Journal of
Risk and Financial Management

MDPI

Article

Flood Insurance, Building Codes, and Public Adaptation: Implications for Airport Investment and Financial Constraints

Abderrahim Assab

Accounting and Finance Group, University of Edinburgh Business School, University of Edinburgh, Edinburgh EH8 9JX, UK; a.assab@sms.ed.ac.uk

Abstract: This paper investigates the impact of flood management policies on airport investment and the resulting financial constraints. Specifically, it examines the effects of flood insurance, building codes, and public adaptation investment on the investment decisions of 100 United States airports located in flood-prone areas. The paper estimated the financial loss from extreme precipitations and flooding using novel data from the United States Federal Emergency Management Agency, and a differences-in-differences framework leveraging the introduction of the 2012 Biggert–Waters reform of the National Flood Insurance Program. The findings reveal that while flood insurance costs negatively influence overall airport investment, they do not significantly affect investment–cash sensitivity. On the other hand, the introduction of stricter building codes and public adaptation investment leads to increased cash usage for investment purposes, particularly among airports exposed to extreme precipitation and flood risks. Furthermore, the analysis suggests that the observed increase in financial constraints resulting from stricter building codes and public adaptation investment is likely driven by the asymmetry of information rather than the materiality of flood risk. In other words, public investment in flood risk reduction appears to signal to investors that the airport is exposed to flood risk, potentially leading to increased financial constraints. This finding highlights the importance of considering information asymmetry when assessing the impact of flood management policies on financial constraints. Understanding the underlying drivers of these effects is crucial for supporting resilient infrastructure development and informing effective decision-making in flood-prone areas.

Keywords: flood insurance; physical climate risk; flood risk management; financial constraints; infrastructure finance; climate finance; NFIP; Biggert–Waters

JEL Classification: F21; F34; G12; G15; G21; G23

Citation: Assab, Abderrahim. 2023. Flood Insurance, Building Codes, and Public Adaptation: Implications for Airport Investment and Financial Constraints. *Journal of Risk and Financial Management* 16: 363. https://doi.org/10.3390/jrfm16080363

Academic Editors: Eleftherios I. Thalassinos and Simon Grima

Received: 7 July 2023
Revised: 31 July 2023
Accepted: 1 August 2023
Published: 7 August 2023

1. Introduction

Airports are highly susceptible to financial losses and damages caused by extreme precipitation and floods (Burbidge 2016; Poo et al. 2018; Vogiatzis et al. 2021). In the meanwhile, airport operators need to regularly invest in the upgrade and maintenance of buildings and runways. They can finance such investments externally through capital markets or using internal cash resources. The emerging climate finance literature shows that exposure to flood risk increases the cost of external finance when investment is financed through instruments such as sovereign (Kling et al. 2021; Dey 2022), municipal (Painter 2020; Goldsmith-Pinkham et al. 2021), and corporate (Allman 2022) bonds or through project finance (Assab 2023). When external finance is constrained, airports might shift to cash as an alternative way to finance investment. The pecking order theory (Myers and Majluf 1984) and investment–cash sensitivity literature (Fazzari et al. 2000; Hovakimian and Hovakimian 2009; Mulier et al. 2016) predict such a shift.

The flood-related financing constraints that would lead airport operators to shift from external financing to cash in order to finance investment are not only linked to exposure to floods. Such financial constraints could also result from the policies in place in response to flood risk. Policymakers can respond to flood risk through market-based instruments such as flood insurance, command-based instruments such as building codes or public investment in flood risk adaptation (Filatova 2014). These policies are often implemented at the same time with more or less consistency across sectors (Kunreuther 2021). They can contribute to increasing external financial constraints by signalling to investors that a given asset is located in a flood-prone area. Evidence from the United States and Europe suggests that the housing sector has experienced these constraints. Increases in flood insurance premiums result in large reductions in property prices, reduced access to finance, and increased maintenance costs (MacDonald et al. 1990; Abbott 2014; Indaco et al. 2019).

To the best of our knowledge, the impact of exposure to flooding on financial constraints, measured through an increase in reliance on cash to finance investment, has not been studied. In addition, studies of the implications of flood risk on external finance have focused on flood risk exposure, and not on the policies put in place in response to the flood risk. Our study aims at bridging this gap.

Our objective was to provide evidence that flood risk management policies can lead to financial constraints on infrastructure operators, as exhibited by an increase in the use of cash to finance investment. We selected 100 airports located in the United States. We identified three types of airports: airports that are not exposed to flood risk, airports that experience large financial losses in cases of extreme precipitation, and airports that are located in flood-prone areas. For each airport, we collected data on investment per asset, cash per asset, a proxy of Tobin's q, and flood management policies in place in the county where it is located. We chose to use a differences-in-differences framework to study the effects of flood insurance, building codes, and public adaptation investment. As a shock, we used the reform of the National Flood Insurance Program (NFIP) introduced in 2012, known as the Biggert–Waters reform.

We found that increases in flood insurance costs had a negative effect on investment among airports in the sample, with a standard deviation increase in insurance costs leading to a 30% increase in investment. However, flood insurance costs did not appear to impact investment-cash sensitivity, indicating that flood management through market-based instruments such as insurance does not result in financial constraints. The introduction of the Biggert–Waters 2012 reform, which partly focused on flood risk mapping, led to the increased usage of cash for investment among airports located in FEMA-designated flood-prone areas. These airports used 15% more cash for investment compared to non-exposed airports after the reform, potentially due to information asymmetries and the availability of new flood maps.

Across our sample, the presence of the International Building Code (IBC) 2015 in the county where an airport is located resulted in a 14% increase in cash used for investment. For airports in flood-prone areas, this figure rose to 17%. Interestingly, the airport operators who were most attentive to building codes were not those located in flood-prone areas but, rather, those experiencing drops in free cash flows due to extreme precipitation. These airports used 27% more cash for investment.

We found that a standard deviation increases in adaptation investment per unit of benefit led to a 3.8–5% increase in the use of cash for investment among airports exposed to extreme precipitation and flood risks. These findings highlight the impact of flood insurance costs, flood risk mapping, building codes, and public adaptation investment on airport finances, as well as their varying effects on investment and cash usage.

Our findings expand the climate finance literature on financial constraints due to physical climate risk. We provide evidence about financial constraints complementary to the results on external finance from previous studies (Panagoulia and Dimou 1997; Wilby and Keenan 2012; Barrage and Furst 2019; Berg et al. 2016; Bernstein et al. 2019; Painter 2020; Allman 2022; Dey 2022). We expand the literature on the financial implications of flood insurance for infrastructure asset operators and confirm the findings of previous studies (MacDonald et al. 1990; Abbott 2014; Indaco et al. 2019) for housing finance.

Our results expand the rich corporate finance literature on investment–cash sensitivity (Brown and Petersen 2009). In particular, we contribute to the literature on the information asymmetry and agency issues that could lead to increased investment–cash sensitivity (Ascioglu et al. 2008; Chen and Chen 2012; Francis et al. 2013; Andrén and Jankensgård 2015). All three of the policies that we studied can contribute to alleviating some of the information asymmetry regarding airports' exposure to climate risks.

Finally, this paper contributes to the policy discussion on the role of climate risk disclosure in promoting the transfer of and reduction of physical climate risks. It highlights the need for a design of risk transfer mechanisms, such as flood insurance, in combination with public risk reduction and adaptation investment, that create incentives for infrastructure companies to engage in autonomous flood risk mitigation investment, thereby ensuring an optimal allocation of climate risk between the public and private sectors.

Our investigation, while concentrated on airports, opens up promising avenues for future research. These include looking into smaller issuers who face higher initial external financial constraints and extending the analysis to other types of infrastructure assets. The dynamic relationship between insurance premiums and adaptation investment further poses intriguing questions for subsequent studies.

Section 2 of this paper discusses our motivation and hypothesis construction. Section 3 presents our methodology. Section 4 discusses the results of our analysis, and Section 5 presents a series of robustness checks that support our findings.

2. Infrastructure Flood Risk Management and Financial Constraints

2.1. Flood Management Policies as a Financial Constraint

The pecking order theory of Myers and Majluf (1984) provides a framework for how firms select sources of financing in order to pursue investment opportunities. This suggests that firms tend to rely on internal sources of funds first before external financing through debt or equity.

Most of the literature investigating the impact of physical climate risks on asset pricing is concerned with how these climate risks change the external financing conditions of firms (Panagoulia and Dimou 1997; Wilby and Keenan 2012; Hirabayashi et al. 2013; Kundzewicz et al. 2014; Burbidge 2016; Barrage and Furst 2019; Bernstein et al. 2019; Baldauf et al. 2020; Cevik and Jalles 2020; Filippova et al. 2020; Garcia-Alonso et al. 2020; Pagliari 2021; Garbarino and Guin 2021; Kling et al. 2021; Wasko et al. 2021; Vogiatzis et al. 2021; Bajaj and Kaur 2022; Cevik and Jalles 2022). Several studies (Mizen and Vermeulen 2005; Arslan et al. 2006; Hovakimian and Hovakimian 2009; Mulier et al. 2016) show that when external financing conditions are constrained, the sensitivity of firms' investment to their cash holdings increases. Firms resort back to cash in order to finance investments.

The study of investment–cash sensitivity is one of the largest bodies of literature in corporate finance (Brown and Petersen 2009). However, to the best of our knowledge, the impact of climate change considerations on investment–cash sensitivity has not been studied. The investment–cash relationship is a measure of internal financing constraints (Fazzari et al. 2000). Studying the impact of physical climate risks on investment–cash sensitivity is a way to provide a more complete view of how these risks can lead to financial constraints for firms.

Flood management policies such as the ones introduced by the NFIP could impact investment–cash sensitivity in two ways: first, through the direct impact on cash flows caused by increasing insurance costs; second, because of the information asymmetry and agency issues that can arise due to the lack of understanding of flood risk (Ascioglu et al. 2008; Chen and Chen 2012; Francis et al. 2013; Andrén and Jankensgård 2015).

2.2. Market- vs. Command-Based Flood Risk Management Incentives

We chose to focus our study on airports. Airports are exposed to financial losses and damages as a result of extreme precipitation and floods. Poo et al. (2018) performed a comprehensive literature review of 105 papers on the adaptation of seaports and airports to climate change and concluded that "comparing all climate threats, sea level rise (SLR) and storming and flooding currently present, according to the literature, the most severe impact in ports and airports".

Airports need to implement flood risk management measures to respond and adapt to this challenge. The measures can be classified as hard and soft strategies (Becker et al. 2013). Soft strategies can include enhanced emergency evacuation plans, increased standards of construction, and increased access to finance for adaptation, while hard strategies can include raising elevation, building coastal defenses, expanding dredging, and nourishment programmes (Becker et al. 2013; Yang et al. 2018; Lin et al. 2020).

Burbidge (2016) studied climate change risks to European airports and identified five risk areas, including precipitation and floods. Changes in precipitation patterns can require increases in the separation distance between aircraft, the size of the drainage infrastructure, or additional protection of ground transport equipment and electrical equipment that can be inundated. Vogiatzis et al. (2021) performed an adaptation study on Athens International Airport (A.I.A.). They projected the usual temperature, rainfall, and wind speed parameters up to 2040 and 2070 using various climate models. They identified three risks facing the airport: (1) the increase in energy demand for cooling and, therefore, in the energy bill; (2) localized flooding in the drainage infrastructure during heavy rain events; (3) safety and health risks for airport staff. They showed that stressing drainage infrastructure to ensure robustness to extreme flooding events is the most effective physical adaptation strategy for airports (Vogiatzis et al. 2021).

Policymakers have an array of incentives that they can implement to encourage infrastructure operators to invest in adaptation to flooding. Some of these policies are market-based, while others are command-based. The climate economics literature often debates the relative merit of market-based instruments in comparison with command-and-control policies (Lamperti et al. 2020). Aerts (2018), Filatova (2014), and Kunreuther (2021) concluded that policymakers should use market-based instruments and command-based instruments in combination. Filatova (2014) reviewed climate adaptation policies and studied the role of market-based instruments for flood risk management. She found that flood risk management is dominated by "planned adaptation" measures, such as spatial planning and engineered flood defences, which are driven by command-and-control policies such as building codes and public investment in flood management. Market-based instruments, on the other hand, such as flood insurance or preferential taxes, are designed to promote autonomous adaptation.

