sales by exposed insurers experienced reduced GDP growth and higher unemployment. We conclude that swings in the redistribution of federal funding are unlikely to explain our results on hospital investment.

To sum up, the investments of NY public hospitals that rely on municipal bonds decreased significantly, and the decrease was mostly concentrated in investments in non-movable hospital buildings, whereas investments in hospital equipment remained stable after Katrina. These results already point to the possibility that the fire sale of NY bonds triggered by Katrina-exposed property insurers did have adverse aggregate effects on the NY State economy. On the other hand, it is still possible that the investment opportunities foregone by the public hospitals were picked up by their private competitors. Therefore, in the next section we examine the investment activity by private hospitals over the same period.

F. Private Hospitals' Investments

The previous sections show that the Katrina-driven liquidity shock in the New York municipal bond market led to a decrease in municipal borrowing for muni-reliant (affected) public hospitals, and to a decrease in investments in non-movable assets (buildings) by those hospitals. This section studies whether the private sector, i.e., private hospitals, stepped in to take advantage of the investment opportunities forgone by public hospitals after Katrina.

In a DD framework, we examine whether private hospitals in the neighborhoods of the affected public hospitals —increased their investments relative to private hospitals farther away from the affected public hospitals after Katrina. We estimate

$$\begin{aligned} \text{Private Hospital Investment}_{i,t} &= \beta_0 + \beta_1 \text{PrvHNeibr}_i * \text{Post Katrina}_t + \beta_2 \text{PrvHNeibr}_i * + \beta_3 \text{Post Katrina}_t \\ &+ \beta_4 \text{X}_{i,t} + \beta_5 \text{X}_{i,t} * \text{Post Katrina}_t + \beta_6 \text{X}_{i,t} * \text{PrvHNeibr}_i + \sum_i \text{Hospital}_i \\ &+ \sum_t \text{Year}_t + \epsilon_{i,t} \end{aligned}$$

The dependent variable is the same as in Table 8, capital expenditures divided by lagged assets. The key variable of interest is the interaction between the post-Katrina dummy and an indicator for a private hospital neighboring an affected public hospital (PrvHNeibr). For a given private hospital, PrvHNeibr equals one if the hospital is located in the neighborhood of a public hospital whose PubHMuni value is one.

To establish the neighborhood, we measure the distances (in miles) between a given private hospital and all NY state public hospitals, and we keep the shortest distance. Then PrvHNeibr equals one if the shortest distance is below the mean, and zero otherwise (Columns 1 to 4 of Table 9). Similarly, PrvHNeibr2 equals one if the hospital is located in the neighborhood of a public hospital whose PubHMuni2 value is one, i.e., a public hospital that we believe has issued a municipal (non-conduit) bond during 2000-2005 (Columns 5 to 8).

Appendix B (Table B4) shows results using alternative measures of PrvHNeibr and PrvHNeibr2. We use two continuous measures of distance, LogCloseness and LogCloseness2, respectively. LogCloseness is the natural logarithm of one divided by the shortest distance (in miles) used in PrvHNeibr. LogCloseness2 is the natural logarithm of one divided by the shortest distance in miles used in PrvHNeibr2. As in Table 8, we consider both OLS (Columns 1, 2, 5, and 6), and DD specifications that include hospital and year-quarter fixed effects (Columns 3, 4, 7, and 8). Standard errors are clustered at the hospital level.

Table 9 presents the results. Panel A shows results for total investments (a private hospital's total capital expenditure divided by lagged total assets). The OLS point estimate indicates that the investments of private hospitals near affected public hospitals after Katrina increased by 3.6% (16% of the sample mean). The OLS point estimate is larger when we control for asset growth, as shown in Column 2. Columns 3 and 4 report DD estimates by controlling for hospital and time fixed effects. The DD estimates are very close to the OLS estimates; the Katrina liquidity shock caused a 3.7% increase in the total investments of private hospitals near affected public hospitals. Columns 5 to 8 show the results when we repeat the analysis using a different measure of neighboring private hospitals (PrvHNeibr2), and the estimates are larger than those in Columns 1 to 4. As shown in Appendix B (Table B4), the results are also qualitatively similar when alternative continuous measures of closeness (LogCloseness and LogCloseness2) are used as shown in the second part of Panel A.

Next, we decompose the effect of Katrina on total private hospital investments and consider different types of investments. Panel B shows results for investments in non-movable assets such as hospital buildings, and Panel C shows results for investments in movable assets such as hospital equipment. Both the OLS (Columns 1 and 2) and DD (Columns 3 and 4) estimates are significant and have similar economic magnitudes. For example, the DD estimate with controls for asset growth in Column 4 is 0.029, which implies that after Katrina investments in non-movable assets such as hospital buildings (scaled by lagged assets) increased 2.9% more for private hospitals in the neighborhood of affected public hospitals than for those farther away from public hospitals. The results in Columns 5 to 8 show that the estimates are similar (or slightly larger) when a different measure of affected public hospital is used (PrvHNeibr2). Also, the results are qualitatively similar when we use continuous measures of closeness to affected public hospitals (LogCloseness and LogCloseness2) as shown in Appendix B (Panel B of Table B4). For example, in Column 8, the DD estimate on the interaction (LogCloseness2 x Post-Katrina) is 0.014, which indicates that a one standard deviation (1.49) increase in the LogCloseness2 measure causes a 2.09% increase in investments of non-movable assets, which amounts to 9.1% of the sample mean (0.23). In contrast, as shown in Panel C, investments in movable assets (scaled by lagged assets) are much smaller in economic magnitude and often insignificant in many specifications. For example, the DD estimate in Column 8 (using LogCloseness2 x Post-Katrina) is 0.004, which is much smaller than that for non-movable assets (0.01).

In Figure 8 we examine differences in trends between neighbor and distant private hospitals, and again we find no differences in trends before Katrina, indicating that pre-Katrina neighbor and distant private hospitals present parallel trends in capital expenditures. After Katrina, we find that neighbor private hospitals increase their capital expenditures relative to distant private hospitals.

In sum, private hospitals in the neighborhoods of affected NY public hospitals, that is, muni-bond reliant public hospitals that cut their investment after Katrina, increased investments, especially in non-movable assets such as hospital buildings. However, such increase in investment by private hospitals was not as large in absolute value as the decline in investment by public hospitals, and occurred with several years delay. These results again point to the possibility of Katrina-driven net sales of NY bonds by affected insurers causing a decline in aggregate output in NY State. One remaining concern is that these results may not necessarily reflect directly the workings of the fire sale of NY bonds but some other unobserved event affecting around the same time as Katrina the NY public and private hospitals in opposite directions. Therefore, in the next section we use directly as our instrument for the impact of Katrina on hospitals' investment the instrumented net sales of NY bond by Katrina-exposed property insurers.

G. *Estimating the Real Effects of Hurricane Katrina Using Predicted Net Sales*

This section estimates the impact of Hurricane Katrina (on financing and investments by public and private hospitals) directly through instrumented net sales of NY bond by insurers. The empirical specifications are similar to those used in Tables 6 (public hospital financing),

Table 8 (public hospital investments), and Table 9 (private hospital investments), except Post-Katrina indicator is replaced with *PredictedSales*, which is the sum of predicted (instrumented) net sales from Equation (2) for each year. This measures the aggregate net sales of NY bond by (affected) insurers due to Hurricane Katrina in each year. For example, the empirical specification to study the impact on municipal financing by public hospitals (who have relied and not relied on municipal bond prior to Hurricane Katrina) is

$$\text{Public Hospital Financing}_{i,t} = \beta_0 + \beta_1 \text{PubHMuni}_i * \text{PredictedSales}_t + \beta_2 \text{PubHMuni}_i * + \beta_3 \text{PredictedSales}_t + \beta_4 \text{X}_{i,t} + \sum_i \text{Hospital}_i + \sum_t \text{Year}_t + \epsilon_{i,t}.$$

Since *PubHMuni* is collinear with hospital fixed effects and *PredictedSales* is collinear with year fixed effects, both *PubHMuni* and *PredictedSales* are dropped from the regression. The parameter estimate of the interaction term ($\text{PubHMuni}_i * \text{PredictedSales}_t$) measures the differences-in-differences effect of Hurricane Katrina on municipal financing by public hospitals, which rely on municipal financing prior to Hurricane Katrina (relative to those who don't). Similarly, to study the impact of Hurricane Katrina on public hospital investments (those who rely on municipal bond prior to Katrina vs. who don't), we replace the dependent variable to public hospital-year total capital expenditure scaled by last year-end total assets. To study the impact of Hurricane Katrina on private hospital investments (those who are near muni-bond relying public hospitals and who aren't), we estimate

$$\text{Private Hospital Investment}_{i,t} = \beta_0 + \beta_1 \text{PrvHNeibr}_i * \text{PredictedSales}_t + \beta_2 \text{PrvHNeibr}_i * + \beta_3 \text{PredictedSales}_t + \beta_4 \text{X}_{i,t} + \sum_i \text{Hospital}_i + \sum_t \text{Year}_t + \epsilon_{i,t}.$$

Since *PrvHNeibr* is collinear with hospital fixed effects and *PredictedSales* is collinear with year fixed effects, both *PrvHNeibr* and *PredictedSales* are dropped from the regression.

Table 10 presents the results. In Column 1 we show results for municipal financing by public hospitals. The DD point estimate is large and statistically negative (-1.357). Consistent with findings in Table 5, the difference in municipal bond issuance between muni bond reliant and non-reliant public hospitals decreased after Hurricane Katrina (instrumented by aggregate net sales of NY bond by insurers through loss ratio induced by interaction of Post-Katrina and Katrina affected region as in Table 4). In Column 2, we obtain similar DD estimate when asset growth is included as a control variable (-1.36). Columns 3 and 4 show DD estimates for investments by public hospitals. The DD point estimates are significantly negative, which implies that the Katrina liquidity shock caused significant decrease in the total investments of public hospitals which relied on municipal financing prior to Hurricane Katrina relative those who don't. Column 5 and 6 show results for total investments by private hospitals (a private hospital's total capital expenditure divided by lagged total assets). The DD point estimates indicate that the investments of private hospitals near affected public hospitals after Katrina significantly increased relative to those who are not neat affected public hospitals.

Overall, results from Table 10 using instrumented aggregate net sales of New York bond by insurers are economically large, statistically significant and overall similar to those obtained using a simple Post-Katrina indicator as we did in Tables 6, 7, 8, and 9). These results indicate that Katrina-driven net sales by Katrina-exposed insurers caused a decline in NY public hospital investment and financing, and a corresponding increase in private hospital investment, particularly by private hospitals located nearby affected public ones. In the next section we examine to what extent our results about Katrina generalize to all natural disaster in the US over 2000-2010.

