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Climate Risk & Commercial Property Values:

A review and analysis of the literature

Acknowledgements

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Executive summary

This paper was commissioned to help support real estate practitioners and investors in understanding and managing the physical risks from climate change with a specific focus on how these risks affect commercial real estate asset values and prices. Regulators and market actors are signalling the need for forward-looking climate risk analysis and assessment of asset value impact, and the authors sought to assess the evidence that property markets are, or are not, responding to climate risk through pricing, capex or opex decisions. If climate change risks are being recognised by real estate participants, then this should be observable through the literature that examines purchase/sale or opex/capex decisions. If such market evidence is lacking, on what basis are forward-looking projections of value at risk being made?

Climate events are not new—assets have always been exposed to extreme events sometimes. But an increase in extreme weather events is having greater financial consequences that are being borne by insurers, owners and occupiers, as well as governments. The research thus focused on academic literature from the last decade to address the link between climate hazard and financial materiality through the variables and parameters that go into financial modelling of climate impacts on value. With an emphasis on commercial property investment, the study sought to understand:

- the extent to which the evidence demonstrates that real estate markets have priced in the risks from extreme weather and climate change; and
- the channels through which the impacts of these risks on value have materialised.

A systematic, thematic review of English language academic literature on climate risk and real estate pricing and values was undertaken, focusing on developed real estate markets in North America, Australasia and Europe. The review found that evidence to date is more plentiful for residential rather than commercial real estate markets, although some recent research has begun to examine the commercial real estate sector in a more rigorous way. From the evidence on residential real estate, inferences were made for how these findings might apply to commercial real estate, noting that decisions by homeowners tend to be more subjective and less informed by professional advice than decisions taken by the real estate investment community who often adopt formal, rules-driven processes. Little literature was found on the response by commercial real estate tenants.

The findings from the literature are presented in the report so that evidence of financial impact can be considered both by hazard and thematically by market factors, structured as follows:

Climate hazard (peril) exposure	Thematic findings (how and why climate risk affects markets)
▪ Flood ▪ Hurricane / Cyclone ▪ Sea Level Rise ▪ Wildfire	▪ Perceptions and beliefs ▪ Adjacency and amenity ▪ Governance ▪ Valuation practices ▪ Short-term and bounce-back, or sustained value erosion ▪ Liquidity ▪ Lending behaviour and securitisation ▪ Insurability ▪ Asset level investment in resilience

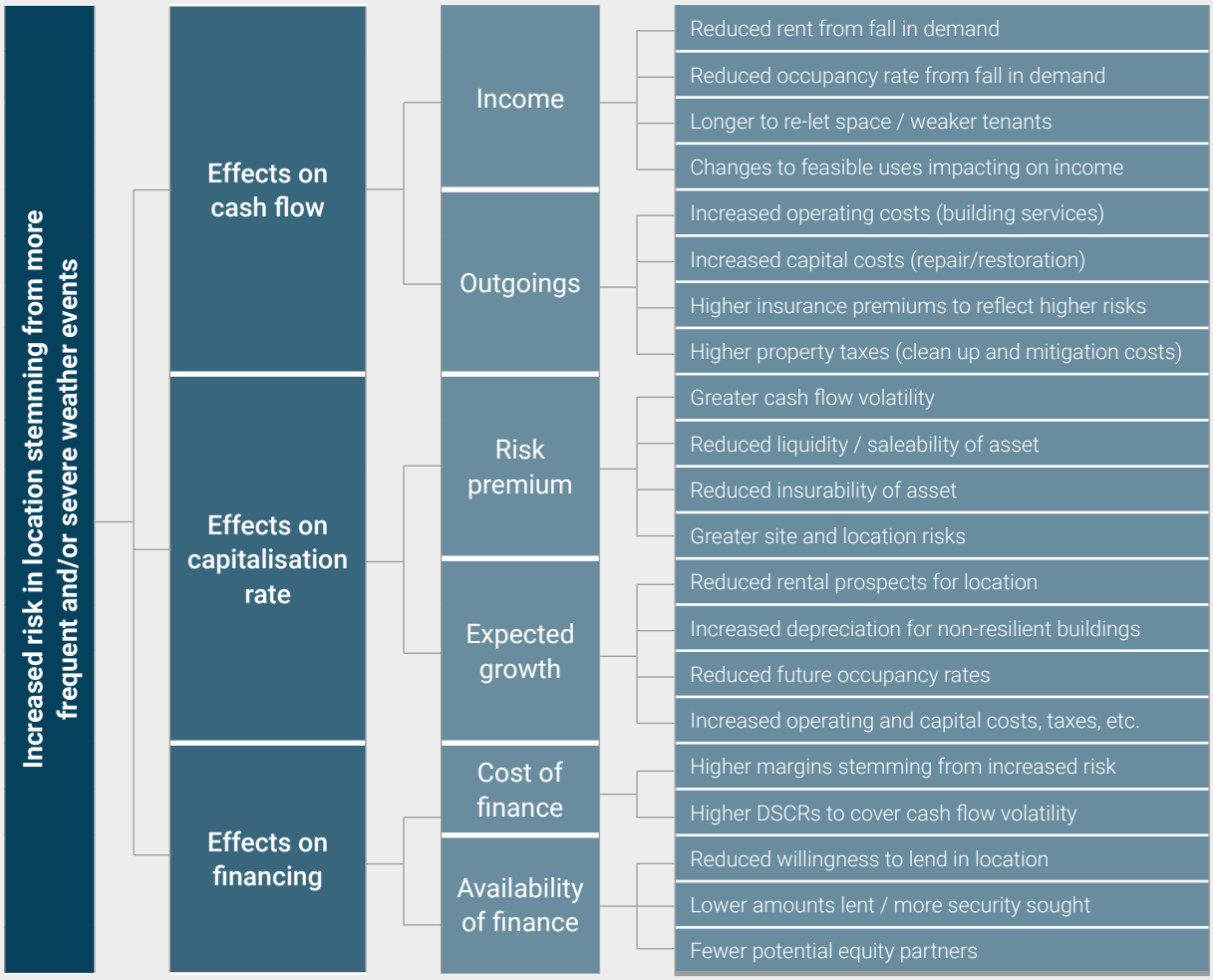
Many studies come with caveats to their analysis and the results are sometimes in conflict with similar research. For these reasons, the transmission channels through which pricing and value are influenced by climate risks are cloudy. Nonetheless, key headlines that emerged from the literature review were as follows:

- Property prices decline after climate events, but historically the drop has been modest and short-lived in locations where there is strong awareness of, and experience with, extreme weather-related events (particularly flooding and exposure to hurricanes/cyclones). Potential explanations include that climate risk was already capitalised into property values or that pricing was myopic in nature.
- There is a small body of recent evidence that certain events can lead to a long-lasting decline in prices or liquidity in geographies that have heretofore been relatively unexposed to extreme weather or climate events, or where intensity and frequency have appreciably increased. This may be a correction to previous under-acceptance or awareness of risk.
- Trading volumes or time on market may provide early signals of how markets are reacting to climate events and risks through lower liquidity that could ultimately feed into prices. Evidence is starting to emerge that buyer demand has shifted in response to climate risk exposure, rather than changes in lender or insurer behaviour, although these might follow.
- Proactive public investment and strong governance as risk mitigating factors may contribute to the modest and short-term nature of pricing reductions. There is some countervailing evidence that a lack of governance capacity or proactive investment may be harming prices, for example in sea level rise studies.
- Commercial owners/investors in some geographies are placing a higher risk premium on all properties in metro areas affected by climate events, regardless of whether their individual properties have been directly affected. There is some evidence that this may extend to areas with similar climate risk profiles, even where events have not occurred.

- There is some evidence from residential markets that levels of belief in climate change and its impacts may result in differing levels of price impacts of climate risk. In areas with high levels of climate change 'deniers' the price impacts may be muted.
- For areas affected by wildfires, floods and storms, significant short-term value drops may, in part at least, be offset by amenity value. Further, the very limited number of commercial studies points to greater persistence of urban agglomeration benefits offsetting perceived climatic risks.
- Access to information on risks and on mitigation measures is a contributing factor in value assessment and pricing. The evidence suggests that better information leads to greater awareness, belief acceptance and integration of climate impacts on prices achieved.
- Valuation practices, which are largely driven by lagging indicators, suffer from a paucity of specific climate risk evidence and available data. Some papers also claim that valuers may lack the necessary specific interdisciplinary skills and professional standards to enable or require them to fully integrate climate effects.
- There is evidence in the U.S. context of lender concerns about climate risk being manifested through a shift in mortgage originations to loans that are able to be securitised. In this way, lenders can sell the loans and transfer risk to government sponsored enterprises (GSEs) through the MBS (mortgage-backed securities) market.
- There is little evidence in recent literature that quantifies the financial performance benefits from asset-level risk mitigation expenditure. There is also a lack of evidence that insurance pricing reflects owner investment in resilience.