We are interested in understanding whether these market-based and command-based instruments result in financial constraints for airport companies. The climate finance literature provides evidence that exposure to flood risk can increase the cost of external finance. Such evidence is lacking when it comes to understanding the link between flood risk "management policies" and "internal" financial constraints.

To investigate this linkage, we need to observe an economy where both market-based and command-based instruments are in place, along with financial data for airports. The United States implemented both instruments in the context of its Federal Emergency Management Agency (FEMA)'s National Flood Insurance Program (NFIP). In the rest of this section, we will present the NFIP's market-based and command-based policies, as well as our measure of financial constraints.

2.3. U.S. Flood Risk Management Policy

Insurance-based incentives can promote flood adaptation. Surminski and Oramas-Dorta (2014) studied 27 flood insurance schemes in low- and middle-income countries and found that risk transfer without risk reduction, i.e., insurance without adaptation, can lead to moral hazard. Looking at public–private flood insurance in France and Germany, Hudson et al. (2019) found that, for households, insurance-based incentives are able to promote adaptation to flood risk. FEMA's NFIP is an example of such an insurance-based incentive.

The National Flood Insurance Act of 1968 created the National Flood Insurance Program (NFIP) in the United States to provide households and businesses with flood insurance solutions[1]. This programme is managed by the Federal Emergency Management Agency (FEMA) and has delivered more than USD 1.3 trillion in flood risk insurance coverage[2].

Multiple reforms were introduced to the initial flood insurance act, including in 1994, 2004, 2012, and 2014[3]. The Biggert–Waters Flood Insurance Reform Act of 2012[4] authorized two changes that had a significant impact on households and firms: first, the reform authorized the funding of the national flood mapping programme; second, it authorized increases in certain insurance premiums in order to better reflect the risks.

The NFIP's insurance component put financial constraints on residential property owners. MacDonald et al. (1990) found that increases in flood insurance premiums had an impact on housing prices. Abbott (2014) found that the Biggert–Waters reform resulted in increases of up to USD 12,000 a year in insurance costs for owners of homes located in flood-prone locations. Indaco et al. (2019) found that properties located in areas identified as flood zones after the 2012 NFIP reform had lower values. Indaco et al. (2019) also found that insurance costs were USD 3500 higher on average for properties located in flood zones.

To the best of our knowledge, the impact of the NFIP's insurance component on infrastructure finances has not been studied. The NFIP is a programme that also influences the evolution of building codes and public investment, at the county-level, for flood risk reduction.

The introduction of flood management requirements in building codes is one of the key incentives driving investment in flood risk management (Aerts 2018). Building codes[5] are an important part of the global climate change adaptation strategies (Kreibich et al. 2015). They fall under the soft flood risk reduction strategies (Du et al. 2020) and are characterized by a high benefit–cost ratio in comparison to hard flood risk reduction strategies (Aerts et al. 2013; Du et al. 2020; de Ruig et al. 2020). However, evidence indicates, in the case of households for instance, that private agents can underinvest in private adaptation if driven only by the exposure to flood risk under a building code requirement (Hovekamp and Wagner 2023).

Under the current NFIP, purchasing flood insurance is currently mandatory for properties located in 100-year flood areas. As climate change increases the frequency and severity of floods, McShane and Yusuf (2019) studied the possible impacts of increasing the requirement for properties located in 500-year flood areas and concluded that such a mandate could put pressure on local governments to increase public adaptation investment.

As climate change increases the frequency and severity of flood events, it will be critical to understand whether planning- and engineering-based flood management policies and public adaptation investment, in combination with insurance, result in additional financial constraints on infrastructure operators.

2.4. Hypothesis Construction

Infrastructure companies such as airports located in flood-prone areas are expected to take action either to transfer flood risk, e.g., through insurance, or to invest in adaptation to reduce flood risk. This can result in increased financial constraints on the airport companies. Such constraints have been documented in the residential property sector (Thomas and Leichenko 2011; Abbott 2014; Indaco et al. 2019; Han and Peng 2019).

Investment–cash sensitivity is a key measure of financial constraints. Our objective was to understand the effects of flood insurance, building codes, and public flood adaptation investment on airport investment–cash sensitivity. We built three hypotheses to achieve this objective.

One of the major reforms of the NFIP was the Biggert–Waters 2012 reform, which promoted flood mapping and insurance rate increases to better reflect exposure to flood risk. Our first hypothesis was that the Biggert–Waters 2012 reform should alleviate information asymmetry around flood risk and induce changes in investment-cash sensitivity. The insurance reform signals to investors the level of risk exposure of the airports. As a result, we expect that after the introduction of the reform, airports will resort to the use of cash for investment as their cost of external financing increases. Our first hypothesis is as follows:

H1. *There was an increase in airports' investment sensitivity to cash after the introduction of the Biggert–Waters 2012 reform for airports exposed to flood risk.*

Han and Peng (2019); Sastry (2021), and Benetton et al. (2022) suggested that the risk reduction (i.e., adaptation) behaviour of households is also affected by public sector flood risk reduction investment in the county where the residence is located. This means that when a county's public authorities invest in measures to reduce flood risk, households also invest in measures at the level of their property. We expect that such a relationship should also exist for airport operators. In the same way, the introduction of insurance can signal to investors that a given airport is exposed to flooding, and public flood risk reduction measures in a county can signal to investors that all the infrastructure assets located in such a county are exposed to flooding. Investors might become risk averse as a result of the asymmetry of information regarding the adaptation measure in place at the airport.

Our second hypothesis was that public adaptation spending in the county where an airport is located can also result in financial constraints on airports. Our second hypothesis is therefore as follows:

H2. *Public flood adaptation investment in the county where an airport is located increases the sensitivity of investment to cash for airports exposed to flood risk.*

Finally, the implementation of enhanced flood management requirements as a part of building regulations for assets located in flood-prone areas might also trigger investor risk aversion. The flood-proofing of buildings located in flood-prone areas is mandatory in many areas where the airports in our sample are located. Insurance risk transfer mechanisms and public adaptation investment are implemented in parallel with the introduction of flood risk reduction measures in building codes. We assessed the effect of the introduction of the 2015 International Building Code (IBC) on airports' investment–cash sensitivity through the following hypothesis:

H3. *Investment–cash sensitivity is higher for airports exposed to flood risk and located in areas where the 2015 IBC is in place.*

We procured data for our key explanatory variables from FEMA's NFIP portal. To examine the impact of flood insurance, we employed a multivariate regression that incorporated the average flood insurance premium in an airport's county, along with a differences-in-differences approach using the implementation of the Biggert-Waters reform as a regulatory shock. In order to assess the influence of public investment, we constructed our investment variable as FEMA's public investment in the airport's county divided by the economic benefit derived from these investments. We then executed a multivariate analysis using our investment variable to elucidate variations in investment sensitivity to cash.

To explore the effect of building codes and flood management policies, we referred to the FEMA building codes platform to determine the specific building code enforced in the county where each airport is situated. We subsequently estimated a multivariate model incorporating a dummy variable denoting the presence of the 2015 International Building Code in each airport's county.

We estimated exposure to extreme precipitations and flooding in terms of potential financial losses, considering firstly the financial repercussions arising from drops in operational income and secondly, those due to physical damage to structures and runways. We adhered to standard practices within the investment-sensitivity literature when selecting control variables. The comprehensive methodology is elaborated in the following section.

3. Methodology and Data

3.1. Variable Construction

Our objective was to understand how policies aiming at transferring and reducing flood risk can result in financial constraints.

We proceeded following a six-step process: First, we collected the balance sheets, income statements, and cash flow statements of 100 airports in the United States. Second, we analyzed the exposure of the airports' operations and cash flows to variations in precipitation and identified the most exposed airports. Third, we analyzed the exposure of the airports' buildings to flood risk and identified the most exposed airports. Fourth, we compiled adaptation investment and economic benefit data for the counties and states where the airports are located and constructed an adaptation variable expressed in terms of investment in adaptation per unit of benefit. Fifth, we collected information on building codes in the county where each airport is located.

Except for the financial data that we collected from Bloomberg, we used publicly available data for the construction of our variables. In particular, we extensively used FEMA resources in combination with geospatial analysis using ArcGIS pro.

Finally, we ran a multivariate analysis on airports' investment, with the objective of understanding the sensitivity of investment to cash in the presence of insurance, building codes, and public investment. We compared airports exposed to extreme precipitation and flooding to those that are not.

In the rest of this section, we describe each step in detail.

3.1.1. Identification of the Airports in Our Sample

We selected the Bloomberg Municipal Bond Monitor's top 100 airport bond issuers. We concentrated on these 100 prominent bond issuers due to their significant dependence on external financing. We anticipated that these U.S. airports might demonstrate potential shifts from external financing to cash as a response to the implementation of flood management policies. Figure 1 shows the locations of the airports. We used Bloomberg LP to access the financial statement of each airport between 2005 and 2021. We focused on three time series for each airport: the free cash flow[6] (FC), operating cash inflow (OCI), and capital expenditure to the asset (CEA) ratio. We used free cash flows to compute airports' exposure to variations in precipitation, CEA as our independent investment variable, and OCI as our dependent cash variable.

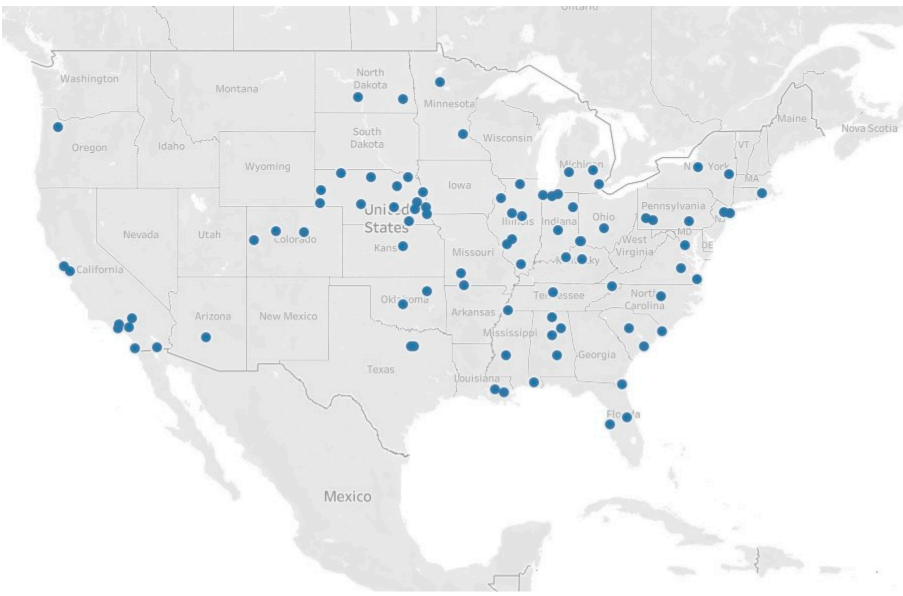

Figure 1. Airport locations.

We classified airports into two categories: exposed and non-exposed to flood risk. We further assessed the exposure to flood risk in two different ways: First, we considered airports as being exposed to flood risk when their FCs are impacted by extreme precipitation. Second, we considered airports as being exposed to flood risk when they are located in flood areas. The first measure assesses flood risk exposure based on the impact of precipitation on operations—for instance, disruption of traffic. The second assesses flood risk exposure based on the damage to airports in cases of flooding.

In the rest of this section, we explain the design of each of these two flood risk indicators.