H. All Disasters

In this section, we examine the other major disasters in the US in our sample period. Table 11 reports the disasters in our sample, the quarter in which they occurred, the states affected, the municipal bonds most sold by property insurers after the disasters, the largest CAR of those bonds in the three months after the disasters, and the percent of insurers' sales relative to the excess supply of those bonds. Our results on Katrina do generalize to other disasters, and if anything, our results are even stronger for other disasters. For example, the Alison hurricane that affected Texas and Missouri resulted in DC bonds being sold, for a CAAR of –2.84%. The hurricanes Charles, Frances, Ivan, and Jeanne of 2004 resulted in Puerto Rico bonds being sold, for a CAAR of –0.91%. The hurricanes Gustav and Ike of 2008 resulted in

Georgia bonds being sold, for a CAAR of –1.28%. In this last case, our data shows that the insurers' sales pressure amounted to the entire excess supply of those bonds during the fire sale.

Table 12 reports the results from difference-in-differences (DD) estimations using all major disasters during our sample period. Specifically, Hurricanes Charley, Frances, Ivan, Jeanne in 2004 impacted PR muni bonds and hospitals; Hurricane Katrina in 2005 impacted NY muni bond and hospitals; Hurricanes Gustav, Ike in 2008 impacted GA muni bond and hospitals. In the Online Appendix C, Tables C1 to C13, we report detailed results on the loss ratio, net sales of muni bonds, public hospitals financing and investment, and private hospital investment for each separate disaster. We use post-Disaster indicator instead of a post-Katrina indicator to reflect post disaster years for corresponding states, that is, post-Disaster is one if observation is after 2004 for PR hospitals, is one if observation is after 2005 for NY hospitals, and is one if observation is after 2008 for GA hospitals. We find qualitatively similar results as is Tables 6 (municipal bond financing by public hospitals), 8 (investments by public hospitals), 9 (investments by private hospitals). For example, Columns 3 and 4 show DD estimates for investments by public hospitals for major disasters during our sample period. The DD point estimates are significantly negative (-0.048): the average liquidity shock for caused significant decrease in the total investments of public hospitals which relied on municipal financing prior to corresponding hurricane relative those who don't. In contrast, Columns 5 and 6 show that the DD estimates for investments of private hospitals are significantly positive (0.055): the investments of private hospitals near affected public hospitals after corresponding hurricane (in PR, NY, and GA) significantly increased relative to those who are not neat affected public hospitals. Overall, our results in Table 12 indicate that the substitution of investments between public and private hospitals that we documented in NY State after Katrina in the previous section does extend to the other hurricanes during our sample period in similar ways. Public hospitals cut their investment and financing; neighbor private hospitals increase their investment, although not as much as to fully make up for the decreased investment by public ones, and with several years delay. Overall, our results indicate that aggregate sales of exposed insurers following all natural disasters do translate into fire sales and do produce real effects also using micro data on investment, after the aggregate real effects we have documented at the start of the paper. In the next section we offer some concluding remarks.

IV. CONCLUSIONS

We have examined the role of insurance companies in propagating natural disaster shocks to the real economy. We find that insurance companies are able to withstand even the largest shocks thanks to their reinsurance activity. Even after the biggest natural disasters of the past decade such as hurricane Katrina and others, property insurers did not suffer a deterioration of their financial and operating performance. Nevertheless, we find that they engage in substantial portfolio rebalancing to meet the large and unexpected redemption demands following the disasters-induced property damages.

In particular, following the Katrina natural disaster, insurance companies faced a massive and unexpected demand for redemptions, which they had to meet at short notice by selling their most liquid assets, which turned out to be NY muni bonds. These sales generated price pressure in the market for NY bonds and thus caused a fire sale. In turn, the fire sale of NY bonds caused an increase in the cost of capital for public hospitals, particularly for those relying on municipal bonds, and caused a decrease in those hospitals' financing and capital expenditures, particularly on non-movable assets such as hospital buildings. Conversely, private hospitals located in the neighborhood of the affected NY public hospitals increased their own investments, especially in non-movable assets such as hospital buildings. Our findings indicate that these NY private hospitals were able, to a large extent, to take advantage of the investment opportunities forgone by their neighboring affected public hospitals. However, this public-for-private substitution was incomplete, occurred with several years delay, and was ultimately insufficient to shield the real economy from the adverse consequences of the insurers' sales. In fact, in the aggregate we find that the disaster-driven net sales of muni bonds by disaster-exposed insurers cause low subsequent GDP growth and high unemployment. These results extend to all natural disasters in the US over 2000-2010.

Our results have implications for the way to account for systemic risk. Existing measures of systemic risk (Acharya et al 2017; Adrian and Brunnermeier 2016; Engle et al 2015) record that bank capital shortfalls and bank stock prices strongly co-move with aggregate measures of stock market capitalization and performance, while insurance companies' capital shortfalls and stock prices co-move much less with aggregate measures of stock market capitalization and performance. As a result, these studies estimate banks to be major contributors to systemic risk, and insurance companies to play a more limited role. Our results imply that, even if insurance companies' performance is unaffected by adverse shocks because of the insurers' reinsurance activity, insurance companies may still fuel systemic instability via their portfolio rebalancing and aggregate sales of similar assets. As a result, aggregate measures of systemic risk may need to take into account the extent of portfolio overlap of insurance companies and their potential to trigger aggregate fire sales of financial assets even in the absence of stock price co-movement.

Finally, our results indicate that insurance companies do generate a systemic risk externality to the real economy via their asset sales. Our results suggest that the role of insurance companies in generating financial instability may become even more prominent in the future. Climate change risk and longevity risks are increasingly under the purview of insurance companies' contracts. As a result, future adverse events and realizations stemming from climate shocks and longevity risks may generate insurers' responses that further exacerbate their negative effects, thereby enhancing financial instability.

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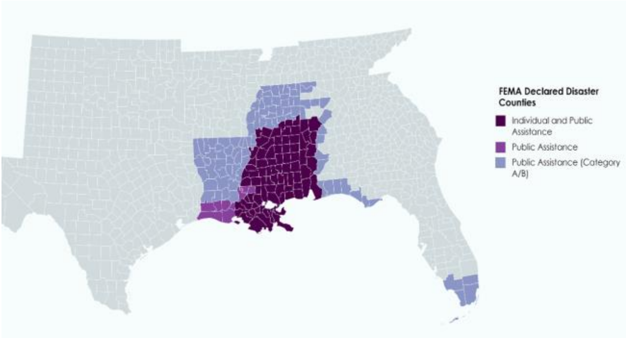


Figure 1: Disaster Counties of Hurricane Katrina

The figure presents the map of disaster counties declared by the Federal Emergency Management Agency (FEMA) after Hurricane Katrina in files DR-1602, DR-1603, DR-1604, and DR-1605. Dark purple indicates full federal assistance, including both individual and public assistance. Violet indicates public assistance while blue indicates public assistance category A/B. Individual assistance is provided by FEMA to individuals and families who have sustained losses due to disasters. Public assistance is provided by FEMA to state, local, tribal and territorial governments and certain private-non-profit organizations for emergency work and the repair or replacement of disaster-damaged facilities. Category A/B is for emergency work including debris removal and emergency protective measures. Category C-G is for permanent work including roads, bridges, public utilities, public buildings, parks, and other facilities.

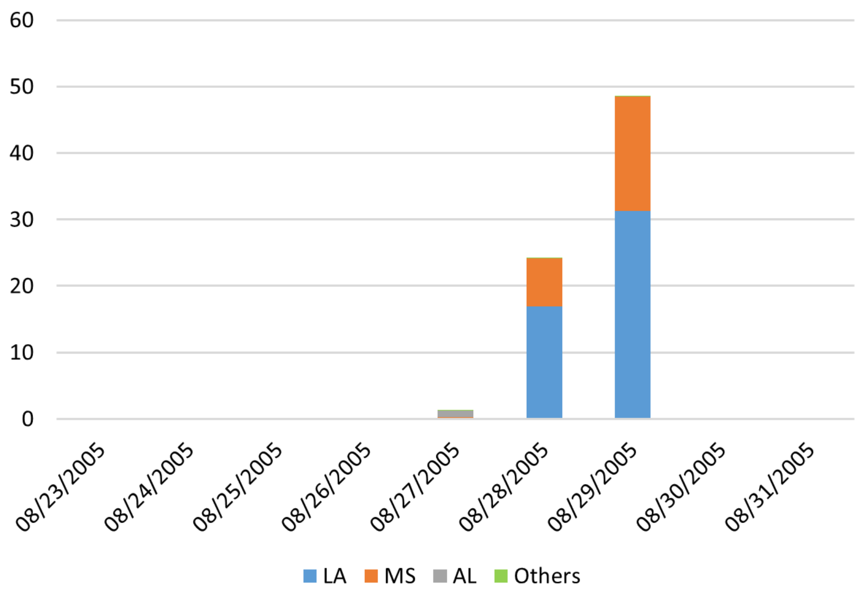


Figure 2: Property Damage in $Billion Due to Hurricane Katrina

This figure depicts the daily property damage for the period 08AUG2005-31AUG2005 reported in the Spatial Hazard Events and Losses Database (SHELDUS) at the University of South Carolina. The major disaster states are Mississippi, Louisiana, and Alabama.