To help apply the research practically, the diagram below was developed to conceptualise the potential financial materiality of climate risk on commercial real estate assets. It demonstrates how, in theory, climate change physical risks could, or have in some cases been found to, feed through to income-property pricing in a discounted cash flow (DCF) appraisal framework. At a general level, it is expected that climate risk could be incorporated in property valuations through an impact on three primary valuation components: 1) cash flow—leasing fundamentals (rent, rental growth and vacancy) net of operating expenses and capital expenditures; 2) capitalisation rate—capital market conditions including the overall required return that embeds the required risk premium, which captures expectations of cash flow prospects (including exit price) and liquidity within a conventional multi-year pro forma; and 3) financing—the cost and availability of funds from both equity partners and mortgage debt finance are directly related to return requirements and indirectly to property liquidity.

Figure: Anticipated effects on commercial real estate asset performance of increased exposure to climate risk



Developed with reference to de Wilde and Coley (2011)

The effects are not all evidenced equally by the literature, and there is limited evidence therefore on the validity of some of the 'sub-channels' of impact shown on the far-right side of the Figure. Presently, the overwhelming body of evidence is on sale prices without further decomposition of the components of pricing or value. This reflects what was noted earlier about the greater availability of research on residential real estate and climate risk, as direct capital comparison dominates the value and price fixing process for residential units.

While the findings offer some clarity and nuance to the links between values and price and extreme weather and chronic climate events, significant knowledge gaps remain. Most studies to date are based on analyses of prices, but not the channels through which prices are determined. This suggests difficulties for commercial real estate market participants to estimate future asset values. Institutional investors will need to embed better planning and management of uncertainty within their internal appraisals, asset location, stock selection (buy-hold-sell) decisions, and external disclosure, particularly as the market shifts to more forward-looking climate risk analyses.

Inadequate or considerably different evaluation of climate risks by market participants raises the prospect of the misallocation of capital, both for individual investors and for the investment industry generally. The extent to which physical climate risk is presently capitalised in assets and markets is unclear, as is how different market setters and actors influence investor calculations. For example, providers of insurance and debt have their own perspectives on climate risk which may impact on the pricing of their products. Moreover, each have decision timeframes that differ from those typical of owners/investors, i.e., property hold periods may be 8–10 years, whereas insurance premiums are priced annually and secured lending agreements range from 3–7 years. This creates cash flow and financing risks which may exert downward pressure on prices where physical climate risks are identified or found to be increasing post-acquisition. Similarly it is unclear on how occupiers will respond to climate events and risks, creating another cash flow uncertainty. Other stakeholders such as advisors and valuers may lack uniform knowledge, instruction in professional standards on climate risk, and access to data which may impact value. Lastly, government regulations for and investments in resilience plausibly contributes to investor confidence, but the extent to which this is revealed in values and prices is imprecise.

Clearly more data is needed, especially on commercial real estate pricing, as is attention to how financial modelling should be structured or investment/portfolio allocation decisions weighted to best balance risk and return. Further research work can improve understanding of the transmission channels through which pricing and value impacts are revealed, and inform policy makers, regulators and practitioners in their efforts to increase resilience and advance socially equitable markets. To that end, the following engagement and research activities are suggested to strengthen the field of physical climate risk and real estate investment:

1. Market surveillance and improving data flow on hazard exposure and asset pricing

A structured engagement with regulators, lenders, insurers, and owners/investors on a national or local/regional level can be initiated to discuss voluntary and/or mandatory practices so that information on current and projected climate hazard exposure, asset damages and losses, insurance pricing, and sales volume and pricing can be catalogued and shared between market setters and participants.

2. Asset-level financial and valuation modelling

As demonstrated by the above graphic, there are a wide range of variables that may be influenced by climate risk and that could ripple through cash flow modelling or calculation of exit or terminal values. To address this, a working group of asset owners and managers is proposed to conceptualise and test 'climate-adjusted' financial modelling utilising a wider range of input variables than is typical, and undertaking sensitivity testing against future climate scenarios. The outputs from such a working group should be disseminated to inform industry best practices.

3. Governance and resilience investment planning

The interplay between asset- and area-scale resilience and property values may create a 'virtuous' investment opportunity for investors with exposure to real estate, infrastructure, and sovereign/sub-sovereign debt. Meanwhile, government borrowing for investment in resilience infrastructure may be recaptured in part or whole through land and property

owners via rates or other value capture instruments. An engagement and dialogue exercise involving local/regional/national government actors, asset owners and investors, lenders, insurers and credit rating agencies can support understanding of the dynamics between strategic resilience investment and asset value, the need for strategic investment planning, and capital raising and innovative capital repayment channels.