3.1.2. Measuring the Impact of Extreme Precipitation

Airports can be subject to financial losses following extreme precipitation events. For each airport, we identified the year where the greatest precipitation occurred. We then calculated the variation in free cash flows as a percentage between the year before the event and the year after the event (Equation (1)). We used annual precipitation data, measured in inches between 2005 and 2021, at the location of the airports acquired through the United States (US) National Centers for Environmental Information of the National Oceanic and Atmospheric Administration (NOAA). We considered airports experiencing a drop in FCF of more than 30% as being highly exposed to variations in precipitation.

$$OperationsExposure_i = \frac{FreeCashFlow_{i,YearMaxPrecipitations} - FreeCashFlow_{i,YearMaxPrecipitations-1}}{FreeCashFlow_{i,YearMaxPrecipitations-1}}. \quad (1)$$

3.1.3. Measuring the Impact of Flood Damage

Airports can also be exposed to financial losses when floods damage their buildings and runways. We estimated the expected loss from this damage for each of the airports in our sample using Equation (2) and as described in previous studies (Dawson and Hall 2006; Huizinga et al. 2017; Dawson et al. 2018; Assab 2023).

$$\begin{aligned} ExpectedDamage_i = \sum BuildingDamage(d)_j \times MaxDamage_j + \\ \sum RunwayDamage(d')_k \times MaxDamage_k. \end{aligned} \quad (2)$$

For every airport i, we manually identified all of the buildings and runways using the airport's satellite image and the geospatial analysis tool ArcGIS. We then estimated the expected damage to each building or runway based on the flood depth at the building's location, the damage function, and the maximum damage. We used flood maps for the counties where the airports are located, obtained from the US Federal Emergency Management Agency (FEMA)'s Flood Map Service Center, to identify the flood depths d at the location of buildings and d' at the location of runways.

We then used two separate damage functions to estimate the expected damage as a percentage of the maximum damage to buildings and runways. For buildings, we used Huizinga et al.'s damage function for commercial buildings in North America. For runways, we used damage functions for roads as a close approximation. To estimate the maximum damage to buildings, we multiplied the size of the building in square meters by the average cost per square meter of building a commercial building in the area where the airport is located. For runways, we multiplied the length of the runway by the average cost of building a runway, in USD per meter.

Figure 2 provides an illustrative assessment for Gulfport-Biloxi International Airport. The areas labelled as "Building" and "Runway" in the graphic denote the airport's infrastructure. The remaining colors in Figure 2 correspond to flood hazard zones with different frequencies, as per FEMA's flood mapping for the city of Gulfport, where the airport is located. The overlapping area between the airport's infrastructure and the flood zones indicates the portions of the airport that would be susceptible to damage in the event of a flood.

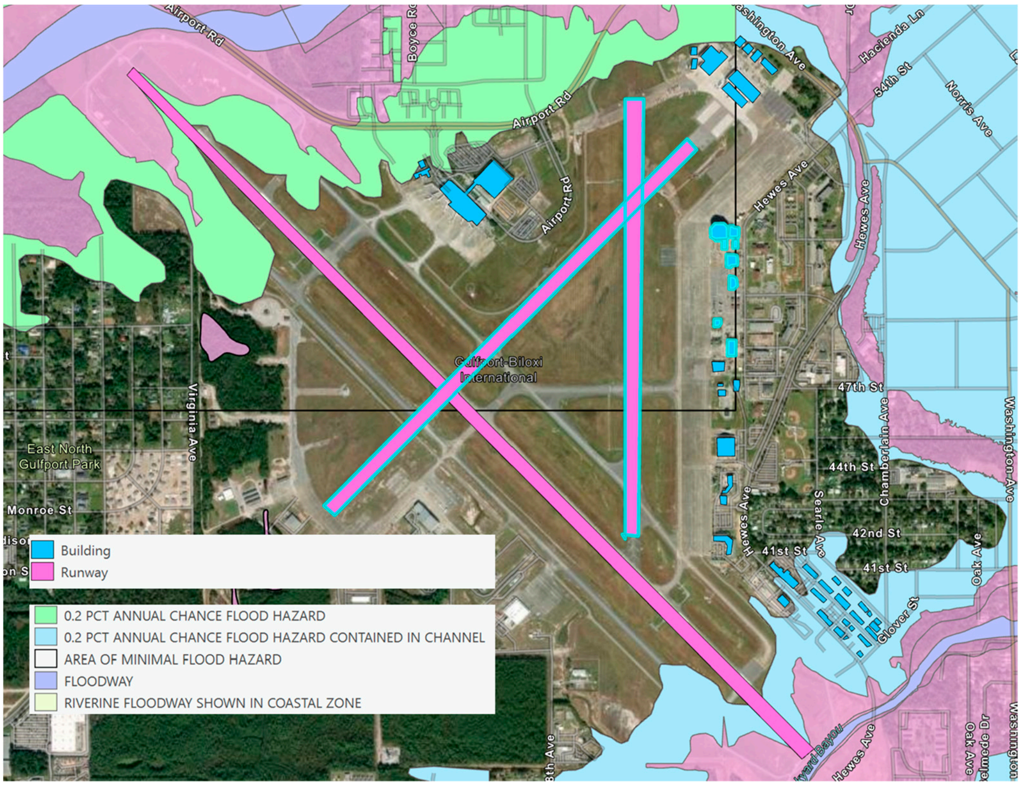

Figure 2. Example of flood exposure analysis for Newark Liberty International Airport.

3.1.4. Estimating Flood Insurance Premiums

First, we are interested in the effect of the Biggert–Waters 2012 reform on the sensitivity of investment to cash. In addition to the introduction of the reform as a shock, we also used time series describing the evolution of insurance premiums in the county where the airport is located as a control variable in our multivariate model. We collected data on the flood premiums from the FEMA Flood Insurance Data and Analytics platform[7] and calculated the annual average insurance premiums for our airports.

3.1.5. Estimating County-Level Public Adaptation Investment

Our objective was to understand whether public investment in adaptation to flooding in the county where an airport is located has an effect on the airport's investment–cash sensitivity.

We used the Federal Emergency Management Agency (FEMA) data on flood adaptation investment. For each airport, we calculated the cumulative annual investment in flood management between 2005 and 2021.

FEMA also quantifies and tracks the benefits of each of its programs through a benefit–cost analysis (BCA) assessment. We calculated the cumulative benefit of the flood management interventions in the county and state where the airport is located. The result was a time series of cumulative benefits of flood management programs between 2005 and 2020 for each airport.

Finally, we used the two time series to estimate adaptation investment per unit of benefit as our adaptation variable *FloodAdaptation*, as described in Equation (3), where y refers to the year in which the investment took place.

$$FloodAdaptation_y = \frac{\sum_{j=2005}^{y} FloodProgramInvestment_j}{\sum_{j=2005}^{y} FloodProgramBenefit_j}. \quad (3)$$

3.1.6. 2015 International Building Codes

In addition to the effects of public adaptation investment and insurance on airports' investment–cash sensitivity, we are interested in understanding the role of private adaptation measures implemented by the airports themselves. The best way to capture such private adaptation measures is through the mandatory flood management requirements in the building code. The 2015 International Building Code (IBC) has multiple flood management provisions and is in place in 70% of the counties where our airports are located.

We used FEMA's National Building Code Adoption Tracking Portal[8] to identify the building code in place in the county where a given airport is located.

3.2. Sample and Summary Statistics

Table 1 reports summary statistics for our variables of interest.

We included 100 U.S. airports in our sample. The annual operating inflow for the 100 airports increased from an average of USD 130 million in 2006 to USD 190 million. The average annual capital expenditure to asset ratio stayed relatively stable, at an average multiple of 6.4 between 2005 and 2022. Figure 3 shows the dynamic of the average operating cash inflow and capital expenditure to asset ratio over this period for Newark Liberty International Airport.

The average operating cash inflow was USD 160 million, the median was USD 33 million, and the maximum was around USD 5 billion. The average capital expenditure to asset multiple was 6, the median value was 5, and the maximum was around 33. Newark Liberty International Airport (EWR) is the airport with the highest operating cash inflow, at around USD 5 billion. In terms of capital expenditure to assets, Syracuse Hancock Airport and Eagle County Regional Airport showed the largest figures, at a multiple of around 32.

Our first indicator of exposure to flood risk is the percentage drop in free cash flows after an event of extreme precipitation. The maximum precipitation for the airports in our sample was 50 inches on average. For each airport, we identified the year of maximum precipitation in the period between 2005 and 2022 and estimated the variation in free cash flows between the event year and the year before.

Table 1. Summary Statistics.

	Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum
Year	2005	2009	2014	2014	2018	2022
Anomaly	−35.3	−5.0	−0.4	−1.1	3.0	26.3
Capital Expenditure to Asset Ratio	0.0	2.7	5.3	6.3	8.2	34.0
Operating Cash Flow Income	0.0	6.9	33.1	162.8	96.7	5548.6
Investment per Benefit	0.5	1.0	1.1	1.7	1.8	16.1
Investment per Benefit Awareness	0.1	0.1	0.8	18.2	1.9	182.5
Investment per Benefit Planning	1.0	3.0	12.0	295,102.0	45.0	21,119,798.0
Investment per Benefit Feasibility	0.0	0.0	0.3	8428.8	0.6	768,790.0
Investment per Benefit FloodControl	0.0	0.3	0.4	0.4	0.5	1.3
Investment per Benefit InfraProtectionInvest	0.1	0.4	0.6	0.5	0.6	1.0

Figure 3. Newark Liberty International Airport's operating cash inflow and capital expenditure to assets ratio.

Twenty-six airports in our sample saw a drop in free cash flows after an event of major precipitation. The average drop was −116%, the smallest was a 3% drop for Newark Liberty International Airport in 2011, and the maximum was almost 500% for Oklahoma City Airport in 2015. Figure 4 shows the free cash flows before and after the year of maximum precipitation.

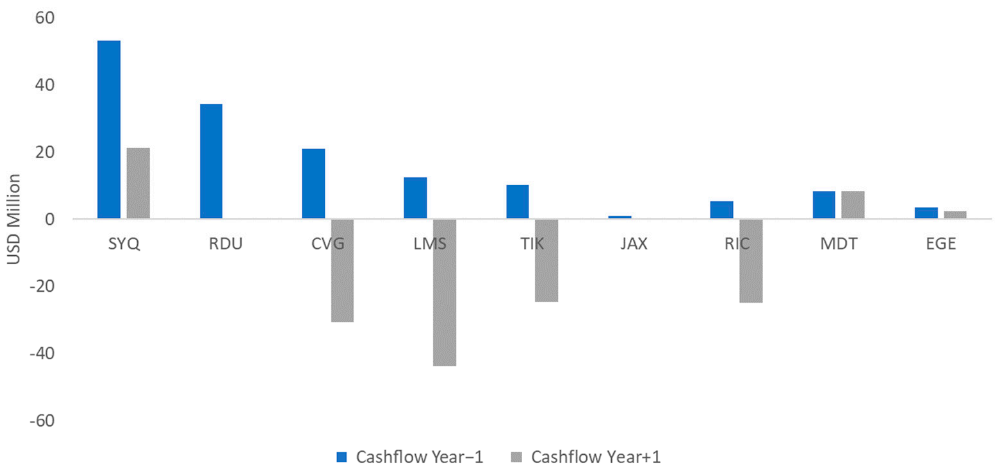

Figure 4. Examples of decreases in free cash flows after major precipitation events.

We assessed exposure to floods based on the methodology discussed earlier and the Federal Emergency Management Agency (FEMA) county-level flood maps. Twenty-five airports in our sample are located in flood-prone areas. For exposed airports, floods can result in an average of 1% damage to buildings and runways. Reagan National Airport (DCA), Newark Liberty International Airport (EWR), Harrisburg International Airport (MDT), Ontario International Airport Southern California (ONT), and San Francisco International Airport are all exposed to damage from flooding that amount to more than 2% of the value of the buildings and runways.

For our robustness checks, we used the correlation between free cash flows and precipitation as an alternative treatment. On average, the correlation between free cash flows and maximum annual precipitation was negative and around 10%. The largest correlation was for Huntsville Alabama Airport, at negative 60%. Ten airports in our sample had free cash flows that were negatively correlated with maximum precipitation, with a correlation of more than 30%.

The Federal Emergency Management Agency (FEMA) provides financing for a range of adaptation interventions aiming at mitigating the risk of floods. These interventions are implemented at the level of the state or the county.

The average cumulative investment in adaptation to flooding for a county or state where one of the airports in our sample is located was USD 134 million. The maximum investment was around USD 2.5 billion and corresponded to the state of Louisiana.