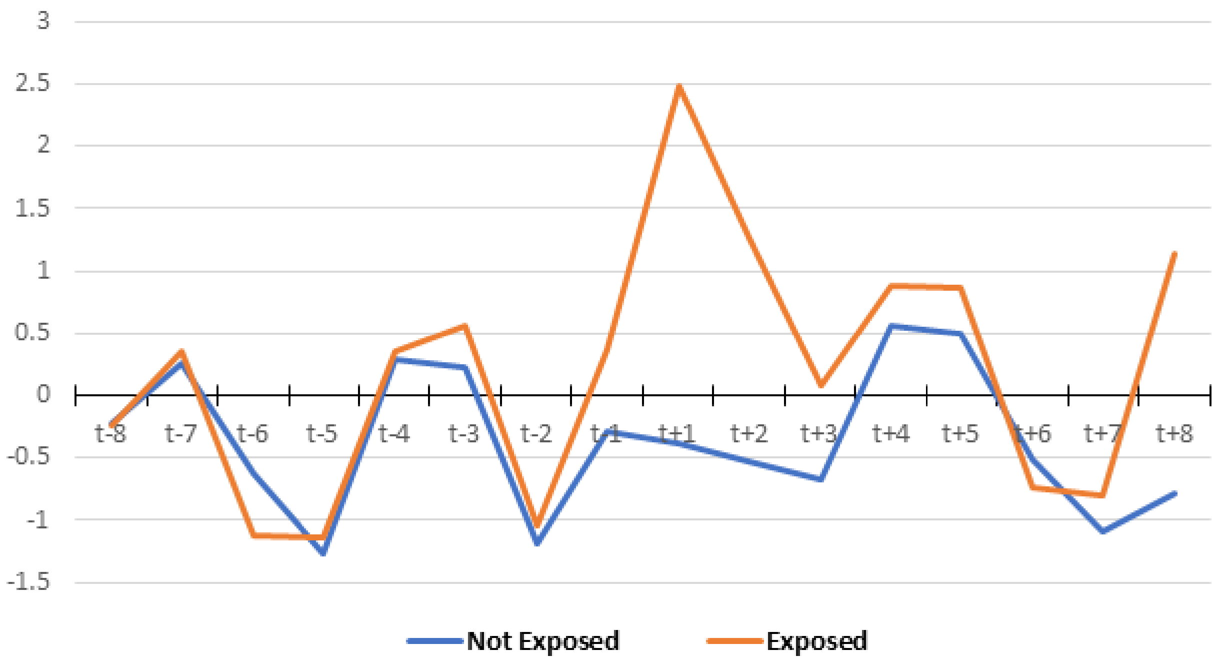


Figure 3: Average Net Sales of Municipal Bonds

The figure presents the average net sales of municipal bonds (in $million) by affected and unaffected insurers. An insurer is affected if it conducted insurance business in Mississippi, Louisiana, or Alabama at the end of 2005Q2, and its direct loss ratio is greater than zero at the end of 2005Q3 (the reporting quarter after Hurricane Katrina). At the end of 2004, we match affected and unaffected insurers to each other on their risk-based capital ratios, size, and surplus using a propensity score matching technique, namely, the nearest neighbor method without replacement. The event date is August 10th, 2005; event quarter t+1 is the 3-month period after August 10th, 2005; event quarter t–1 is the 3-month period before August 10th, 2005; and so on. Net sales are averaged at the insurer level first, and then at the event-quarter level.

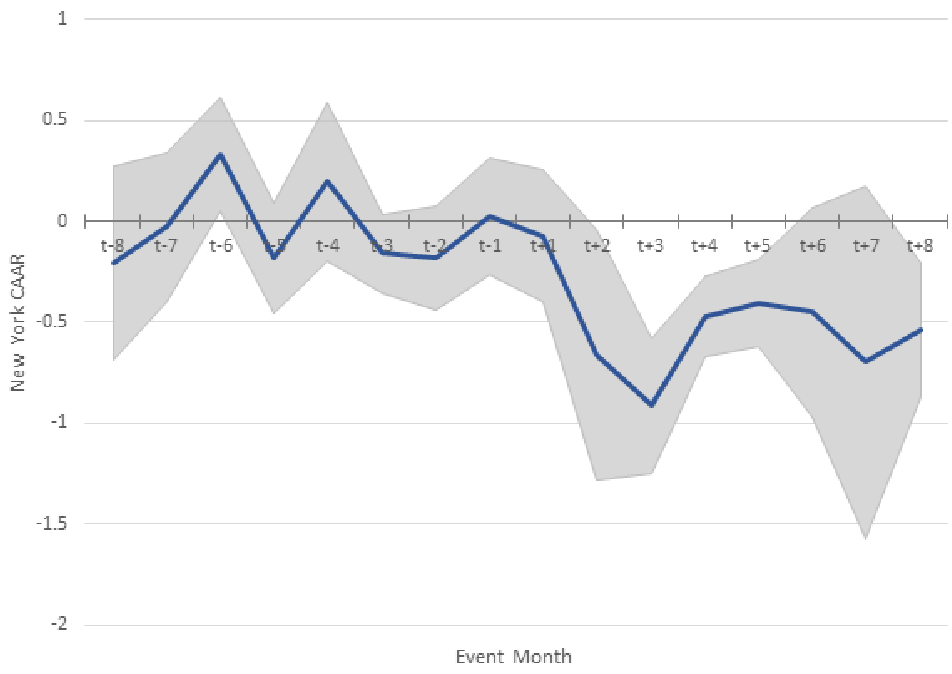


Figure 4: Monthly Cumulative Average Abnormal Returns (CAAR) for New York Bonds

This figure shows the monthly percent CAAR for New York bonds, along with 95% confidence bands, from event month t-8 to t+8. Event month t+1 is September 2005. The orange blocks indicate quarterly average CAARs. We use the five-factor bond model developed by Fama and French (1993) to estimate abnormal bond returns. This model includes the commonly used three factors (i.e., market risk premium, small minus big factor, and high minus low factor) and two additional factors, Term and Def. Term represents the slope of the Treasury yield curve, and Def the default premium measured as the difference between the returns on long-term corporate bond indices and long-term Treasuries. The intercept is the estimate of the abnormal bond return. We first estimate bond-level abnormal weekly returns using weekly Fama-French five factors, and then aggregate the weekly returns to get monthly abnormal returns.

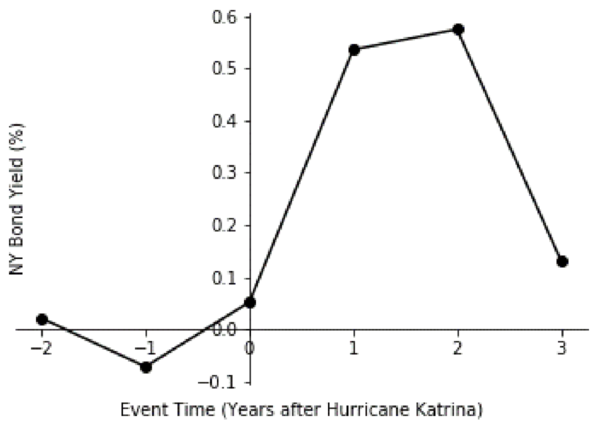
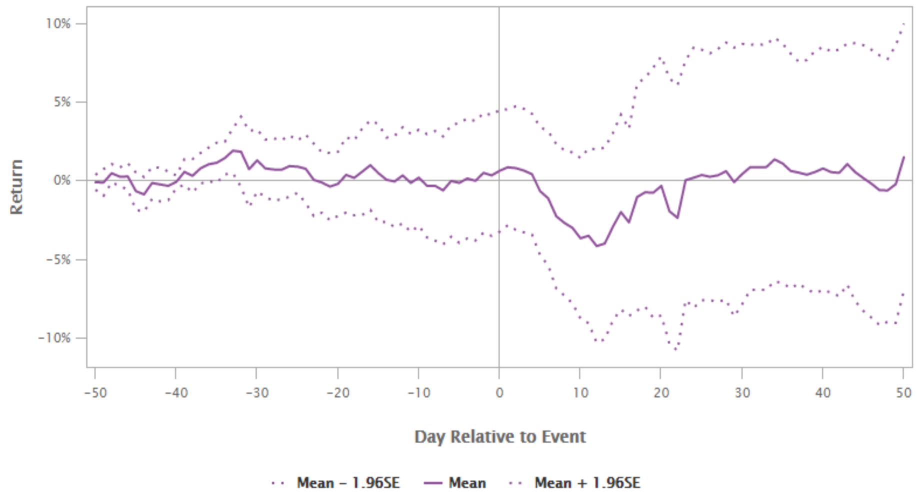
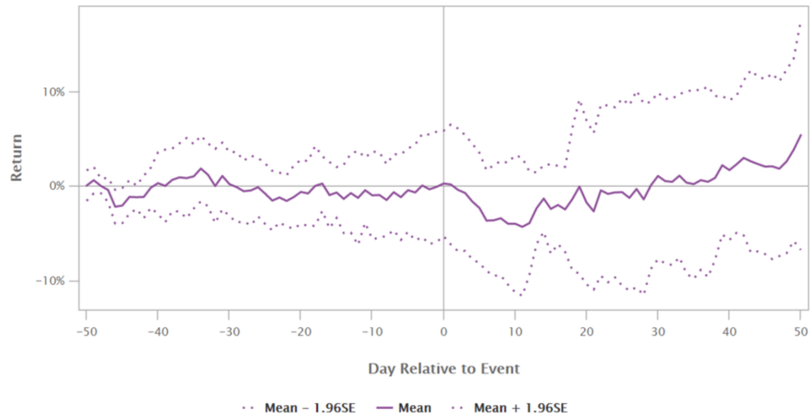


Figure 5: Average Yield of Newly Issued New York Municipal Bonds Around Hurricane Katrina

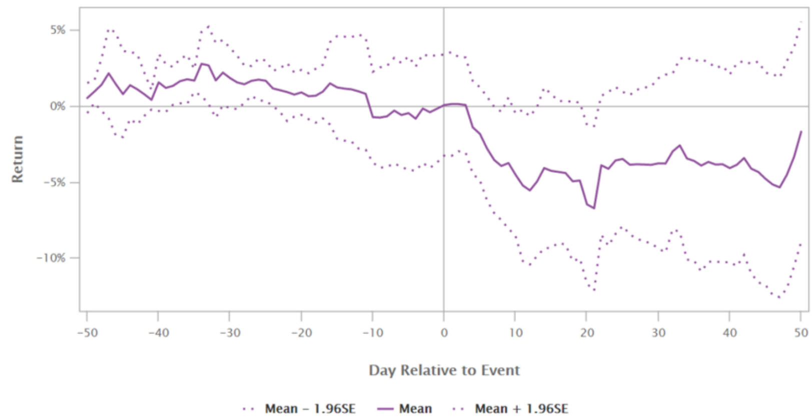
NY Bond Yield (%) is the average offering yield (percent) of newly issued New York municipal bonds (AA- or higher without bond insurance) for three years before and after Hurricane Katrina (August 2005). The yield is reference to Bond Buyer Go 20-Bond Municipal Bond Index, and offset by pre-Katrina mean. We exclude event period (one quarter before and after Katrina, August 2008). Bond yield data are obtained from the Mergent Municipal Bond (BondViewer) database, and Bond Index (MSLB20) is obtained from Federal Reserve Bank of St.Louis Economic Data (FRED).



Panel A – Full Sample



Panel B – High Reinsurance Sample



Panel C – Low Reinsurance Sample

Figure 6: The Impact of Katrina on the Stock Price of Affected Property Insurers

This figure shows the daily percent CAAR for property insurers, along with a 95% confidence interval, from event day t-50 to event day t+50. Event day t=0 is August 23, 2005. To compute abnormal returns we use the Fama-French 3-Factor Model, and a gap of 40 trading days between estimation window and event window [-50,+50]. Panel A reports results for the full sample. Panel B report results for insurers with above-median reinsurance activity. Panel C report results for insurers with below-median reinsurance activity.