3.3. Model Specification

We used a difference-estimator methodology to evaluate the effect of the Biggert–Waters 2012 reform, following the approach used by Aretz et al. (2020) to trace the effect of collateral reform on credit, as well as by Benetton et al. (2022) to evaluate the impact of public adaptation investment on housing prices. We also referred to previous studies (Hovakimian and Hovakimian 2009; Schleicher et al. 2010; Larkin et al. 2018) when selecting the control variables for our study of the relationship between investment and cash. We estimated multivariate models, including time and firm fixed effects. The multivariate models can be written as follows:

$$I_{i,t} = \beta_0 + \beta_1 \text{Post}_t \times \text{Treated}_i + \beta_2 \text{CF}_{i,t-1} + \beta_3 \text{CND}_{i,t-1} + \gamma_a + \gamma_t + \varepsilon_{i,t} \quad i = 1, \ldots, N, \tag{4}$$

where I is the capital expenditure in year t divided by the total assets in year t for the airport i. *Post* is a dummy variable that is equal to 1 from the year 2012 onward. *Treated* is a dummy variable that is equal to 1 when the airport is exposed to variations in precipitation or flooding according to our risk variables. *CF* is the operating cash flow income of airport i in year $t-1$ divided by the total assets in year $t-1$. *CND* is the invested capital assets net of debt in year $t-1$ for airport i divided by the total assets in year $t-1$ for airport i. We used the invested capital assets net of debt as a proxy for the airport company's equity value and the ratio of CND divided by the total assets as a proxy of Tobin's q. This proxy is needed because the airports are not all listed and the data on the book value of the firms are absent. Gamma a is an airport fixed effect, and gamma t is a temporal fixed effect.

The β_1 coefficient in Equation (16) can be interpreted as the regression-based DID estimate after accounting for controls and fixed effects (Aretz et al. 2020).

In order to further investigate hypothesis H1, we ran a multivariate analysis including insurance premiums (*InsuranceCost*) in interaction with cash flows (*CF*), as described in Equation (9).

$$I_{i,t} = \beta_0 + \beta_1 \text{CF}_{i,t-1} + \beta_2 \text{CND}_{i,t-1} + \beta_3 \text{CF}_{i,t-1} \times \text{InsuranceCost}_{i,t-1} + \gamma_a + \gamma_t + \varepsilon_{i,t}. \tag{5}$$

We used the following model specification to test the validity of hypothesis H2 on the role of public investment in adaptation:

$$I_{i,t} = \beta_0 + \beta_1 \text{Post}_t \times \text{Treated}_i + \beta_2 \text{CF}_{i,t-1} + \beta_3 \text{CND}_{i,t-1} + \beta_4 \text{AI}_{i,t-1} + \beta_5 \text{CF}_{i,t-1} \times \text{AI}_{i,t-1} + \gamma_a + \gamma_t + \varepsilon_{i,t} \quad i = 1, \ldots, N, \tag{6}$$

where *AI* is the investment in adaptation to flooding in the county where the airport is located divided by the total economic benefit of the adaptation interventions. In Equation (6), the *CF* regressor is included in interaction with the *AI* variable.

We used the following model specification to test the validity of H3:

$$I_{i,t} = \beta_0 + \beta_1 \text{CF}_{i,t-1} + \beta_2 \text{CND}_{i,t-1} + \beta_3 \text{CF}_{i,t-1} \times \text{IBC}_{i,t-1} + \gamma_a + \gamma_t + \varepsilon_{i,t}, \tag{7}$$

where *IBC* is a dummy variable that is equal to 1 when the 2015 International Building Code, or more, is in place in the county where the airport is located.

Finally, we estimated a model that includes all of the indicators for the three policies in order to evaluate the comparative effect of each policy on investment–cash sensitivity, using Equation (8):

$$I_{i,t} = \beta_0 + \beta_1 \mathrm{CF}_{i,t-1} + \beta_2 \mathrm{CND}_{i,t-1} + \beta_3 \mathrm{CF}_{i,t-1} \times \mathrm{InsuranceCost}_{i,t-1} + \beta_4 \mathrm{CF}_{i,t-1} \times \mathrm{AI}_{i,t-1} + \beta_5 \mathrm{CF}_{i,t-1} \times \mathrm{IBC}_{i,t-1} + \gamma_a + \gamma_t + \varepsilon_{i,t}. \quad (8)$$

The variables are all defined in Table 2 below.

Table 2. Variables Description.

Variable	Description	Source
I	Capital expenditure to asset ratio is the capital expenditure of a given airport divided by the total assets of the airport at a given year	Financial statements data from Bloomberg LP
CF	Cash flow to asset ratio is the cash flow income from the operations of the airport divided by the total assets of the airport in a given year	Financial statements data from Bloomberg LP
CND	Invested capital assets net of debt is the difference between the invested capital assets and the total debt for the airport divided by the total assets of the airport in a given year	Financial statements data from Bloomberg LP
Exposed	Exposure to expected loss from the flood dummy variable equal to 1 when the airport's exposure to losses from flooding is non-null	Flood maps from FEMA
AI	Variable constructed as the cumulative investment in flood management measures, divided by the cumulative benefit estimation from these measures	Data on flood management programs of the Federal Emergency Management Agency (FEMA)

3.4. Addressing Endogeneity Concerns

To mitigate the risk of endogeneity, we employed several strategies in our study.

Simultaneity: We sought to address simultaneity bias by using exogenous variables in our model specification. The public investment in adaptation at the county level is exogenous to investment by airports as it considers investment in the entire county. For small countries, where an airport is the main target of investment, there could be simultaneity concerns, however, this is not the case for any airport in our sample. The 2015 IBC is a regulatory shock not linked to airports specific investment. Finally, in the case of insurance premiums, simultaneity could be an issue as premiums might be higher due to the lack of flood risk reduction by airports. We address such potential bias by using a differences-in-differences framework with the Biggert–Waters reform as a regulatory shock.

Omitted Variable Bias: We integrated a comprehensive set of control variables in our model, chosen based on prior literature and theoretical considerations, to reduce the risk of omitted variable bias. We also conducted a robustness check by varying the model specification and testing whether the main results were sensitive to the inclusion or exclusion of specific controls.

Measurement Error: We addressed the potential for measurement error by carefully selecting reliable data sources and conducting rigorous data checks. Measurement errors could have resulted.

Sample Selection Bias: We made a conscious effort to obtain a sample that is representative of the population of interest.

Common Cause Bias (Confounding Variables): We used fixed effects models to account for time-invariant unobserved confounding variables.

Autocorrelation (Serial Correlation): We addressed autocorrelation by examining the residuals of our regression models for autocorrelation using the Durbin–Watson test.

By adopting these measures, we believe our study effectively addresses potential sources of endogeneity, thereby increasing the validity and robustness of our findings. The main area of concern remains sample selection bias as we mainly focus on airports. Our findings need to be checked against the dynamic in other infrastructure sectors and using other methods of evaluation of flood risk.

Further details of these methods are discussed in the following subsections.

4. Flood Risk Management-Induced Financial Constraints

Our hypothesis is that policies aiming at transferring or reducing flood risk led to additional financial constraints on airport operators. For risk transfer, we chose to study a market-based instrument, i.e., flood insurance. For risk reduction, we chose two command-and-control risk reduction policies: public investment in flood adaptation and flood risk reduction in building codes.

In the rest of this section, we explore the sensitivity of cash flows to investment in the presence of each intervention.

4.1. Investment-Cash Sensitivity and the Biggert–Waters 2012 NFIP Reform

Before investigating the effect of the Biggert–Waters 2012 reform, we started by simply investigating whether flood insurance premiums have an effect on the sensitivity of investment to cash.

Table 3 reports the results of ordinary least squares and fixed-effect panel regressions, where *LogInsurance* is our key explanatory variable of interest. In Models (1) and (2), we performed the regressions on our entire data sample. In Models (3) and (4), we added *Exposure Flood Dummy*, a dummy variable that is equal to 1 when the airport is located in a floodplain according to FEMA's flood maps. Finally, in Models (5) and (6), we replaced *Exposure Flood Dummy* with *Operations Risk Dummy*, a dummy variable that is equal to 1 when an airport experiences losses in free cash flows of over 30% after an extreme precipitation event.

For all models, the effect of our control variables was consistent with the literature. We found that there is a positive and statistically significant relationship between *LogCF* and investment, as well as between *LogCND* and investment ($p < 0.01$).

For all model specifications, we found that increases in flood insurance costs led to decreases in investment per asset. This relationship is statistically significant ($p < 0.01$). A standard deviation increase in insurance cost leads to a 2.4–7% increase in investment per asset.

Except for Model (5), in all models, the cash's effect on investment was not sensitive to variations in insurance costs. The interaction term between *LogCF* and *LogInsurance* was not statistically significant.

There is no robust evidence supporting the hypothesis that investment–cash sensitivity is affected by insurance premiums based on these first results alone.

This table shows the results from the following regression:

$$I_{i,t} = \beta_0 + \beta_1 \text{CF}_{i,t-1} + \beta_2 \text{CND}_{i,t-1} + \beta_3 \text{CF}_{i,t-1} \times \text{InsuranceCost}_t + \gamma_a + \gamma_t + \varepsilon_{i,t}, \quad (9)$$

where I is the capital expenditure in year t divided by the total assets in year t for airport i. *CF* is the operating cash flow income of airport i in year $t-1$ divided by the total assets in year $t-1$. *CND* is the invested capital assets net of debt in year $t-1$ for airport i divided by the total assets in year $t-1$ for airport i. The proxy is needed because the airports are not all listed and the data on the book value of the firms are absent. *InsuranceCost* is the insurance cost per asset in year t for airport i. Gamma a is an airport fixed effect, and gamma t is a temporal fixed effect.

Table 3. Investment–cash sensitivity and flood insurance cost.

	Dependent Variable:					
	LogI					
	OLS	***Panel***	***OLS***	***Panel***	***OLS***	***Panel***
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Exposure Flood Dummy		0.123 *** (0.047)				
Operations Risk Dummy					−0.028 (0.059)	
LogCF	0.321 *** (0.056)	0.318 *** (0.060)	0.324 *** (0.055)	0.318 *** (0.060)	0.314 *** (0.065)	0.327 * (0.073
LogCND	0.642 *** (0.062)	0.632 *** (0.066)	0.642 *** (0.061)	0.632 *** (0.066)	0.633 *** (0.071)	0.603 * (0.079
LogInsurance	−0.079 *** (0.018)	−0.084 *** (0.020)	−0.077 *** (0.018)	−0.084 *** (0.020)	−0.084 *** (0.024)	−0.088 (0.026
LogCF×LogInsurance	0.007 (0.008)	0.006 (0.009)	0.006 (0.008)	0.006 (0.009)	0.020 ** (0.010)	0.016 (0.012
Constant	−0.528 *** (0.065)		−0.577 *** (0.067)		−0.472 *** (0.080)	
Firm Fixed Effect	No	Yes	No	Yes	No	Yes
Temporal Fixed Effect	No	Yes	No	Yes	No	Yes
Observations	283	283	283	283	180	180
Adjusted R^2	0.883	0.869	0.885	0.869	0.886	0.860

Note: *t*-statistics are in parentheses; * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

We then performed a differences-in-differences regression using the introduction of the Biggert–Waters 2012 reform as a shock. Table 4 reports the results of the analysis. Model (1) reports the results of the differences-in-differences regression when the treated group consists of airports that experience severe drops in free cash flows after an event of extreme precipitation. Model (2) describes the results when the treatment group consists of airports located in flood-prone areas.

The effects of the control variables *LogCF* and *LogCND* are positive and statistically significant, in line with the investment–cash sensitivity literature.

For the first treatment, the results in Table 2 for Model (1) show that investment increased after the introduction of the Biggert–Waters 2012 reform for airports with free cash flow affected by extreme precipitation ($p < 0.1$).

After 2012, investment per asset was 19% higher for airports experiencing large drops in cash flows after extreme precipitation events than for airports that did not. However, the effect of the interaction term between *LogCF* and a dummy variable equal to 1 after 2012 was not significant. The effect of cash on investment was not sensitive to the introduction of the reform.

For the second treatment, the results were different. When the treated airports were the ones located in flood areas, the interaction term between *LogCF* and the reform year was positive and statistically significant ($p < 0.01$). After 2012, a standard deviation increase in cash led to a 15% greater increase in investment in assets for airports located in flood-prone areas than for those not located in flood-prone areas.

This result indicates that the Biggert–Waters reform led to an increase in financial constraints measured through investment–cash sensitivity for airports located in flood-prone areas.

The Biggert–Waters reform, and flood insurance in general, was not introduced in isolation. FEMA has been constantly updating the building code with increasingly stringent flood management requirements. It has also been investing in flood management infrastructure and projects. Next, we explore the effects of each of these two policies on investment-cash sensitivity.

Table 4. Investment–cash sensitivity and the Biggert–Waters 2012 NFIP reform.

	Dependent Variable:	
	LogI	
	(1)	**(2)**
POST 2012	−0.022 (0.104)	0.080 (0.076)
LogCF	0.444 *** (0.063)	0.400 *** (0.051)
LogCND	0.569 *** (0.067)	0.576 *** (0.055)
Operations Risk Dummy×POST 2012	0.173 * (0.100)	
Exposure Flood Dummy×POST 2012		0.086 (0.083)
POST 2012×LogCF	0.071 (0.047)	0.104 ** (0.036)
Firm Fixed Effect	Yes	Yes
Temporal Fixed Effect	Yes	Yes
Observations Adjusted R^2	298 0.843	473 0.860

Note: *t*-statistics are in parentheses; * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

This table shows the results from the following regression:

$$I_{i,t} = \beta_0 + \beta_1 \text{Post}_t \times \text{Treated}_i + \beta_2 \text{CF}_{i,t-1} + \beta_3 \text{CND}_{i,t-1} + \gamma_a + \gamma_t + \varepsilon_{i,t} \; i = 1, \ldots, N, \quad (10)$$

where I is the capital expenditure in year t divided by the total assets in year t for airport i. *Post* is a dummy variable that is equal to 1 from the year 2012 onward. *Treated* is a dummy variable that is equal to 1 when the airport is exposed to variations in precipitation or flooding according to our risk variables. *CF* is the operating cash flow income of airport i in year $t-1$ divided by the total assets in year $t-1$. *CND* is the invested capital assets net of debt in year $t-1$ for airport i divided by the total assets in year $t-1$ for airport i. The proxy is needed because the airports are not all listed and the data on the book value of the firms are absent. Gamma a is an airport fixed effect, and gamma t is a temporal fixed effect.

4.2. Stringent Flood Risk Management Measures in Building Codes

In 2015, the International Building Code (IBC) was updated with additional flood risk management requirements. Such requirements are intended to stimulate investment in flood risk management.

Table 5 summarizes the results of the OLS and fixed-effect panel regressions based on Equation (12). We added the dummy variable *IBC Dummy* to our model specification. *IBC Dummy* is equal to 1 when the 2015 IBC is in place in the county where a given airport is located.

We found that the effects of our control variables *LogCF* and *LogCND* on investment per asset were positive and statistically significant, in line with the literature on investment–cash sensitivity ($p < 0.01$).

Table 5. Investment–cash sensitivity and building code implementation.

	Dependent Variable:	
	LogI	
	OLS	***Panel***
		Linear
	(1)	**(2)**
LogCF	0.410 ***	0.437 ***
	(0.044)	(0.048)
LogCND	0.611 ***	0.574 ***
	(0.051)	(0.056)
IBC Dummy	0.038	0.067
	(0.068)	(0.103)
LogCF×IBC Dummy	0.066 **	0.086 **
	(0.033)	(0.035)
Constant	−0.469 ***	
	(0.055)	
Firm Fixed Effect	No	Yes
Temporal Fixed Effect	No	Yes
Observations	464	464
R^2	0.879	0.886
Adjusted R^2	0.878	0.858
Residual Std. Error F Statistic	0.388 (df = 459) 832.881 *** (df = 4; 459)	724.491 *** (df = 4; 373)

Note: *t*-statistics are in parentheses; ** $p < 0.05$; *** $p < 0.01$.

The interaction term between *LogCF* and *IBC Dummy* was positive and statistically significant ($p < 0.05$). The presence of the 2015 IBC increased the sensitivity of investment to cash. A standard deviation increase in cash led to a 14% greater increase in investment when the 2015 IBC was in place.

This table shows the results from the following regression:

$$I_{i,t} = \beta_0 + \beta_1 \mathrm{CF}_{i,t-1} + \beta_2 \mathrm{CND}_{i,t-1} + \beta_3 \mathrm{CF}_{i,t-1} \times \mathrm{IBC}_t + \gamma_a + \gamma_t + \varepsilon_{i,t}, \quad (11)$$

where *I* is the capital expenditure in year *t* divided by the total assets in year *t* for airport *i*. *CF* is the operating cash flow income of airport *i* in year $t-1$ divided by the total assets in year $t-1$. *CND* is the invested capital assets net of debt in year $t-1$ for airport *i* divided by the total assets in year $t-1$ for airport *i*. The proxy is needed because the airports are not all listed and the data on the book value of the firms are absent. *IBC* is a dummy variable that is equal to 1 when the 2015 edition of the International Building Code is in place in the area where the airport is located. Gamma *a* is an airport fixed effect, and gamma *t* is a temporal fixed effect.

This result also holds when we focus only on airports exposed to floods. We added the *Operations Risk Dummy* and *Exposure Flood Dummy* to our model specification. The results are summarized in Table 6.

When the IBC was in place, we found that for airports exposed to drops in free cash flows due to extreme precipitation, a standard deviation increase in cash led to a 27% greater increase in investment in assets than for airports that were not. For airports located in flood-prone areas, a standard deviation increase in cash led to a 17% greater increase in investment in assets than for airports that are not.

Table 6. Investment–cash sensitivity and building codes for flood-exposed airports.

	Dependent Variable:	
	LogI	
	(1)	**(2)**
IBC Dummy	0.206 (0.176)	0.120 (0.113)
LogCF	0.456 *** (0.058)	0.436 *** (0.048)
LogQ	0.552 *** (0.067)	0.577 *** (0.056)
Operations Risk Dummy: IBC Dummy	0.196 (0.212)	
Exposure Flood Dummy: IBC Dummy		−0.216 (0.187)
IBC Dummy:LogCF	0.122 ** (0.048)	0.083 ** (0.035)
Firm Fixed Effect	Yes	Yes
Temporal Fixed Effect	Yes	Yes
Observations Adjusted R^2	298 0.844	464 0.858

Note: *t*-statistics are in parentheses; ** $p < 0.05$; *** $p < 0.01$.

This table shows the results from the following regression:

$$I_{i,t} = \beta_0 + \beta_1 \text{CF}_{i,t-1} + \beta_2 \text{CND}_{i,t-1} + \beta_3 \text{CF}_{i,t-1} \times \text{IBC}_t + \beta_1 \text{Treat}_i + \gamma_a + \gamma_t + \varepsilon_{i,t}, \quad (12)$$

where I is the capital expenditure in year t divided by the total assets in year t for airport i. *IBC* is a dummy variable that is equal to 1 when the 2015 edition of the International Building Code is in place in the area where the airport is located. *Treated* is a dummy variable that is equal to 1 when the airport is exposed to variations in precipitation or flooding according to our risk variables. *CF* is the operating cash flow income of airport i in year $t-1$ divided by the total assets in year $t-1$. *CND* is the invested capital assets net of debt in year $t-1$ for airport i divided by the total assets in year $t-1$ for airport i. The proxy is needed because the airports are not all listed and the data on the book value of the firms are absent. Gamma a is an airport-fixed effect, and gamma t is a temporal fixed effect.

4.3. The Role of Public Flood Risk Management Investment

FEMA is financing adaptation projects aiming at managing flood risk. The agency performs a benefit–cost analysis (BCA) each time to prioritize projects with high flood risk reduction benefits for each unit of cost. *LogAI* is the flood management investment per unit of economic benefit achieved by a project in terms of reducing the flood risk in the county where an airport is located. Table 7 summarizes the results of our fixed-effect panel regression, including our adaptation investment variable *LogAI*.

In Table 7, Model (1) reports the results for the entire sample and over our entire period of study. We found that the interaction term between *LogCF* and *LogAI* was positive, and the effect of its coefficient was statistically significant ($p < 0.01$). A standard deviation increase in adaptation investment per unit of benefit increased the effect of cash on investment by 3.8%.

Table 7. Investment–cash sensitivity and flood risk management investment.

	Dependent Variable:		
	LogI		
	(1)	**(2)**	**(3)**
POST 2012		−0.066 (0.072)	−0.064 (0.054)
LogCF	0.417 *** (0.051)	0.434 *** (0.061)	0.413 *** (0.052)
LogQ	0.587 *** (0.060)	0.554 *** (0.074)	0.594 *** (0.062)
LogAI	0.496 *** (0.173)	0.667 *** (0.241)	0.497 *** (0.181)
Operations Risk Dummy×POST 2012		0.191 * (0.105)	
Exposure Flood Dummy×POST 2012			0.161 * (0.087)
LogCF:LogAI	0.296 *** (0.088)	0.403 *** (0.108)	0.299 *** (0.089)
Firm Fixed Effect	Yes	Yes	Yes
Temporal Fixed Effect	Yes	Yes	Yes
Observations Adjusted R^2	381 0.848	251 0.826	381 0.849

Note: *t*-statistics are in parentheses; * $p < 0.1$; *** $p < 0.01$.

In Models (2) and (4) in Table 7, we report the effect of *LogAI* on investment–cash sensitivity after the Biggert–Waters 2012 NFIP reform. We found that the effect of *LogAI* increased after the introduction of the reform. When we considered the airports exposed to drops in free cash flows due to extreme precipitation, in Model (2), we found that a standard deviation increase in adaptation investment per unit of benefit increased the effect of cash on investment by 5%. When we considered airports located in flood-prone areas, in Model (3), the increase was 3.8%.

Public investment in the management of flood risk increases financial constraints on airports.

This table shows the results from the following regression:

$$I_{i,t} = \beta_0 + \beta_1 \text{Post}_t \times \text{Treated}_i + \beta_2 \text{CF}_{i,t-1} + \beta_3 \text{CND}_{i,t-1} + \beta_4 \text{CF}_{i,t-1} \times \text{AI}_t + \gamma_a + \gamma_t + \varepsilon_{i,t} \quad i = 1, \ldots, N, \tag{13}$$

where I is the capital expenditure in year t divided by the total assets in year t for airport i. *AI* is the investment in flood risk management per unit of benefit in year $t-1$ for the county where airport i is located. *Treated* is a dummy variable that is equal to 1 when the airport is exposed to variations in precipitation or flooding according to our risk variables. *CF* is the operating cash flow income of airport i in year $t-1$ divided by the total assets in year $t-1$. *CND* is the invested capital assets net of debt in year $t-1$ for airport i divided by the total assets in year $t-1$ for airport i. The proxy is needed because the airports are not all listed and the data on the book value of the firms are absent. Gamma a is an airport fixed effect, and gamma t is a temporal fixed effect.

4.4. Flood Risk Management Policy Interactions and Financial Constraints

When evaluated individually, all three policy interventions have an effect on investment–cash sensitivity. We estimated a final model where we considered the three policies together:

the introduction of the Biggert–Waters reform, the 2015 International Building code and investment in adaptation to flood risk. The results are reported in Table 8.

Table 8. Flood risk management policies and investment–cash sensitivity.

	Dependent Variable:	
	LogI	
	(1)	**(2)**
POST 2012	−0.164 (0.115)	−0.050 (0.087)
LogCF	0.465 *** (0.074)	0.392 *** (0.062)
LogAI	0.641 ** (0.256)	0.454 ** (0.194)
IBC Dummy	0.135 (0.181)	0.120 (0.133)
Operations Risk Draw Dummy× POST 2012	0.187 * (0.106)	−0.216 (0.187)
Exposure Flood Dummy× POST 2012		0.166 * (0.088)
POST 2012×LogCF	−0.062 (0.058)	0.015 (0.043)
LogCF×LogAI	0.388 *** (0.124)	0.274 *** (0.100)
LogCF×IBC Dummy	0.058 (0.066)	0.043 (0.049)
Firm Fixed Effect	Yes	Yes
Temporal Fixed Effect	Yes	Yes
Observations Adjusted R^2	251 0.825	376 0.847

Note: *t*-statistics are in parentheses; * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table 8 shows the results of differences-in-differences regressions where the first treatment is exposure to drops in cash flows due to extreme precipitation, and the second is being located in flood-prone areas.

We can see that, for both treatments, only the effect of the interaction term between *LogCF* and *LogAI* is positive and statistically significant ($p < 0.01$). Only investment in adaptation has an effect on investment–cash sensitivity. A standard deviation increase in adaptation investment increased the effect of cash on investment by 3.5 and 5% for the two treatments, respectively.