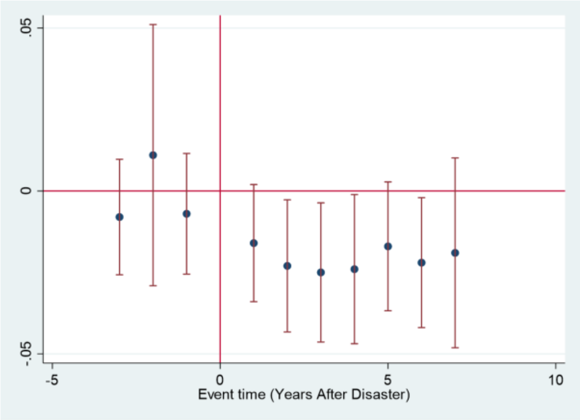


Figure 7: Tests for Differences in Trends Between Affected and Unaffected Public Hospitals' Capital Expenditures

This figure shows the differences in capital expenditures between affected NY public hospitals and matched unaffected NY public hospitals in the event window [-4,+7], along with a 95% confidence interval. Event year 0 is 2005. Therefore, there is no difference in trends pre-2005 between affected and unaffected public hospitals.

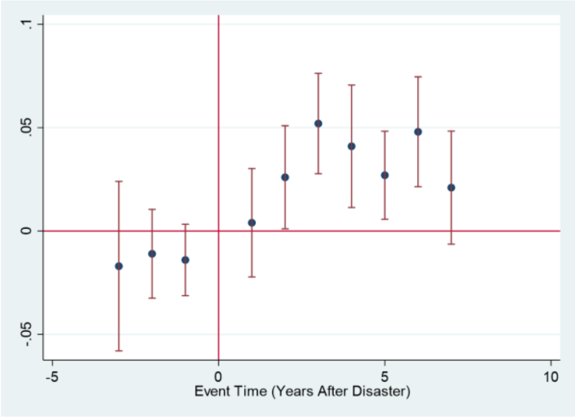


Figure 8: Tests for Differences in Trends Between Neighbor and Distant Private Hospitals' Capital Expenditures

This figure shows the differences in capital expenditures between NY private hospitals located in the neighborhood of an unaffected private hospital, and matched NY private hospitals that are located farther away from unaffected NY public hospitals in the event window [-4,+7], along with a 95% confidence interval. Event year 0 is 2005. Therefore, there is no difference in trends pre-2005 between neighbor and distant private hospitals.

Table 1 – Summary statistics

This table presents summary statistics. The sample period is 2001 to 2009 for insurers and bonds data. The full sample refers to insurers with more than 10% municipal bond holding at end of 2004. There are 1,068 insurance companies for 34,438 observations at the insurer-quarter level in the full sample. The focused sample refers to insurers with more than 3% holdings of municipal New York bonds at the end of 2004. There are 195 insurance companies for 6,230 observations at the insurer-quarter level in the focused sample. The sample period is 1999 to 2012 for public and private hospitals in New York State. There are 37 public hospitals and 171 private hospitals for 406 and 1890 hospital-year observations, respectively. See Appendix A for all variable definitions. Loss ratio is dropped if it is negative or above 80. Net sales, loss ratio, asset growth for private and public hospitals, RBCExposure, insurer liability ratio, and measures of public and private hospital investments are winsorized at the 1^{st} and 99^{th} percentiles. Panel B reports portfolio holdings (in percentage) in major asset classes by insurers affected by Hurricane Katrina. Affected insurers are those with a positive loss ratio in the states of Mississippi, Louisiana, and Alabama in 2005Q3 and 2005Q4. The last column of Panel B reports aggregate dollar amount (in $billion) of portfolio holdings by all affected insurers. Panel C reports the top and bottom five net sales of municipal bonds (in $million) by affected and unaffected insurers during the event quarter window [t-3, t+3]. Event quarter t+1 is 2005Q3, and event quarter t-1 is 2005Q2.

Panel A: Summary Statistics of Variables

Variable	N	Mean	S.D.	25^{th}	50^{th}	75^{th}
Insurer-quarter Level (Full Sample)						
Net Sale ($million)	34,438	-0.40	10.94	0.00	0.00	0.00
LossRatio	34,438	3.28	11.58	0.00	0.00	0.00
LossDummy	34,438	0.14	0.35	0.00	0.00	0.00
KatrinaRegion	34,438	0.17	0.38	0.00	0.00	0.00
RBCExposure	34,438	1.19	7.26	0.00	0.00	0.18
RBCDummy	34,438	0.35	0.48	0.00	0.00	1.00
Trading Volume	34,438	10.84	55.72	1.00	1.00	1.00
Time-to-maturity	34,438	1.95	5.48	0.00	0.00	0.00
Insurer Liability Ratio	34,438	1.72	2.43	0.62	1.43	2.28
ZeroTrade	34,438	0.86	0.35	1.00	1.00	1.00
Reinsurance	34,438	39.66	35.83	6.35	28.92	71.04
Insurer-quarter Level (Focused Sample)						
Net Sale ($million)	6,230	-1.23	36.94	0.00	0.00	0.00
LossRatio	6,230	3.45	11.72	0.00	0.00	0.00
LossDummy	6,230	0.11	0.32	0.00	0.00	0.00
KatrinaRegion	6,230	0.14	0.35	0.00	0.00	0.00
RBCExposure	6,230	0.70	2.19	0.00	0.00	0.13
RBCDummy	6,230	0.32	0.46	0.00	0.00	1.00
Trading Volume	6,230	21.94	71.40	1.00	1.00	4.91
Time-to-maturity	6,230	4.25	7.47	0.00	0.00	7.67
Insurer Liability Ratio	6,230	1.96	2.13	0.71	1.67	2.57
ZeroTrade	6,230	0.70	0.46	0.00	1.00	1.00
Reinsurance	6,230	38.14	36.38	2.66	26.06	71.99
Public Hospital Investment						
PubHMuni	406	0.52	0.50	0.00	1.00	1.00
PubHMuni2	406	0.34	0.48	0.00	0.00	1.00
Capex/LagAsset	406	0.07	0.04	0.05	0.07	0.09
Capex in Building/LagAsset	406	0.06	0.03	0.04	0.06	0.08
Capex in Equipment/LagAsset	406	0.01	0.02	0.00	0.00	0.02
Asset Growth	406	0.03	0.12	0.01	0.02	0.05
Hospital Asset ($million)	406	166.57	153.65	62.81	104.70	251.20

Public Hospital Financing						
PubHMuni	417	0.55	0.50	0.00	1.00	1.00
PubHMuni2	417	0.39	0.49	0.00	0.00	1.00
Log(Public Hospital Issuance)	417	6.03	8.45	0.69	0.69	16.60
Log(Public Hospital Issuance/LagAsset)	417	-13.22	8.73	-19.23	-18.10	-2.40
Public Hospital Issuance/LagAsset	417	3.18	16.92	0.00	0.00	0.09
Asset Growth	417	0.02	0.10	0.01	0.02	0.05
Hospital Asset ($million)	417	218.74	197.27	70.67	131.19	316.16
Private Hospital Investment						
PrvHNeibr	1,890	0.47	0.50	0.00	0.00	1.00
PrvHNeibr2	1,890	0.48	0.50	0.00	0.00	1.00
Closeness	1,890	0.20	0.65	0.01	0.05	0.14
Closeness2	1,890	0.18	0.64	0.01	0.05	0.13
LogCloseness	1,890	-3.02	1.55	-4.37	-3.10	-1.95
LogCloseness2	1,890	-3.08	1.49	-4.37	-3.10	-2.03
Capex/LagAsset	1,890	0.22	0.31	0.06	0.08	0.13
Capex in Building/LagAsset	1,890	0.15	0.23	0.03	0.04	0.08
Capex in Equipment/LagAsset	1,890	0.07	0.08	0.03	0.04	0.06
Asset Growth	1,890	0.12	0.48	0.01	0.05	0.16
Hospital Asset ($million)	1,890	121.57	212.02	9.80	58.99	133.83
Macro Variables						
Disaster-Driven Aggregate Sales of Disaster-Unaffected Bonds by Exposed Insurers ($billion)	550	0.01	0.05	0.00	0.00	0.00
Disaster-Driven Aggregate Purchases of Disaster-Unaffected Bonds by Exposed Insurers ($billion)	550	0.01	0.06	0.00	0.00	0.00
Disaster-Driven Aggregate Trades of Disaster-Affected Bonds by Exposed Insurers ($billion)	550	-0.02	0.15	0.00	0.00	0.00
Real GDP Growth	550	2.24	3.17	0.59	2.32	3.96
Real GDP ($billion)	550	269.87	324.37	62.75	162.42	350.13
Unemployment rate change	550	0.41	1.15	-0.40	0.10	1.00
Unemployment rate	550	5.31	1.86	4.10	4.95	6.00

Panel B: Affected Insurers Portfolio Holdings in % and dollar amount by Asset Classes before Hurricane Katrina 2004

Asset Class	Portfolio Holding (%)	Amount ($ billion)
Municipal	19.56	28.44
Corporate	29.00	42.17
Treasury	24.00	34.90
Preferred Stock	0.97	1.41
Common Stock	10.31	14.99
Real Estate	0.48	0.70
Mortgage	0.13	0.19
Cash	14.57	21.18
Other Assets	1.18	1.72
Total	100.00	145.40

Panel C: Top/Bottom Five Net Sales ($million) of Municipal Bonds

(1) Top 5 net sales by states for the event quarter t=t-2 to t=t+2 (in $million)							
Pre-Katrina (t-2,t-1)				**Post-Katrina (t+1,t+2)**			
Not Exposed		Exposed		Not Exposed		Exposed	
States	Netsales	States	Netsales	States	Netsales	States	Netsales
ID	10.67	DE	47.60	LA	171.43	NY	1529.54
NH	8.47	NH	36.89	PR	72.88	CA	569.97
CT	7.32	WV	23.16	AR	19.76	IA	524.80
ME	6.30	IA	0.71	OR	10.32	VA	382.91
DE	0.27	WY	-1.04	AK	7.83	FL	366.82

(2) Bottom 5 net sales by states for the event quarter t=t-2 to t=t+2 (in $million)							
Pre-Katrina (t-2,t-1)				**Post-Katrina (t+1,t+2)**			
Not Exposed		Exposed		Not Exposed		Exposed	
States	Netsales	States	Netsales	States	Netsales	States	Netsales
TX	-640.34	TX	-770.12	AZ	-416.79	GA	-425.91
NY	-377.94	CA	-449.78	GA	-361.58	MA	-380.81
CA	-350.94	WA	-395.17	WA	-332.29	MI	-228.71
PA	-235.30	MI	-387.74	TX	-317.84	AZ	-214.59
FL	-233.54	IL	-354.05	NJ	-303.57	WI	-176.34

Table 2 – Aggregate Effects of Disaster-Driven Sales of Disaster-Unaffected Bonds by Exposed Insurers

This table shows the impact of disaster-driven net sales of municipal bonds by insurance companies on aggregate output and unemployment. The sample period is from 1999 to 2013. The dependent variables are the annual percent change one year ahead (Columns I and IV) and two years ahead (Columns II and V); and the cumulative biannual percent change (Columns III and VI) of the real GDP (Columns I to III) and unemployment (Columns IV to VI) for each state. The independent variables are constructed by aggregating insurance-level trades for insurance companies with exposure to the corresponding disaster area in the post-disaster period (2005:Q4-2006:Q4 for 2005's Hurricane Katrina; and 2008:Q4-2009:Q4 for 2008's Hurricanes Gustav and Ike, and zero otherwise) for each state (municipal bond issuing state) in each year. The main dependent variable is disaster-driven aggregate sales of disaster-unaffected bonds by exposed insurers, which is defined as the aggregate trade by exposed insurers of bonds issued by disaster-unaffected regions when such aggregate trade is negative, and we take the absolute value. Other independent variables include disaster-driven aggregate purchases of disaster-unaffected bonds by exposed insurers, defined as the aggregate trade by exposed insurers of bonds issued by disaster-unaffected regions when such aggregate trade is positive; and disaster-driven aggregate sales of disaster-affected bonds by exposed insurers, defined as the aggregate trade by exposed insurers of bonds issued by disaster-unaffected regions. Regressions include state and year fixed effects. Standard errors are clustered at state level and t-statistics are reported in parentheses. ∗∗∗, ∗∗, and ∗ indicate significance at the 1%, 5%, and 10% level, respectively.