When comparing the effects of the policies together, it appears that adaptation investment per unit of economic benefit has the largest effect on investment–cash sensitivity for airports exposed to flood risk.

In the next section, we discuss the channels through which these policies induce financial constraints, and we articulate our findings in the context of the broader literature.

This table shows the results from the following regression:

$$I_{i,t} = \beta_0 + \beta_1 \text{Post}_t \times \text{Treated}_i + \beta_2 \text{CF}_{i,t-1} + \beta_3 \text{CND}_{i,t-1} + \beta_4 \text{CF}_{i,t-1} \times \text{IBC}_t + \beta_5 \text{CF}_{i,t-1} \times \text{AI}_t + \gamma_a + \gamma_t + \varepsilon_{i,t} \quad i = 1, \ldots, N, \tag{14}$$

where I is the capital expenditure in year t divided by the total assets in year t for airport i. AI is the investment in flood risk management per unit of benefit in year $t-1$ for the county where airport i is located. IBC is a dummy variable that is equal to 1 when the

2015 edition of the International Building Code is in place in the area where the airport is located.

5. Discussion and Mechanisms: Information Asymmetry or Risk Materiality?

Sastry (2021) found that the presence of insurance is an important determinant of the risk allocation between households, lenders, and the government. Increases in insurance premiums to reflect flood risk lead to significant financial constraints (Chivers and Flores 2002; Abbott 2014; Indaco et al. 2019) and affect the adaptation strategies of households. Analyzing loan-level data, flood zone designations, and loan performance before and after Hurricane Harvey in the US, Kousky et al. (2020) found that in areas where flood insurance is required the delinquency rate of mortgages is lower. This is evidence that there is a relationship between the penetration of flood insurance and the presence of flood adaptation strategies in houses on the one hand, and investment needs on the other. We observed similar financial constraints for airports.

Looking at the general population of airports in our sample, the increase in insurance costs has a negative effect on investment. A standard deviation increase in flood insurance costs led to a 30% increase in investment. However, flood insurance costs did not appear to have an effect on investment–cash sensitivity. This is an important finding because the first pillar of the Biggert–Waters 2012 reform is the adjustment of flood risk premiums to better reflect the risk. Flood insurance, as a market-based flood management strategy, seemed not to lead to financial constraints in the investment–cash sensitivity sense.

The second pillar of the Biggert–Waters reform aimed at promoting flood risk mapping. When we focus on airports in locations designated as flood-prone by FEMA's flood maps, we can see that these airports used more cash for investment after the introduction of the Biggert–Waters 2012 reform. After 2012, these airports used 15% more cash to finance investments than did non-exposed ones. The Biggert–Waters 2012 reform most likely resulted in financial constraints through the channel of information asymmetries (Ascioglu et al. 2008). The availability of new flood maps might have brought new information to the attention of airport operators that led to increases in flood-risk-management-related investments using cash.

The increased availability and accuracy of flood maps often constitute an evidence base for updating building codes. The updated International Building Code (IBC) of 2015 included more stringent flood risk management requirements for commercial and residential buildings. The IBC 2015 is a form of command-and-control flood management regulation that can be an incentive for airports to invest in flood management. When looking at our entire sample of airports, we found that the presence of the IBC 2015 in the county where an airport is located led to a 14% greater increase in cash for investment purposes. For airports located in flood-risk areas, this figure was higher at 17%. These results suggest that the airport operators who are most attentive to building codes are not the ones located in flood-risk areas but, rather, those who actually experience drops in free cash flows due to extreme precipitation. These airports used 27% more cash for investment than the rest of the sample. Flood risk requirements in building codes result in financial constraints for those agents who experience actual losses linked to precipitation, and less as a result of information asymmetry. Perhaps, as building codes change to better reflect changes in precipitation, airports also spontaneously invest to adapt to these same changes.

In parallel to the spontaneous private investment in flood risk adaptation, FEMA uses public resources to invest in flood adaptation. Public adaptation investment in the county where an airport is located can have a signaling effect on airport operators and trigger spontaneous investment in flood risk management.

When comparing the three types of policies, we found that public adaptation investment was what resulted in the largest financial constraints for airports exposed to extreme precipitation and floods. Our results show that a standard deviation increase in adaptation investment per unit of benefit increased the use of cash for investment by between 3.8 and 5% for airports exposed to extreme precipitation and flood risks.

This is consistent with the findings in the residential sector. Han and Peng (2019) and Sastry (2021) found that there is a role of county-level public investment in the financial response of households to flood insurance. Benetton et al. (2022) also found that adaptation investment in infrastructure (sea walls) led to an increase in the value of houses located in flood-prone areas.

This effect seems to be driven by the asymmetry of information rather than the materiality of flood risk. If materiality was the driver of this effect, we would see that public investment in flood risk reduction would result in fewer financial constraints. In this case, the public investment seems to increase financial constraints by potentially signaling to investors that the county is exposed to flood risk.

To understand this last result, it is important to unpack our adaptation investment metric. We measured adaptation investment in terms of flood risk adaptation investment per unit of benefit. High adaptation investment per unit of benefit can mean high investment relative to the benefit or low benefit relative to the investment. In both cases, an increase in this metric can mean that investment in low-benefit projects is taking place. It is possible, then, that these investments could reduce flood risk with limited cost-efficiency, therefore pushing airports to engage in spontaneous adaptation investment and, in turn, generating financial constraints.

These findings have important policy implications. Policymakers should strive to educate investors about the benefits of adaptation. The introduction of flood risk management policies should not result in financial constraints for all infrastructure operators in flood-prone areas. Investors should have the means to reward spontaneous adaptation behaviors—both risk reduction and risk transfer. One way to do so is to track adaptation measures implemented by infrastructure operators and enhance environmental due diligence in the context of financing operations in order to better incorporate adaptation.

This study notably expands the depth of the existing investment-cash sensitivity literature, being the inaugural exploration of climate risk-related factors impacting investment–cash sensitivity.

However, it is crucial to acknowledge certain limitations of this study, which in turn present intriguing opportunities for future research. Initially, our findings are confined to the top 100 airport bond issuers possessing robust access to capital markets. An interesting extension to our study might scrutinize smaller issuers, who generally grapple with a greater degree of initial external financial constraints.

Secondly, our investigation is exclusive to airports. Broadening our research to include different types of infrastructure assets could prove both feasible and beneficial. Financial information akin to what we have utilized in this study is readily available for other infrastructure types in the United States, such as power plants, hospitals, ports, and roads.

Moreover, the correlation between insurance premiums and adaptation investment is dynamic. Our study offers preliminary insights into the interplay between risk reduction and risk transfer. Future research could delve deeper into this interaction by examining other financial constraint indicators or alternative assets. Studies could also employ more granular measures of risk reduction and risk transfer. For instance, they could consider the precise insurance premium paid by an infrastructure company and specific adaptation spending, not merely at the county level, but directly at the level of the individual airport.

There are also various methods to conceptualize anticipated damage from flood risk. Firstly, upcoming studies could contemplate consolidating the measures of financial losses originating from operational disruptions and damages to infrastructure such as buildings and runways.

Additionally, future research could apply more detailed damage functions tailored to the unique circumstances of airports or even individual airport facilities. The development of such damage functions is a principal area where current literature on physical climate risk for infrastructure is lacking, hence paving the way for valuable contributions in future research.

6. Robustness Checks

6.1. Self-Selection and Autocorrelation in Outcome Variables

Self-selection is recognized as one of the features of corporate finance decision-making (Kai and Prabhala 2007; Roberts and Whited 2013). In the case of airports, companies' self-selection in areas exposed to flood or extreme precipitation is not supported by an economic rationale. Erkan and Elsharida (2019) reviewed airport location selection methods and found that Geographic Information Systems (GISs) are often used in combination with multi-criteria decision-making analysis (MCDA) frameworks (Belbag et al. 2013; Palczewski and Sałabun 2019). The main airport location selection objective of Erkan and Elsharida (2019) was the optimization of the transport system. The mainstreaming of flood risk analysis in infrastructure planning, as supported by FEMA, should if anything lead to the avoidance of flood-prone areas. Since the transport system constraints do not always enable such risk avoidance strategies, risk transfer, and risk reduction are the remaining options for airports. These are the strategies discussed in this paper. Self-selection is not likely in this case.

Since we used panel data to verify our hypothesis, we checked whether the residuals of our regression model were independent of one another or whether autocorrelation occurred. We performed a Durbin–Watson test for serial correlation in the panel models. For our panel regressions, we rejected the null hypothesis that there is a serial correlation in the idiosyncratic errors. For all three models, the Durbin–Watson statistics were around 2.3 and the p-values were above 0.9. We, therefore, conclude that there is no autocorrelation among the residuals.

6.2. Placebo Tests

As described by Eggers et al. (2021), we ran a series of placebo tests to check the robustness of the effects of the Biggert–Waters reform and public adaptation investment on investment–cash sensitivity and further alleviate endogeneity concerns. We first explored the effects of the reform considering an alternative treatment. We adopted an alternative measure of airports' exposure to precipitation by using the correlation of the airports' free cash flows and the precipitation levels. We then explored the effects of the reform using an alternative outcome. Instead of measuring the effect on investment in total assets, we explored the effect of the reform on debt to total assets. Our results are robust to these two tests.

6.2.1. Alternative Treatment: Correlation between Precipitation and Cash Flows

Airports can incur financial losses due to precipitation through multiple channels. We previously focused on the financial losses due to the physical damage to buildings and runways in the event of floods. We now focus on the financial losses due to drops in operations (number of flights, sales in airport shops, etc.).

We estimated each airport's exposure to financial losses due to changes in precipitation. We used annual precipitation data, measured in inches between 2005 and 2021 at the location of the airports and acquired through the United States (US) National Centers for Environmental Information of the National Oceanic and Atmospheric Administration (NOAA).

We estimated the correlation between an airport's free cash flow (FC) and annual precipitation levels using Equation (15). This simple correlation is our first measure of exposure. The higher the negative correlation of an airport's FCs, the more it is exposed to financial losses due to variations in precipitation. We considered the airports with a negative correlation of more than 30% between FC and annual precipitation as being highly exposed to variations in precipitation.

$$\text{OperationsExposure}_i = \text{corr}\,(\text{FreeCashflow}_i, \text{Precipitations}_i). \quad (15)$$

Models (1) and (2) in Table 9 report the results of the multivariate regression described in Equation (16), where the *Treated* dummy is equal to 1 for airports where the correlation between precipitation and cash flow operating income is above 30%. There is a positive and statistically significant relationship ($p < 0.01$) between cash flow (CF), equity (Q), and investment (I). However, the interaction term between *Post*−2012 and *Treated* is not statistically significant when using the correlation between airports' cash flow income and precipitation as the treatment variable. This suggests that the introduction of Biggert–Waters reform does not result in increased financial constraints for airports exposed to flood risk in the case of our new measure of risk. On the other hand, we see that interaction term between logCF and logAI suggesting that public adaptation investment does lead to an increase in financial constraints for airports.

Table 9. Investment–cash sensitivity after the Biggert–Waters reform of 2012.

	Dependent Variable:	
	LogI	
	(1)	**(2)**
POST 2012	−0.068 (0.042)	−0.008 (0.047)
LogCF	0.466 *** (0.046)	0.414 *** (0.053)
LogQ	0.583 *** (0.056)	0.590 *** (0.063)
LogAI		0.487 *** (0.182)
Operations Risk Corr Dummy×POST 2012	0.012 (0.129)	0.002 (0.140)
LogCF×LogAI		0.293 *** (0.089)
Firm Fixed Effect	Yes	Yes
Temporal Fixed Effect	Yes	Yes
Observations Adjusted R^2	472 0.856	381 0.847

Note: *t*-statistics are in parentheses; *** $p < 0.01$.

This table shows the results from the following regression:

$$I_{i,t} = \beta_0 + \beta_1 \text{Post}_t \times \text{Treated}_i + \beta_2 \text{CF}_{i,t-1} + \beta_3 \text{CND}_{i,t-1} + \gamma_a + \gamma_t + \varepsilon_{i,t}, \quad (16)$$

where I is the capital expenditure in year t divided by the total assets in year t for airport i. *Post* is a dummy variable that is equal to 1 from the year 2012 onward. *Treated* is a dummy variable that is equal to 1 when the airport's free cash flows are highly correlated with precipitation. *CF* is the operating cash flow income of airport i in year $t-1$ divided by the total assets in year $t-1$. *CND* is the invested capital assets net of debt in year $t-1$ for airport i divided by the total assets in year $t-1$ for airport i. The proxy is needed because the airports are not all listed and the data on the book value of the firms are absent. Gamma a is an airport-fixed effect, and gamma t is a temporal fixed effect.

6.2.2. Alternative Outcome: Financing Adaptation through External Finance

Our baseline hypothesis was that key flood management policies resulted in external financing constraints for airports through increased use of cash to finance investment. The underlying assumption was that airport companies did not resort to external financing, e.g., in the form of debt, as a result of such policies. To evaluate the robustness of our findings, we ran our model specification with total debt to total assets as the outcome variable. We expect to see the same results as for investment-to-assets. If a policy increases financial constraints, it should reduce the debt-to-assets ratio.

Models (1), (2), and (3) reported in Table 10 summarize the results. For Models (2) and (3), we used our baseline treatments. Model (2) was the specification where the treated group was the set of airports exposed to drops in cash flow income following an extreme precipitation event. Model (3) was the specification where the treated group was the set of airports exposed to flood risk. Finally, Model (1) was the specification where we considered the alternative treatment used in the previous robustness test (i.e., the correlation between cash flows and precipitations). Regardless of the treatment considered, the introduction of the Biggert–Waters reform act does not seem to have had an effect on airport companies' total debt to total assets.

Table 10. Public adaptation investment and firm-level debt-cash sensitivity after the Biggert–Waters reform of 2012.

	Dependent Variable:		
	LogI		
	(1)	**(2)**	**(3)**
LogCF	0.764 *** (0.052)	0.756 *** (0.055)	0.766 *** (0.052)
LogCND	0.282 *** (0.062)	0.280 *** (0.066)	0.279 *** (0.062)
LogAI	0.697 *** (0.179)	−0.469 ** (0.217)	0.701 *** (0.179)
Operations Risk Corr Dummy× POST 2012	0.125 (0.137)		
Operations Risk Draw Dummy× POST 2012		0.073 (0.094)	
Exposure Flood Dummy× POST 2012			0.015 (0.086)
LogCF×LogAI	−0.292 *** (0.088)	−0.219 ** (0.097)	−0.293 *** (0.088)
Firm Fixed Effect	Yes	Yes	Yes
Temporal Fixed Effect	Yes	Yes	Yes
Observations Adjusted R^2	381 0.858	251 0.855	381 0.857

Note: *t*-statistics are in parentheses; ** $p < 0.05$; *** $p < 0.01$.

This table shows the results from the following regression:

$$D_{i,t} = \beta_0 + \beta_1 \text{Post} \times \text{Treated}_i + \beta_2 \text{CF}_{i,t-1} + \beta_3 \text{CND}_{i,t-1} + \beta_4 \text{AI}_{i,t-1} + \beta_5 \text{CF}_{i,t-1} \times \text{AI}_{i,t-1} + \gamma_a + \gamma_t + \varepsilon_{i,t}, \quad (17)$$

where D is the total debt divided by the total assets for a given airport. The other variables are the same as described in Table 9.

7. Conclusions

In conclusion, this paper examined the impact of flood management policies on airport investment and the resulting financial constraints. The analysis focused on three key policies: flood insurance, building codes, and public adaptation investment. The findings shed light on the relationship between these policies and the financial decisions made by airport operators in flood-prone areas.

The study revealed that flood insurance costs have a negative effect on overall airport investment. However, it did not find evidence of a significant impact on the investment-cash sensitivity, suggesting that market-based flood management measures such as flood insurance do not directly lead to financial constraints in terms of investment–cash sensitivity.

On the other hand, the introduction of flood risk mapping and the subsequent adoption of stricter building codes—particularly the IBC 2015—were found to have an impact on investment decisions. Airports located in flood-prone areas were more likely to use cash for investment purposes, indicating that building codes act as incentives for flood risk management investment. We observed that airport operators experiencing drops in free cash flows due to extreme precipitation were particularly attentive to building codes, suggesting that their investment decisions were driven by the materiality of flood risk and the need for flood risk adaptation, and not by considerations of information asymmetry.

Furthermore, public adaptation investment in flood risk reduction had a signaling effect on airport operators, triggering spontaneous investment in flood risk management. This study found that higher levels of public adaptation investment per unit of benefit increased the use of cash for investment by airports exposed to extreme precipitation and flood risks. This is consistent with findings in the residential sector, indicating the role of government investment in influencing flood risk management behavior.

It is worth noting that public adaptation investment resulted in the largest financial constraints for airports exposed to extreme precipitation and floods. Perhaps these investments are not cost-efficient, or they may signal to investors that the airports are exposed to flood risks.

These findings underscore the importance of educating investors about the benefits of adaptation and ensuring that flood risk management policies do not impose undue financial constraints on infrastructure operators. Policymakers should encourage and reward spontaneous adaptation behavior by tracking and acknowledging the adaptation measures implemented by infrastructure operators. Enhancing environmental due diligence in financing operations can also help factor in adaptation efforts, ensuring that the financial landscape supports effective flood risk management. Overall, this research provides valuable insights into the complex relationship between flood management policies, financial constraints, and investment decisions in the context of airport operations. By understanding these dynamics, policymakers and investors can work together to foster resilient infrastructure and mitigate the impacts of flooding on critical sectors of the economy.

However, acknowledging the limitations of our study opens up a multitude of potential research avenues. Future studies could aim to analyze smaller issuers, diversify the infrastructure assets studied, and delve deeper into the dynamic interplay between risk reduction and risk transfer. Furthermore, a more comprehensive approach to quantifying anticipated damage from flood risk, encompassing financial losses from both operational disruptions and physical damages, would enhance the understanding of physical climate risk for infrastructure. Crafting more detailed, asset-specific damage functions could fill a significant gap in the current literature and pave the way for future studies that hold significant potential for enhancing our understanding of physical climate risk for infrastructure assets.

Funding: This research received no external funding.

Acknowledgments: I would like to express my profound gratitude to Luca Taschini and Leonidas Babopoulos, for their unwavering support, insightful suggestions, and constructive feedback throughout the course of this study. Their expertise and dedication have been invaluable to my research and have significantly contributed to the quality of this paper. Additionally, I wish to extend my sincere appreciation to the anonymous reviewers for their thoughtful and perceptive comments. Their expertise and attention to detail have played a pivotal role in refining this manuscript. Their suggestions have not only enriched the quality of this paper but have also stimulated my ongoing research. This acknowledgement encapsulates only a fraction of my gratitude, and I am incredibly thankful for their combined contributions.

Conflicts of Interest: The author declares no conflict of interest.

Notes

1 The National Flood Insurance ACT of 1968: https://www.fema.gov/sites/default/files/2020-07/national-flood-insurance-act-1968.pdf (accessed on 5 March 2023).

2 The National Flood Insurance ACT of 1968: https://sgp.fas.org/crs/homesec/IN11049.pdf (accessed on 5 March 2023).

3 NFIP Governing Laws and Regulations: https://www.fema.gov/flood-insurance/rules-legislation/laws (accessed on 5 March 2023).

4 Biggert-Waters Flood Insurance Reform Act of 2012: https://www.govinfo.gov/content/pkg/PLAW-112publ141/pdf/PLAW-112publ141.pdf (accessed on 5 March 2023).

5 https://www.fema.gov/sites/default/files/2020-07/2015-icodes-flood-provision.pdf (accessed on 5 March 2023).

6 Free cash flow (FCF) is the cash a company generates after taking into consideration cash outflows that support its operations and maintain its capital assets.

7 https://nfipservices.floodsmart.gov/reports-flood-insurance-data (accessed on 5 March 2023).

8 https://www.fema.gov/emergency-managers/risk-management/building-science/bcat (accessed on 5 March 2023).

References

Abbott, Ernest B. 2014. Flood insurance and climate change: Rising sea levels challenge the NFIP. *Fordham Environmental Law Review* 26: 10.

Aerts, Jeroen C. J. H. 2018. A review of cost estimates for flood adaptation. *Water* 10: 1646. [CrossRef]

Aerts, Jeroen C. J. H., W. J. Wouter Botzen, Hans de Moel, and Malcolm Bowman. 2013. Cost estimates for flood resilience and protection strategies in New York City. *Annals of the New York Academy of Sciences* 1294: 1–104. [CrossRef] [PubMed]

Allman, Elsa. 2022. Pricing climate change risk in corporate bonds. *Journal of Asset Management* 23: 596–618. [CrossRef]

Andrén, Niclas, and Håkan Jankensgård. 2015. Wall of cash: The investment-cash flow sensitivity when capital becomes abundant. *Journal of Banking & Finance* 50: 204–13.

Aretz, Kevin, Murillo Campello, and Maria-Teresa Marchica. 2020. Access to collateral and the democratization of credit: France's reform of the Napoleonic Security Code. *The Journal of Finance* 75: 45–90. [CrossRef]

Arslan, Özgür, Chrisostomos Florackis, and Aydin Ozkan. 2006. The role of cash holdings in reducing investment–cash flow sensitivity: Evidence from a financial crisis period in an emerging market. *Emerging Markets Review* 7: 320–38. [CrossRef]

Ascioglu, Asli, Shantaram P. Hegde, and John B. McDermott. 2008. Information asymmetry and investment–cash flow sensitivity. *Journal of Banking & Finance* 32: 1036–48.

Assab, Abderrahim. 2023. Did We Open The Floodgates? Flood Damage and Infrastructure Loan Defaults. In *Flood Damage and Infrastructure Loan Defaults*. Available online: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4326663 (accessed on 17 May 2023).

Bajaj, Isha, and Mandeep Kaur. 2022. Validating multi-dimensional model of financial literacy using confirmatory factor analysis. *Managerial Finance*, *ahead-of-print*.

Baldauf, Markus, Lorenzo Garlappi, and Constantine Yannelis. 2020. Does climate change affect real estate prices? Only if you believe in it. *The Review of Financial Studies* 33: 1256–95. [CrossRef]

Barrage, Lint, and Jacob Furst. 2019. Housing investment, sea level rise, and climate change beliefs. *Economics Letters* 177: 105–8. [CrossRef]

Becker, Austin H., Michele Acciaro, Regina Asariotis, Edgard Cabrera, Laurent Cretegny, Philippe Crist, Miguel Esteban, Andrew Mather, Steve Messner, Susumu Naruse, and et al. 2013. A note on climate change adaptation for seaports: A challenge for global ports, a challenge for global society. *Climatic Change* 120: 683–95. [CrossRef]

Belbag, Sedat, Muhammet Deveci, and Ahmet Serhat Uludag. 2013. Comparison of two fuzzy multi criteria decision methods for potential airport location selection. Paper presented at the 2nd International Conference on Operations Research and Enterprise Systems, Barcelona, Spain, February 16–18; vol. 2, pp. 270–76.

Benetton, Matteo, Simone Emiliozzi, Elisa Guglielminetti, Michele Loberto, and Alessandro Mistretta. 2022. Does Climate Change Adaptation Matter? Evidence from the City on the Water. Available online: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4313434 (accessed on 3 July 2023). [CrossRef]

Berg, Florian, Paula Margaretic, and Sébastien Pouget. 2016. Sovereign bond spreads and extra-financial performance: An empirical analysis of emerging markets. In *Central Bank of Chile Working Papers*. Available online: https://www.bcentral.cl/en/detail-news-and-publications/-/asset_publisher/Exzd7l9NC3Y6/content/id/1768203 (accessed on 27 June 2023).

Bernstein, Asaf, Matthew T. Gustafson, and Ryan Lewis. 2019. Disaster on the horizon: The price effect of sea level rise. *Journal of Financial Economics* 134: 253–72. [CrossRef]

Brown, James R., and Bruce C. Petersen. 2009. Why has the investment-cash flow sensitivity declined so sharply? Rising R&D and equity market developments. *Journal of Banking & Finance* 33: 971–84.

Burbidge, Rachel. 2016. Adapting European airports to a changing climate. *Transportation Research Procedia* 14: 14–23. [CrossRef]

Cevik, Serhan, and João Tovar Jalles. 2020. Feeling the Heat: Climate Shocks and Credit Ratings. IMF Working Paper 20(286). SSRN 3772492. Available online: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3772492 (accessed on 12 May 2023).