	Real GDP Growth			Unemployment growth		
	t+1	t+2	t – t+2	t+1	t+2	t – t+2
Disaster-Driven Aggregate Sales of Disaster-Unaffected Bonds by Exposed Insurers	-6.289**	-2.595	-9.233***	1.643***	0.224	1.877***
	(-2.33)	(-0.92)	(-3.09)	(3.52)	(0.59)	(3.60)
Disaster-Driven Aggregate Purchases of Disaster-Unaffected Bonds by Exposed Insurers	0.999	0.109	0.938	0.203	-0.169	0.007
	(0.60)	(0.04)	(0.26)	(0.55)	(-0.37)	(0.01)
Disaster-Driven Aggregate Trades of Disaster-Affected Bonds by Exposed Insurers	-1.059***	-0.469**	-1.559***	0.421***	0.373***	0.799***
	(-3.05)	(-2.37)	(-3.32)	(4.83)	(5.56)	(5.29)
State Fixed Effects	YES	YES	YES	YES	YES	YES
Year Fixed Effects	YES	YES	YES	YES	YES	YES
N	550	550	550	550	550	550
R^2	0.527	0.521	0.585	0.736	0.751	0.796

Table 3 – Katrina, loss ratio, and net sales: two stage least square (2SLS) estimations with geographic measures of Katrina exposure

The table reports the results from 2SLS estimations using an instrumental variable approach. The dependent variable in the first stage in Panel A is the loss ratio at the insurer-quarter level. We control for insurer fixed effects (Insurer FE) and year-quarter fixed effects (Time FE) for the model specifications in Columns 3, 4, 7, and 8, respectively. KatrinaRegion equals one for insurers exposed to Katrina-affected states and zero otherwise. Post-Katrina equals one in the quarters after 2005Q2 and zero otherwise. The dependent variable in the second stage in Panel B is insurer-quarter level net sales (in $million) of New York municipal bonds. The instrumented loss ratio enters the second stage as an independent variable. In Panel C, we perform an ordinary least square (OLS) estimation where the dependent variable is the net sales of New York bonds. The full sample (Columns 1-4) considers insurers who held more than 10% municipal bond holding at the end of 2004. The focused sample (Columns 5-8) considers insurers who held more than 3% of New York municipal bond at the end of 2004. F-test statistics and P-values are reported for the first stage. Standard errors are clustered at the insurer level and t-statistics are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. See Appendix A for all other variable definitions.

Panel A: The dependent variable is the loss ratio (first stage)

	(1) Loss Ratio	(2) Loss Ratio	(3) Loss Ratio	(4) Loss Ratio	(5) Loss Ratio	(6) Loss Ratio	(7) Loss Ratio	(8) Loss Ratio
KatrinaRegion *Post-Katrina	14.907***	14.432***	14.344***	13.868***	15.226***	14.150***	14.540***	14.073***
	(16.05)	(15.94)	(15.19)	(15.16)	(6.78)	(6.80)	(6.51)	(6.93)
KatrinaRegion	-0.032	-1.964			-0.098	2.746		
	(-1.57)	(-1.18)			(1.01)	(0.76)		
Post-Katrina	5.087***	3.732***			6.062***	0.036		
	(16.81)	(3.79)			(7.92)	(0.02)		
Reinsurance		-0.001		-0.026***		-0.001		-0.040**
		(-0.64)		(-3.82)		(-0.42)		(-2.54)
Trading Volume		-0.001		0.001		0.001		0.002
		(-0.35)		(0.47)		(0.25)		(0.63)
Time-to-maturity		-0.007		-0.123***		0.015		-0.127*
		(-0.34)		(-2.99)		(0.49)		(-1.94)
Insurer Liability Ratio		-0.028		-0.194		0.029		-0.670**
		(-1.26)		(-1.64)		(0.82)		(-2.37)
ZeroTrade	-1.315***	-0.163	1.776***	0.336	-1.833***	0.233	1.692***	-0.134
	(-4.55)	(-0.57)	(5.21)	(0.69)	(-3.55)	(0.57)	(3.18)	(-0.16)
X_{it}*Post-Katrina	NO	YES	YES	YES	NO	YES	YES	YES
X_{it}*KatrinaRegion	NO	YES	YES	YES	NO	YES	YES	YES
Sample	Full	Full	Full	Full	Focused	Focused	Focused	Focused
Insurer FE	NO	NO	YES	YES	NO	NO	YES	YES
Time FE	NO	NO	YES	YES	NO	NO	YES	YES
N	34,438	34,438	34,438	34,438	6,230	6,230	6,230	6,230
R^2	0.198	0.214	0.224	0.235	0.196	0.235	0.240	0.270
F-Statistic	205.69	52.26	24.11	20.39	41.38	10.27	5.88	8.51
P-value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Panel B: 2SLS with the dependent variable net sales (second stage)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Loss Ratio	0.072***	0.092***	0.132***	0.130***	0.465***	0.631***	0.886***	0.871***
	(4.04)	(4.30)	(6.07)	(6.50)	(2.88)	(2.94)	(4.92)	(5.81)
Reinsurance		-0.003*		-0.003		-0.036**		-0.027
		(-1.69)		(-0.95)		(-2.28)		(-1.06)
Trading Volume		0.004		0.002*		0.012		0.012
		(1.21)		(1.85)		(0.77)		(1.36)
Time-to-maturity		-0.164***		-0.114***		-0.408*		-0.273*
		(-2.90)		(-4.37)		(-1.79)		(-1.71)
Insurer Liability Ratio		-0.021		0.001		-0.132		0.223
		(-1.12)		(0.03)		(-0.90)		(0.60)
ZeroTrade	2.999***	1.021*	1.884***	0.513	5.144***	0.608	2.746**	-0.224
	(6.56)	(1.73)	(9.34)	(1.34)	(4.01)	(0.24)	(2.16)	(-0.09)
X_{it}*Post-Katrina	NO	YES	YES	YES	NO	YES	YES	YES
X_{it}*KatrinaRegion	NO	YES	YES	YES	NO	YES	YES	YES
Sample	Full	Full	Full	Full	Focused	Focused	Focused	Focused
Insurer FE	NO	NO	YES	YES	NO	NO	YES	YES
Time FE	NO	NO	YES	YES	NO	NO	YES	YES
N	34,438	34,438	34,438	34,438	6,230	6,230	6,230	6,230

Panel C: OLS estimation with the dependent variable net sales

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Loss Ratio	0.019***	0.019***	0.021***	0.021***	0.139***	0.146***	0.122**	0.121**
	(3.71)	(3.76)	(3.44)	(3.44)	(3.47)	(3.62)	(2.55)	(2.52)
Reinsurance		-0.001		-0.003		-0.018		-0.023
		(-0.48)		(-0.79)		(-1.37)		(-0.92)
Trading Volume		0.004***		0.003**		0.016**		0.015*
		(3.14)		(2.07)		(2.01)		(1.80)
Time-to-maturity		-0.163***		-0.116***		-0.357**		-0.228
		(-6.63)		(-4.44)		(-2.52)		(-1.46)
Insurer Liability Ratio		-0.014		-0.001		-0.038		-0.070
		(-0.57)		(-0.01)		(-0.17)		(-0.20)
ZeroTrade	2.886***	0.907**	1.863***	0.497	4.439***	0.568	2.411*	0.259
	(17.03)	(2.53)	(9.29)	(1.30)	(4.33)	(0.27)	(1.94)	(0.11)
Sample	Full	Full	Full	Full	Focused	Focused	Focused	Focused
Insurer FE	NO	NO	YES	YES	NO	NO	YES	YES
Time FE	NO	NO	YES	YES	NO	NO	YES	YES
N	34,438	34,438	34,438	34,438	6,230	6,230	6,230	6,230
R^2	0.009	0.010	0.007	0.008	0.005	0.005	0.014	0.015

Table 4 – Katrina, loss ratio, and net sales: two stage least square (2SLS) estimations with dollar measures of Katrina exposure

The table reports the results from 2SLS estimations using an instrumental variable approach. The dependent variables in the first stage in Panel A and Panel C is the loss ratio at the insurer-quarter level. We control for insurer fixed effects (Insurer FE) and year-quarter fixed effects (Time FE) for the model specifications in Columns 3, 4, 7, and 8, respectively. RBCExposure is the insurer's average direct insurance premium written (in $million) for the states of Florida, Louisiana, Mississippi, and Alabama over the pre-Katrina quarters 2005Q1 and 2005Q2. RBCDummy equals one when RBCExposure is above the mean and zero otherwise. Post-Katrina equals one in the quarters after 2005Q2 and zero otherwise. The dependent variables in the second stage in Panels B and D are insurer-quarter level net sales (in $million) of New York municipal bonds. The instrumented loss ratio enters the second stage as an independent variable. The full sample (Columns 1-4) considers insurers who held more than 10% municipal bond holding at the end of 2004. The focused sample (Columns 5-8) considers insurers who held more than 3% of New York municipal bond at the end of 2004. F-test statistics and P-values are reported for the first stage. Standard errors are clustered at the insurer level and t-statistics are reported in parentheses. ∗∗∗, ∗∗, and ∗ indicate significance at the 1%, 5%, and 10% level, respectively. See Appendix A for all other variable definitions.