Cevik, Serhan, and João Tovar Jalles. 2022. An Apocalypse Foretold: Climate Shocks and Sovereign Defaults. *Open Economies Review* 33: 89–108. [CrossRef]

Chen, Huafeng Jason, and Shaojun Jenny Chen. 2012. Investment-cash flow sensitivity cannot be a good measure of financial constraints: Evidence from the time series. *Journal of Financial Economics* 103: 393–410. [CrossRef]

Chivers, James, and Nicholas E. Flores. 2002. Market failure in information: The national flood insurance program. *Land Economics* 78: 515–21. [CrossRef]

Dawson, Richard J., and Jim Hall. 2006. Adaptive importance sampling for risk analysis of complex infrastructure systems. *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences* 462: 3343–62. [CrossRef]

Dawson, Richard J., David Thompson, Daniel Johns, Ruth Wood, Geoff Darch, Lee Chapman, Paul N. Hughes, Geoff V. R. Watson, Kevin Paulson, Sarah Bell, and et al. 2018. A systems framework for national assessment of climate risks to infrastructure. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 376: 20170298. [CrossRef]

de Ruig, Lars T., Toon Haer, Hans de Moel, W. J. Wouter Botzen, and Jeroen C. J. H. Aerts. 2020. A micro-scale cost-benefit analysis of building-level flood risk adaptation measures in Los Angeles. *Water Resources and Economics* 32: 10014. [CrossRef]

Dey, Atreya. 2022. Surging Sovereign Spreads: The Impact of Coastal Flooding on Sovereign Risk. Available online: https://ssrn.com/abstract=4058301 (accessed on 13 April 2023). [CrossRef]

Du, Shiqiang, Paolo Scussolini, Philip J. Ward, Min Zhang, Jiahong Wen, Luyang Wang, Elco Koks, Andres Diaz-Loaiza, Jun Gao, Qian Ke, and et al. 2020. Hard or soft flood adaptation? Advantages of a hybrid strategy for Shanghai. *Global Environmental Change* 61: 102037. [CrossRef]

Eggers, Andrew C., Guadalupe Tuñón, and Allan Dafoe. 2021. Placebo Tests for Causal Inference. Unpublished Manuscript. Available online: https://pelg.ucsd.edu/Eggers2021.pdf (accessed on 13 April 2023).

Erkan, Turan Erman, and Wael Mohamed Elsharida. 2019. Overview of airport location selection methods. *International Journal of Applied Engineering Research* 14: 1613–18.

Fazzari, Steven M., R. Glenn Hubbard, and Bruce C. Petersen. 2000. Investment-cash flow sensitivities are useful: A comment on Kaplan and Zingales. *The Quarterly Journal of Economics* 115: 695–705. [CrossRef]

Filatova, Tatiana. 2014. Market-based instruments for flood risk management: A review of theory, practice and perspectives for climate adaptation policy. *Environmental Science & Policy* 37: 227–42.

Filippova, Olga, Cuong Nguyen, Ilan Noy, and Michael Rehm. 2020. Who cares? Future sea level rise and house prices. *Land Economics* 96: 207–24. [CrossRef]

Francis, Bill, Iftekhar Hasan, Liang Song, and Maya Waisman. 2013. Corporate governance and investment-cash flow sensitivity: Evidence from emerging markets. *Emerging Markets Review* 15: 57–71. [CrossRef]

Garbarino, Nicola, and Benjamin Guin. 2021. High water, no marks? Biased lending after extreme weather. *Journal of Financial Stability* 54: 100874. [CrossRef]

Garcia-Alonso, Lorena, Ticiana Grecco Zanon Moura, and David Roibas. 2020. The effect of weather conditions on port technical efficiency. *Marine Policy* 113: 103816. [CrossRef]

Goldsmith-Pinkham, Paul, Matthew T. Gustafson, Ryan C. Lewis, and Michael Schwert. 2021. Sea level rise exposure and municipal bond yields. In *Jacobs Levy Equity Management Center for Quantitative Financial Research Paper*. Cambridge: National Bureau of Economic Research.

Han, Yu, and Zhong-ren Peng. 2019. The integration of local government, residents, and insurance in coastal adaptation: An agent-based modeling approach. *Computers, Environment and Urban Systems* 76: 69–79. [CrossRef]

Hirabayashi, Yukiko, Roobavannan Mahendran, Sujan Koirala, Lisako Konoshima, Dai Yamazaki, Satoshi Watanabe, Hyungjun Kim, and Shinjiro Kanae. 2013. Global flood risk under climate change. *Nature Climate Change* 3: 816–21. [CrossRef]

Hovakimian, Armen, and Gayan´e Hovakimian. 2009. Cash flow sensitivity of investment. *European Financial Management* 15: 47–65. [CrossRef]

Hovekamp, Winston, and Katherine R. H. Wagner. 2023. Efficient Adaptation to Flood Risk. *AEA Papers and Proceedings* 113: 304–9. [CrossRef]

Hudson, Paul, W. J. Wouter Botzen, and Jeroen C. J. H. Aerts. 2019. Flood insurance arrangements in the European union for future flood risk under climate and socioeconomic change. *Global Environmental Change* 58: 101966. [CrossRef]

Huizinga, Jan, Hans De Moel, and Wojciech Szewczyk. 2017. *Global flood Depth-Damage Functions: Methodology and the Database with Guidelines*. Available online: https://publications.jrc.ec.europa.eu/repository/handle/JRC105688 (accessed on 12 January 2020).

Indaco, Agustın, Francesc Ortega, and Süleyman Taşpınar. 2019. The effects of flood insurance on housing markets. *Cityscape* 21: 129–56. [CrossRef]

Kai, Li, and Nagpurnanand R. Prabhala. 2007. Self-selection models in corporate finance. In *Handbook of Empirical Corporate Finance*. Hoboken: Elsevier, pp. 37–86.

Kling, Gerhard, Ulrich Volz, Victor Murinde, and Sibel Ayas. 2021. The impact of climate vulnerability on firms' cost of capital and access to finance. *World Development* 137: 105131. [CrossRef]

Kousky, Carolyn, Mark Palim, and Ying Pan. 2020. Flood damage and mortgage credit risk: A case study of Hurricane Harvey. *Journal of Housing Research* 29: S86–S120. [CrossRef]

Kreibich, Heidi, Philip Bubeck, Mathijs Van Vliet, and Hans De Moel. 2015. A review of damage-reducing measures to manage fluvial flood risks in a changing climate. *Mitigation and Adaptation Strategies for Global Change* 20: 967–89. [CrossRef]

Kundzewicz, Zbigniew W., Shinjiro Kanae, Sonia I. Seneviratne, John Handmer, Neville Nicholls, Pascal Peduzzi, Reinhard Mechler, Laurens M. Bouwer, Nigel Arnell, Katharine Mach, and et al. 2014. Flood risk and climate change: Global and regional perspectives. *Hydrological Sciences Journal* 59: 1–28. [CrossRef]

Kunreuther, Howard. 2021. Improving the national flood insurance program. *Behavioural Public Policy* 5: 318–32. [CrossRef]

Lamperti, Francesco, Mauro Napoletano, and Andrea Roventini. 2020. Green transitions and the prevention of environmental disasters: Market-based vs. command-and-control policies. *Macroeconomic Dynamics* 24: 1861–80. [CrossRef]

Larkin, Yelena, Lilian Ng, and Jie Zhu. 2018. The fading of investment-cash flow sensitivity and global development. *Journal of Corporate Finance* 50: 294–322. [CrossRef]

Lin, Yufeng, Adolf K. Y. Ng, Anming Zhang, Yimeng Xu, and Yile He. 2020. Climate change adaptation by ports: The attitude of Chinese port organizations. *Maritime Policy & Management* 47: 873–84.

MacDonald, Don N., Harry L. White, Paul M. Taube, and William L. Huth. 1990. Flood hazard pricing and insurance premium differentials: Evidence from the housing market. *Journal of Risk and Insurance* 654–63.

McShane, Michael K., and Juita-Elena Yusuf. 2019. Toward better management of flood losses: Flood insurance in a wetter world. *Public Works Management & Policy* 24: 88–109.

Mizen, Paul, and Philip Vermeulen. 2005. Corporate Investment and Cash Flow Sensitivity: What Drives the Relationship? Available online: https://ssrn.com/abstract=711165 (accessed on 4 May 2023). [CrossRef]

Mulier, Klaas, Koen Schoors, and Bruno Merlevede. 2016. Investment-cash flow sensitivity and financial constraints: Evidence from unquoted European SMEs. *Journal of Banking & Finance* 73: 182–97.

Myers, Stewart C., and Nicholas S. Majluf. 1984. Corporate financing and investment decisions when firms have information that investors do not have. *Journal of Financial Economics* 13: 187–221. [CrossRef]

Pagliari, Maria Sole. 2021. LSIs' Exposures to Climate Change Related Risks: An Approach to Assess Physical Risks. ECB Working Paper No. 2021/2517. Available online: https://ssrn.com/abstract=3797137 (accessed on 4 May 2023). [CrossRef]

Painter, Marcus. 2020. An inconvenient cost: The effects of climate change on municipal bonds. *Journal of Financial Economics* 135: 468–82. [CrossRef]

Palczewski, Krzysztof, and Wojciech Sa·labun. 2019. Influence of various normalization methods in PROMETHEE II: An empirical study on the selection of the airport location. *Procedia Computer Science* 159: 2051–60. [CrossRef]

Panagoulia, Dionysia, and George Dimou. 1997. Sensitivity of flood events to global climate change. *Journal of Hydrology* 191: 208–22. [CrossRef]

Poo, Mark Ching-Pong, Zaili Yang, Delia Dimitriu, and Zhuohua Qu. 2018. Review on seaport and airport adaptation to climate change: A case on sea level rise and flooding. *Marine Technology Society Journal* 52: 23–33. [CrossRef]

Roberts, Michael R., and Toni M. Whited. 2013. Endogeneity in empirical corporate finance1. In *Handbook of the Economics of Finance*. Hoboken: Elsevier, vol. 2, pp. 493–572.

Sastry, Parinitha. 2021. Who Bears Flood Risk? Evidence from Mortgage Markets in Florida. Available online: https://psastry89.github.io/website/psastry_JMP.pdf (accessed on 12 May 2023).

Schleicher, Thomas, Ahmed Tahoun, and Martin Walker. 2010. IFRS adoption in Europe and investment-cash flow sensitivity: Outsider versus insider economies. *The International Journal of Accounting* 45: 143–68. [CrossRef]

Surminski, Swenja, and Delioma Oramas-Dorta. 2014. Flood insurance schemes and climate adaptation in developing countries. *International Journal of Disaster Risk Reduction* 7: 154–64. [CrossRef]

Thomas, Adelle, and Robin Leichenko. 2011. Adaptation through insurance: Lessons from the NFIP. *International Journal of Climate Change Strategies and Management* 3: 250–63. [CrossRef]

Vogiatzis, Konstantinos, Pavlos Kassomenos, Georgia Gerolymatou, Panagiotis Valamvanos, and Evdokia Anamaterou. 2021. Climate Change Adaptation Studies as a tool to ensure airport's sustainability: The case of Athens International Airport (AIA). *Science of The Total Environment* 754: 142153. [CrossRef] [PubMed]

Wasko, Conrad, Seth Westra, Rory Nathan, Harriet G. Orr, Gabriele Villarini, Roberto Villalobos Herrera, and Hayley J. Fowler. 2021. Incorporating climate change in flood estimation guidance. *Philosophical Transactions of the Royal Society A* 379: 20190548. [CrossRef] [PubMed]

Wilby, Robert L., and Rod Keenan. 2012. Adapting to flood risk under climate change. *Progress in Physical Geography* 36: 348–78. [CrossRef]

Yang, Zaili, Adolf K. Y. Ng, Paul Tae-Woo Lee, Tianni Wang, Zhuohua Qu, Vasco Sanchez Rodrigues, Stephen Pettit, Irina Harris, Di Zhang, and Yui-yip Lau. 2018. Risk and cost evaluation of port adaptation measures to climate change impacts. *Transportation Research Part D: Transport and Environment* 61: 444–58. [CrossRef]