Panel A: The dependent variable is the loss ratio (first stage); Katrina Exposure is measured with RBCDummy

	(1) Loss Ratio	(2) Loss Ratio	(3) Loss Ratio	(4) Loss Ratio	(5) Loss Ratio	(6) Loss Ratio	(7) Loss Ratio	(8) Loss Ratio
RBCDummy	18.509***	18.103***	18.969***	18.641***	19.454***	19.339***	19.826***	19.636***
*Post-Katrina	(31.51)	(30.24)	(31.63)	(30.75)	(14.55)	(14.87)	(15.49)	(15.61)
RBCDummy	-0.016	-0.500***			0.019	0.043		
	(-1.29)	(-4.45)			(0.50)	(0.26)		
Post-Katrina	1.580***	1.409*			1.104***	-0.482		
	(7.30)	(1.88)			(1.46)	(-0.36)		
Reinsurance		-0.005**		-0.014***		-0.006**		-0.016*
		(-2.31)		(-2.86)		(-1.98)		(-1.73)
Trading Volume		-0.001		0.001		-0.001		0.002
		(-0.97)		(0.27)		(-0.12)		(1.18)
Time-to-maturity		-0.012		-0.016		-0.005		-0.016
		(-0.84)		(-0.51)		(-0.39)		(-0.32)
Insurer Liability		0.012		-0.079		0.051		-0.198
Ratio		(0.55)		(-1.30)		(1.60)		(-1.11)
ZeroTrade	-0.288	-0.309**	0.523**	0.417	0.157	-0.258*	-0.384	-0.434
	(-1.35)	(-1.97)	(2.20)	(1.14)	(0.52)	(-1.85)	(-1.13)	(-0.70)
X_{it}*Post-Katrina	NO	YES	YES	YES	NO	YES	YES	YES
X_{it}*RBCDummy	NO	YES	YES	YES	NO	YES	YES	YES
Sample	Full	Full	Full	Full	Focused	Focused	Focused	Focused
Insurer FE	NO	NO	YES	YES	NO	NO	YES	YES
Time FE	NO	NO	YES	YES	NO	NO	YES	YES
N	34,438	34,438	34,438	34,438	6,230	6,230	6,230	6,230
R^2	0.342	0.353	0.325	0.328	0.379	0.389	0.349	0.358
F-Statistic	356.99	86.71	41.89	36.86	80.60	26.39	12.71	21.59
P-value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Panel B: The dependent variable is net sales (second stage); Katrina Exposure is measured with RBCDummy

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Loss Ratio	0.066***	0.067***	0.070***	0.069***	0.506***	0.507***	0.558***	0.558***
	(7.56)	(7.51)	(5.17)	(5.14)	(6.93)	(6.95)	(5.17)	(5.25)
Reinsurance		-0.002		-0.003		-0.024*		-0.024
		(-1.23)		(-0.82)		(-1.81)		(-0.95)
Trading Volume		0.004***		0.003**		0.013		0.014*
		(2.85)		(1.99)		(1.56)		(1.66)
Time-to- -maturity		-0.161***		-0.115***		-0.344**		-0.243
		(-6.55)		(-4.40)		(-2.42)		(-1.55)
Insurer Liability Ratio		-0.019		-0.000		-0.114		0.065
		(-0.79)		(-0.01)		(-0.51)		(0.18)
ZeroTrade	2.955***	0.985***	1.868***	0.507	4.652***	0.689	2.447*	0.038
	(17.39)	(2.75)	(9.30)	(1.32)	(4.53)	(0.32)	(1.96)	(0.02)
X_{it}*Post-Katrina	NO	YES	YES	YES	NO	YES	YES	YES
X_{it} *RBCDummy	NO	YES	YES	YES	NO	YES	YES	YES
Sample	Full	Full	Full	Full	Focused	Focused	Focused	Focused
Insurer FE	NO	NO	YES	YES	NO	NO	YES	YES
Time FE	NO	NO	YES	YES	NO	NO	YES	YES
N	34,438	34,438	34,438	34,438	6,230	6,230	6,230	6,230

Panel C: The dependent variable is the loss ratio (first stage); Katrina Exposure is measured with RBCExposure

	(1) Loss Ratio	(2) Loss Ratio	(3) Loss Ratio	(4) Loss Ratio	(5) Loss Ratio	(6) Loss Ratio	(7) Loss Ratio	(8) Loss Ratio
RBCExposure *Post-Katrina	0.268***	0.250***	0.238***	0.214***	1.708***	1.500***	1.565***	1.392***
	(16.58)	(15.75)	(3.25)	(3.63)	(14.78)	(12.77)	(14.47)	(12.68)
RBCExposure	-0.004	0.003			-0.016	0.022		
	(-0.41)	(0.28)			(-0.22)	(0.29)		
Post-Katrina	6.693***	5.786***			5.185***	2.200**		
	(57.17)	(8.36)			(19.89)	(1.96)		
Reinsurance		-0.005**		-0.040***		-0.004		-0.029***
		(-2.45)		(-5.53)		(-0.77)		(-3.93)
Trading Volume		-0.001		-0.001		0.001		-0.003
		(-0.37)		(-0.54)		(0.01)		(-1.07)
Time-to- -maturity		-0.047		-0.112***		-0.006		0.017
		(-1.25)		(-2.63)		(-0.11)		(0.31)
Insurer Liability Ratio		-0.046		-0.188		0.021		-0.449***
		(-1.22)		(-1.58)		(0.27)		(-4.41)
ZeroTrade	-0.924***	-0.635	1.580***	0.767	-0.482*	-0.481	0.349	0.324
	(-5.56)	(-1.23)	(4.75)	(1.47)	(-1.77)	(-0.60)	(0.88)	(0.40)
X_{it}*Post-Katrina	NO	YES	YES	YES	NO	YES	YES	YES
X_{it} *RBCExposure	NO	YES	YES	YES	NO	YES	YES	YES
Sample	Full	Full	Full	Full	Focused	Focused	Focused	Focused
Insurer FE	NO	NO	YES	YES	NO	NO	YES	YES
Time FE	NO	NO	YES	YES	NO	NO	YES	YES
N	34,438	34,438	34,438	34,438	6,230	6,230	6,230	6,230
R^2	0.108	0.154	0.159	0.186	0.137	0.164	0.174	0.190
F-Statistic	1041.55	348.47	15.24	14.63	247.07	67.64	32.46	27.48
P-value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Panel D: Full Sample: The dependent variable is net sales (second stage); Katrina Exposure is measured with RBCExposure

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Loss Ratio	0.089***	0.083***	0.554***	0.302***	1.647***	1.473***	5.443***	3.929***
	(5.55)	(6.03)	(8.53)	(7.61)	(12.53)	(12.07)	(12.12)	(12.44)
Reinsurance		-0.003		-0.004		-0.045***		-0.032
		(-1.48)		(-0.99)		(-3.22)		(-0.92)
Trading Volume		0.004***		0.002		0.003		0.004
		(2.75)		(1.55)		(0.39)		(0.35)
Time-to- -maturity		-0.160***		-0.111***		-0.346**		-0.374*
		(-6.53)		(-4.12)		(-2.30)		(-1.74)
Insurery Liabilit Ratio		-0.021		-0.001		-0.314		1.162**
		(-0.86)		(-0.01)		(-1.31)		(2.33)
ZeroTrade	2.992***	1.012***	1.922***	0.551	5.812***	0.942	3.228	-1.771
	(17.44)	(2.81)	(8.63)	(1.40)	(5.22)	(0.42)	(1.58)	(-0.55)
X_{it}*PostKatrina	NO	YES	YES	YES	NO	YES	YES	YES
X_{it} *RBCExposure	NO	YES	YES	YES	NO	YES	YES	YES
Sample	Full	Full	Full	Full	Focused	Focused	Focused	Focused
Insurer FE	NO	NO	YES	YES	NO	NO	YES	YES
Time FE	NO	NO	YES	YES	NO	NO	YES	YES
N	34,438	34,438	34,438	34,438	6,230	6,230	6,230	6,230

Table 5 – Fire sales of New York municipal bonds

The table reports the cumulative average abnormal returns (CAARs) for New York municipal bonds. Panel A reports the CAARs in event quarter time. Panel B reports the CAARs in event month time. Event month *t+1* is September 2005. Abnormal bond returns are the estimated intercept of the five-factor bond return model developed in Fama and French (1993). This model includes the commonly used three factors (i.e., market risk premium, small minus big factor, and high minus low factor) and two additional factors, Term and Def. Term is the slope of the Treasury yield curve, and Def is the default premium measured as the difference between the returns on long-term corporate bond indices and long-term Treasuries. We first estimate bond-level abnormal weekly returns using weekly Fama-French five factors, and then aggregate the weekly returns to get monthly and quarterly abnormal returns.

Panel A: New York bond event-quarter CAARs

Event Quarters	Mean	t-stats
t-3	-0.0726	-0.4905
t-2	-0.0266	-0.2707
t-1	-0.0849	-0.8666
t+1	-0.6555	-4.9711
t+2	-0.4383	-5.2869
t+3	-0.3313	-1.7207

Panel B: New York bond event-month CAARs

Event Months	Mean	t-stats
t-8	-0.2067	-0.8439
t-7	-0.0289	-0.1529
t-6	0.3280	2.2938
t-5	-0.1829	-1.3274
t-4	0.1949	0.9735
t-3	-0.1592	-1.5931
t-2	-0.1828	-1.4130
t-1	0.0246	0.1677
t+1	-0.0731	-0.4398
t+2	-0.6743	-2.1271
t+3	-0.9181	-5.3576
t+4	-0.4740	-4.7030
t+5	-0.4078	-3.7424
t+6	-0.4500	-1.7115
t+7	-0.6970	-1.5673
t+8	-0.5379	-3.1917

Table 6 – Public hospital financing

The table reports the results from difference-in-differences (DD) estimations. We control for insurer fixed effects (Insurer FE) and year-quarter fixed effects (Time FE) for model specifications in Columns 3, 4, 7, and 8. *PubHMuni* equals one for a given public hospital when it is located in a county that has issued municipal (non-conduit) bonds for hospital purposes between 2000 and 2005, and zero otherwise. Within the sample of hospitals for which *PubHMuni*=1, we further manually identify the hospitals that we believe did indeed issue municipal (non-conduit) bonds during 2000-2005. *PubHMuni2* equals one for these hospitals and zero otherwise. *Post-Katrina* equals one for sample periods after 2005Q2 and zero otherwise. For public hospital financing, we identify the county of a given public hospital and estimate the dollar county-year level total municipal (non-conduit) bond issuance for hospital purposes. We then take the natural logarithm value of the dollar issuance. Standard errors are clustered at the hospital level and t-statistics are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. See Appendix A for all other variable definitions.

Dependent variable: log(county-hospital level issuance for hospital purposes)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
PubHMuni	-3.960***	-3.845***	-4.625***	-4.504***				
* Post-Katrina	(-3.74)	(-3.55)	(-4.21)	(-4.12)				
PubHMuni2					-5.074***	-5.120***	-4.757***	-4.726***
* Post-Katrina					(-4.35)	(-4.50)	(-3.95)	(-3.91)
PubHMuni	9.707***	9.309***						
	(5.92)	(5.75)						
PubHMuni2					9.756***	9.405***		
					(4.80)	(4.65)		
Post-Katrina	0.324	-0.005			0.152	-0.010		
	(0.73)	(-0.01)			(0.23)	(-0.01)		
Asset Growth		-10.982		-3.301		-11.716		-2.490
		(-1.49)		(-0.40)		(-1.38)		(-0.30)
Asset Growth		14.319***		8.132				
* PubHMuni		(3.74)		(1.24)				
Asset Growth						22.024***		9.485
* PubHMuni2						(3.50)		(1.45)
Asset Growth		11.298		-2.972		7.794		-4.028
* Post-Katrina		(1.42)		(-0.33)		(0.84)		(-0.43)
Hospital FE	NO	NO	YES	YES	NO	NO	YES	YES
Time FE	NO	NO	YES	YES	NO	NO	YES	YES
N	417	417	417	417	417	417	417	417
R^2	0.198	0.210	0.221	0.226	0.156	0.176	0.220	0.225

Table 7. Public vs. private hospital Investments: Univariate comparisons (matched sample)

The table reports univariate comparison of investments by New York public hospitals and matched private hospitals. Panel A shows univariate comparison for disaster affected and unaffected hospitals. For each New York muni bond reliant public hospital (PubHMuni=1), we match the closest private hospital and compute average capex/asset six years before and five years after hurricane Katrina. Numbers are in percentage. Panel B shows investments (capital expenditures divided by total assets) of affected public hospitals and matched private hospitals in the years around Hurricane Katrina.

Panel A. Univariate Comparison

	Muni bond-reliant Public Hospital	Matched Private Hospital
CapEx/Assets (Before)	8.12	8.62
CapEx/Assets (After)	6.53	10.92
Change in CapEx/Assets	-1.59***	2.30**

Panel B. Univariate Comparison

Time Period	CapEx/Assets		Change in CapEx/Assets (Post-Katrina – Pre-Katrina)	
	Public Hospital	Private Hospital (Matched)	Public Hospital	Private Hospital (Matched)
Year (t-6)	8.95	9.33		
Year (t-5)	8.40	9.50		
Year (t-4)	6.96	8.81		
Year (t-3)	7.15	7.73		
Year (t-2)	8.36	7.86		
Year (t-1)	7.59	7.83		
Year (t+1)	6.96	10.33	-1.16	1.68
Year (t+2)	6.78	9.67	-1.34*	1.01
Year (t+3)	6.53	11.80	-1.58**	3.14**
Year (t+4)	6.36	11.34	-1.76**	2.68**
Year (t+5)	6.32	11.42	-1.79**	2.76**
Year (t+6)	6.17	10.79	-1.94**	2.14*

Table 8 – Public hospital investment

The table reports the results from difference-in-differences (DD) estimations using panel regressions. *PubHMuni* and *PubHMuni2* are defined in Table 5. We control for insurer fixed effects (Insurer FE) and year-quarter fixed effects (Time FE) for model specifications in Columns 3, 4, 7, and 8. We use different measures to proxy for public hospital investment. In Panel A, the dependent variable is the hospital-year total capital expenditure scaled by last year-end total assets. We partition the total capital expenditure into capital expenditure on hospital buildings in Panel B and capital expenditure on hospital equipment in Panel C. Standard errors are clustered at the hospital level and t-statistics are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. See Appendix A for all other variable definitions.

Panel A: Dependent variable: hospital total capex/lag asset

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
PubHMuni * Post-Katrina	-0.015**	-0.017**	-0.015***	-0.015***				
	(-2.02)	(-2.36)	(-3.06)	(-3.24)				
PubHMuni2 * Post-Katrina					-0.016**	-0.017**	-0.012**	-0.012**
					(-2.07)	(-2.21)	(-2.34)	(-2.39)
PubHMuni	0.001	0.003						
	(0.20)	(0.47)						
PubHMuni2					0.004	0.005		
					(0.77)	(0.87)		
Post-Katrina	-0.002	-0.002			-0.004	-0.005		
	(-0.35)	(-0.35)			(-0.91)	(-1.06)		
Asset Growth		-0.007		0.016		0.010		0.021**
		(-0.46)		(1.45)		(0.73)		(2.24)
Asset Growth * PubHMuni		0.057***		0.019				
		(3.14)		(1.64)				
Asset Growth * PubHMuni2						0.051**		0.020
						(2.51)		(1.58)
Asset Growth * Post-Katrina		0.017		0.003		0.018		0.003
		(0.90)		(0.22)		(0.96)		(0.23)
Hospital FE	NO	NO	YES	YES	NO	NO	YES	YES
Time FE	NO	NO	YES	YES	NO	NO	YES	YES
N	406	406	406	406	406	406	406	406
R^2	0.036	0.087	0.179	0.225	0.030	0.072	0.170	0.215

Panel B: Dependent variable: hospital capex on hospital building/lag asset

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
PubHMuni	-0.015**	-0.016***	-0.013***	-0.013***				
* Post-Katrina	(-2.32)	(-2.64)	(-3.00)	(-3.20)				
PubHMuni2					-0.016**	-0.016**	-0.013***	-0.013***
* Post-Katrina					(-2.37)	(-2.51)	(-2.95)	(-3.05)
PubHMuni	0.007	0.008*						
	(1.40)	(1.68)						
PubHMuni2					0.016***	0.016***		
					(3.11)	(3.22)		
Post-Katrina	-0.003	-0.004			-0.005	-0.006*		
	(-0.71)	(-0.85)			(-1.38)	(-1.68)		
Asset Growth		0.026*		0.013		0.032***		0.017**
		(1.95)		(1.32)		(2.91)		(2.02)
Asset Growth		0.036**		0.018*				
* PubHMuni		(2.30)		(1.71)				
Asset Growth						0.042**		0.021*
* PubHMuni2						(2.44)		(1.88)
Asset Growth		-0.026		0.007		-0.023		0.007
* Post-Katrina		(-1.63)		(0.53)		(-1.41)		(0.57)
Hospital FE	NO	NO	YES	YES	NO	NO	YES	YES
Time FE	NO	NO	YES	YES	NO	NO	YES	YES
N	406	406	406	406	406	406	406	406
R^2	0.041	0.111	0.193	0.241	0.051	0.120	0.193	0.241

Panel C: Dependent variable: hospital capex on hospital equipment/lag asset

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
PubHMuni	0.001	-0.001	-0.002	-0.002				
* Post-Katrina	(0.01)	(-0.14)	(-1.57)	(-1.58)				
PubHMuni2					-0.001	-0.001	0.001	0.002
* Post-Katrina					(-0.03)	(-0.13)	(1.15)	(1.22)
PubHMuni	-0.006*	-0.005*						
	(-1.75)	(-1.68)						
PubHMuni2					-0.011***	-0.011***		
					(-3.38)	(-3.28)		
Post-Katrina	0.001	0.002			0.001	0.002		
	(0.47)	(0.65)			(0.50)	(0.65)		
Asset Growth		-0.033***		0.003		-0.023***		0.004*
		(-3.66)		(1.07)		(-3.06)		(1.83)
Asset Growth		0.021**		0.001				
* PubHMuni		(1.99)		(0.49)				
Asset Growth						0.009		-0.001
* PubHMuni2						(0.76)		(-0.32)
Asset Growth		0.043***		-0.004		0.041***		-0.004
* Post-Katrina		(3.94)		(-0.98)		(3.81)		(-1.11)
Hospital FE	NO	NO	YES	YES	NO	NO	YES	YES
Time FE	NO	NO	YES	YES	NO	NO	YES	YES
N	406	406	406	406	406	406	406	406
R^2	0.018	0.064	0.042	0.051	0.063	0.099	0.038	0.048

Table 9 – Private hospital investment

The table reports the results from difference-in-differences (DD) estimations using panel regressions. For a given private hospital, *PrvHNeibr* equals one if the hospital is located in the neighborhood of a public hospital with a *PubHMuni*=1. To measure the neighborhood, we first manually collect the latitude and longitude for each private hospital and for each qualified public hospital (i.e., hospitals with a *PubHMuni*=1). Using the coordinates, we measure all distances (in miles) between a given private hospital and all qualified public hospitals; of these distances, we keep the shortest, so that a given private hospital has only one "shortest distance." Finally, we calculate the mean of the shortest distance for all private hospitals. For each hospital, *PrvHNeibr* equals one if its shortest distance is below the mean, and zero otherwise. *PrvHNeibr2* equals one if the hospital is located in the neighborhood of a public hospital with a *PubHMuni2*=1, i.e., a public hospital we believe has issued municipal (non-conduit) bonds between 2000 and 2005. The methodology we use to measure neighborhood is the same as that used for *PrvHNeibr*. For a given private hospital, *PrvHNeibr2* equals one if its shortest distance is below the mean, and zero otherwise. In the Appendix, as alternative measures of *PrvHNeibr* and *PrvHNeibr2,* we use *LogCloseness* and *LogCloseness2*, respectively. We use the shortest distance measured for *PrvHNeibr* for a given private hospital and estimate the *LogCloseness* as the natural logarithm value of one to the shortest distance in miles, i.e., *log(1/closest distance in miles)*. *LogCloseness2* is then the natural logarithm value of one to the shortest distance in miles measured for *PrvHNeibr2*. We control for insurer fixed effects (Insurer FE) and year-quarter fixed effects (Time FE) for model specifications in Columns 3, 4, 7, and 8. We use different measures to proxy for public hospital investment. In Panel A, the dependent variable is the hospital-year total capital expenditure scaled by last year-end total assets. We partition the total capital expenditure into capital expenditure on hospital buildings in Panel B and capital expenditure on hospital equipment in Panel C. Standard errors are clustered at the hospital level and t-statistics are reported in parentheses. ∗∗∗, ∗∗, and ∗ indicate significance at the 1%, 5%, and 10% level, respectively. See Appendix A for all other variable definitions.

Panel A: Dependent variable: Private Hospital Capex/Lag Asset

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
PrvHNeibr *Post-Katrina	0.036**	0.045**	0.034**	0.037**				
	(2.19)	(2.25)	(2.04)	(2.01)				
PrvHNeibr2 *Post-Katrina					0.039**	0.049**	0.039**	0.042**
					(2.43)	(2.44)	(2.35)	(2.23)
PrvHNeibr	-0.019	-0.023						
	(-1.29)	(-1.23)						
PrvHNeibr2					-0.018	-0.022		
					(-1.19)	(-1.15)		
Post-Katrina	-0.290***	-0.345***			-0.292***	-0.348***		
	(-28.13)	(-26.99)			(-28.39)	(-26.89)		
Asset Growth		0.275***		0.121***		0.277***		0.122***
		(15.06)		(3.37)		(14.93)		(3.38)
Asset Growth * PrvHNeibr		-0.020		0.009				
		(-0.69)		(0.43)				
Asset Growth * PrvHNeibr2						-0.023		0.008
						(-0.79)		(0.37)
Asset Growth * Post-Katrina		-0.118**		-0.006		-0.116**		-0.006
		(-2.58)		(-0.10)		(-2.56)		(-0.10)
Hospital FE	NO	NO	YES	YES	NO	NO	YES	YES
Time FE	NO	NO	YES	YES	NO	NO	YES	YES
N	1890	1890	1890	1890	1890	1890	1890	1890
R^2	0.197	0.260	0.840	0.845	0.198	0.260	0.841	0.845

Panel B: Dependent variable: Private Hospital Capex on Hospital Building/Lag Asset

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
PrvHNeibr *Post-Katrina	0.028**	0.034**	0.026**	0.029**				
	(2.34)	(2.34)	(2.17)	(2.08)				
PrvHNeibr2 *Post-Katrina					0.029**	0.036**	0.028**	0.031**
					(2.50)	(2.48)	(2.40)	(2.29)
PrvHNeibr	-0.011	-0.014						
	(-0.97)	(-1.01)						
PrvHNeibr2					-0.010	-0.014		
					(-0.90)	(-0.96)		
Post-Katrina	-0.216***	-0.255***			-0.217***	-0.256***		
	(-30.67)	(-28.13)			(-30.71)	(-27.92)		
Asset Growth		0.203***		0.082***		0.204***		0.083***
		(15.07)		(2.97)		(14.98)		(3.00)
Asset Growth * PrvHNeibr		-0.019		0.002				
		(-0.87)		(0.15)				
Asset Growth * PrvHNeibr2						-0.021		0.001
						(-1.00)		(0.02)
Asset Growth * Post-Katrina		-0.113***		-0.015		-0.112***		-0.015
		(-3.36)		(-0.35)		(-3.35)		(-0.35)
Hospital FE	NO	NO	YES	YES	NO	NO	YES	YES
Time FE	NO	NO	YES	YES	NO	NO	YES	YES
N	1890	1890	1890	1890	1890	1890	1890	1890
R^2	0.198	0.257	0.844	0.847	0.198	0.257	0.844	0.847

Panel C: Dependent variable: Private Hospital Capex on Hospital Equipment/Lag Asset

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
PrvHNeibr	0.009	0.011*	0.009	0.009				
*Post-Katrina	(1.62)	(1.89)	(1.57)	(1.57)				
PrvHNeibr2					0.010**	0.013**	0.011**	0.012*
*Post-Katrina					(1.98)	(2.19)	(2.02)	(1.94)
PrvHNeibr	-0.009**	-0.010**						
	(-2.21)	(-1.99)						
PrvHNeibr2					-0.009**	-0.009*		
					(-2.05)	(-1.84)		
Post-Katrina	-0.074***	-0.090***			-0.075***	-0.091***		
	(-20.69)	(-21.85)			(-21.28)	(-22.01)		
Asset Growth		0.073***		0.038***		0.073***		0.038***
		(14.37)		(3.63)		(14.14)		(3.59)
Asset Growth		-0.004		0.005				
* PrvHNeibr		(-0.48)		(0.80)				
Asset Growth						-0.004		0.006
* PrvHNeibr2						(-0.50)		(0.90)
Asset Growth		-0.009		0.008		-0.008		0.008
* Post-Katrina		(-0.61)		(0.44)		(-0.57)		(0.45)
Hospital FE	NO	NO	YES	YES	NO	NO	YES	YES
Time FE	NO	NO	YES	YES	NO	NO	YES	YES
N	1890	1890	1890	1890	1890	1890	1890	1890
R^2	0.185	0.255	0.815	0.824	0.185	0.255	0.816	0.824

Table 10 – Differences-in-differences using instrumented net sales

The table reports the results from difference-in-differences (DD) estimations using predicted sales as independent variable instead of a post-Katrina indicator. For public hospital financing (Columns 1-2), we use as dependent variable the natural logarithm of the dollar county-year level total municipal (non-conduit) bond issuance for hospital purposes. For public hospital investments (Columns 3-4), we use as dependent variable the public hospital-year total capital expenditure scaled by beginning of year total assets. For private hospital investments (Columns 5-6), we use as dependent variable the private hospital-year total capital expenditure scaled by beginning of year total assets. PredictedSales is the fitted value of the dependent variable in the second state regressions reported in Panel B of Table 2. This variable measures the aggregate amount of insurers' net sales of NY municipal bonds caused by Hurricane Katrina. PubHMuni equals one for a given public hospital when it is located in a county that has issued municipal (non-conduit) bonds for hospital purposes between 2000 and 2005, and zero otherwise. For a given private hospital, PrvHNeibr equals one if the hospital is located in the neighborhood of a public hospital with a PubHMuni=1. To measure the neighborhood, we first manually collect the latitude and longitude for each private hospital. Using the coordinates, we measure all distances (in miles) between a given private hospital and all public hospitalswith a PubHMuni=1; of these distances, we keep the shortest, so that a given private hospital has only one shortest distance. Finally, we calculate the average of the shortest distance for all private hospitals. For each hospital, PrvHNeibr equals one if its shortest distance is below the average, and zero otherwise. This table uses the full sample of insurers who held more than 10% municipal bonds at the end of 2004. We control for insurer fixed effects (Insurer FE) and year-quarter fixed effects (Time FE). As a result, the levels of PubHMuni, PrvHNeibr, and PredictedSales are absorbed by these fixed effects. Standard errors are clustered at the hospital level and t-statistics are reported in parentheses. ∗∗∗, ∗∗, and ∗ indicate significance at the 1%, 5%, and 10% level, respectively. See Appendix A for all other variable definitions.

Dependent Variables	*log(county-hospital level issuance for hospital purposes)*		*Public hospital capex/lag asset*		*Private hospital capex/lag asset*	
	(1)	(2)	(3)	(4)	(5)	(6)
PubHMuni * PredictedSales	-1.357***	-1.359***	-0.004***	-0.004***		
	(-3.80)	(-3.77)	(-2.93)	(-2.79)		
PrvHNeibr *PredictedSales					0.017**	0.018**
					(2.03)	(2.07)
Asset Growth		0.553		0.009**		0.031
		(0.46)		(2.14)		(0.67)
Hospital FE	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES
N	290	290	348	348	1,246	1,246
R^2	0.108	0.108	0.669	0.674	0.849	0.849

Table 11 – Fire sales of municipal bonds and insurers' sale pressure, all disasters

The Table reports the municipal bonds most sold in the three months subsequent to the natural disasters in our sample, together with those bonds' lowest Cumulative Abnormal Returns (CARs) over the same period, and also the insurers' aggregate net sales as a proportion of the aggregate excess supply of the bonds. Data on municipal bonds trading by insurers and other investors is not available prior to 2005.

Disasters	Year	States	Bonds most sold	CAAR	Insurers' % of Excess Supply
Alison	2001Q2	TX, MO	DC	–2.84%	N/A
Charley et al.	2004Q3	FL, AL	PR	–0.91%	N/A
Katrina	2005Q3	LA, MS, AL	NY	–0.92%	80%+
Gustav, Ike	2008Q3	TX, LA	GA	–1.28%	100%+

Table 12 – Differences-in-differences pooling all disasters

The table reports the results from difference-in-differences (DD) estimations using all major disasters (Hurricanes Charley, Frances, Ivan, Jeanne in 2004 impacted PR muni bond & hospitals; Hurricane Katrina in 2005 impacted NY muni bond & hospitals; Hurricanes Gustav, Ike in 2008 impacted GA muni bond & hospitals. See Appendix C for further details on other disasters). We use post-Disaster indicator instead of a post-Katrina indicator to reflect post disaster years for corresponding states (post-2004 for PR hospitals; post-2005 for NY hospitals; post-2008 for GA hospitals). For public hospital financing (Columns 1-2), we use as dependent variable the natural logarithm of the dollar county-year level total municipal (non-conduit) bond issuance for hospital purposes. For public hospital investments (Columns 3-4), we use as dependent variable the public hospital-year total capital expenditure scaled by beginning of year total assets. For private hospital investments (Columns 5-6), we use as dependent variable the private hospital-year total capital expenditure scaled by beginning of year total assets. PubHMuni equals one for a given public hospital when it is located in a county that has issued municipal (non-conduit) bonds for hospital purposes during five years prior to the disaster, and zero otherwise. For a given private hospital, PrvHNeibr equals one if the hospital is located in the neighborhood of a public hospital with a PubHMuni=1. To measure the neighborhood, we first manually collect the latitude and longitude for each private hospital. Using the coordinates, we measure all distances (in miles) between a given private hospital and all public hospitals with a PubHMuni=1; of these distances, we keep the shortest, so that a given private hospital has only one shortest distance. Finally, we calculate the average of the shortest distance for all private hospitals. For each hospital, PrvHNeibr equals one if its shortest distance is below the average, and zero otherwise. This table uses the full sample of insurers who held more than 10% municipal bonds at the end of the year prior to the corresponding disaster. We control for insurer fixed effects (Insurer FE) and year-quarter fixed effects (Time FE). As a result, the levels of PubHMuni, and PrvHNeibr,are absorbed by these fixed effects. Standard errors are clustered at the disaster level (clustering at hospital level gives similar statistical significance. See Appendix C Tables C11, C12, and C13) and are reported in parentheses. ∗∗∗, ∗∗, and ∗ indicate significance at the 1%, 5%, and 10% level, respectively. See Appendix A for all other variable definitions.

Dependent Variables	*log(county-hospital level issuance for hospital purposes)*		*Public hospital capex/lag asset*		*Private hospital capex/lag asset*	
	(1)	(2)	(3)	(4)	(5)	(6)
PubHMuni * PostDisaster	-1.862***	-1.884***	-0.048***	-0.047***		
	(-6.30)	(-6.49)	(-3.21)	(-3.22)		
PrvHNeibr * PostDisaster					0.051***	0.055***
					(6.93)	(9.67)
Asset Growth		-1.887***		-0.005		0.104
		(-3.62)		(-0.08)		(1.31)
Asset Growth * PubHMuni		3.414		-0.037		
		(1.55)		(-1.35)		
Asset Growth * PrvHNeibr						-0.005
						(-0.20)
Asset Growth * PostDisaster		3.092***		-0.002		0.003
		(15.03)		(-0.03)		(0.03)
Hospital FE	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES
N	1,317	1,317	1,227	1,227	3,548	3,548
R^2	0.576	0.577	0.512	0.513	0.754	0.758