4. Considerations for future commercial real estate-focused research

Some ideas for research questions include:

- **The size and longevity of pricing effects of climate events and risks on commercial real estate:**
  Further empirical investigation is needed of the impact of recent notable weather events on CRE pricing and adjustment over time—to what extent is this a permanent price erosion and to what extent do values bounce back?—as well as the pricing of SLR and wildfire risk should be a top priority. This can help illuminate how the liquidity impact channel works, both in terms of available indicators and the investment processes (external and internal) in which decisions on purchase, retention and sale are made.

- **The impact of climate events on income and income growth:**
  While some evidence of CRE capital value changes was revealed, there was a dearth of literature on how climate events impacted the landlord and tenant relationship and, in turn, whether such events led to temporary or long-term reduced income, cessation of leases, and/or uninsurable losses for the building occupant.

- **The potential costs and benefits of resilience expenditure on existing stock:**
  The business case for asset-level investment in resilience was largely absent from the literature, as was evidence of a 'resilience premium'. The lack of evidence of cost-benefits from resilience investment suggests opacity on the return such expenditure would generate. Research into the value effects of technical upgrade options, not simply their costs or efficacy, is needed, as well as integrating these expenditures with the business case for carbon neutrality.

- **The required and possible response of insurers and lenders to support of 'at-risk' assets:**
  If real estate cannot be insured against adverse events and cannot be used as loan security, it will lose value and potentially become 'stranded'. The research has uncovered some evidence of this, either in terms of actual value loss or, as a lead indicator, lack of liquidity. Given these linkages, creating effective mechanisms to ensure continuing market liquidity facilitated by insurance and finance is in the interests of all stakeholders, and especially those who may have a diminished ability to fund high premiums.

1. Introduction, aims and objectives

It has been claimed that

> **"climate change is the defining crisis of our time and it is happening even more quickly than we feared."[1]**

Indeed, Smith (2021) maintains that the "physical impacts of climate change are already impacting on our economy and society, and further temperature rise is already baked in". However, despite this it has been argued that "Climate risk … is not an issue that is front-of-mind for many in private real estate" (Lee, 2020).

This latter contention presents a challenge to all those engaged in real estate, whether as investors, occupiers, lenders, insurers, or policy makers, and it pre-supposes that it should be a critical part of decision-making. However, it also raises two questions; first, is this the case and, second, what is the basis of evidence that real estate markets are, or are not, responding to physical climate risk through pricing, capex or opex decisions?

The starting premise of this research project was that, if climate change events are recognised by real estate participants, then they should be observable through examination of the literature that has analysed property pricing at purchase/sale or for opex/capex decisions. If that evidence is lacking, on what basis are forward-looking projections of value at risk being made?

Climate events are not new and many real estate assets have always been exposed to extreme events, though this exposure may not have been anticipated (see for example Higgins, 2014). However, in recent years and in parallel with growing research into climate change, extreme weather is trending more noticeably. In turn, this is having greater financial consequences which are being borne by insurers, owners and occupiers of real estate, as well as governments. It was determined that this research (principally an academic literature review) should focus on studies conducted over the last decade to understand especially with reference to commercial property investment:

- the extent to which the evidence demonstrates that real estate markets have priced in the risks from extreme weather and climate change; and
- the channels through which the impacts of these risks on value have materialised.

Regulators and market actors are signalling the need for forward-looking climate risk analysis and assessment of the asset value impacts arising from this risk. Indeed, many climate models to assist real estate investors in this regard are now available for use, but the evidence to link climate hazards with resultant financial materiality is where there appears to be a limited amount of available and transparent knowledge. It is this gap that this report seeks to examine through an analysis of academic literature that addresses the link between climate hazard and financial materiality, as well as the variables and parameters that go into financial modelling of climate impacts.

1 https://www.un.org/en/un75/climate-crisis-race-we-can-win

To address these objectives and inform the review, the following set of detailed research questions were posed:

- What is known about the impacts of past (notable recent) climate events on property prices or values?
  - Have prices and/or valuations been impacted?
  - If so, have these impacts been short-term (bounce back) or long-term?
  - Does impact vary by type of event, type of tenure and/or type of property?
  - Have resilient or 'better' buildings retained value even where risks have increased?
- What drives observed price discounts/premiums? Is it the impact on:
  - prospective cash flows via rents and occupancy rates;
  - liquidity;
  - ability to finance;
  - insurability; and/or
  - asset management policies towards opex/capex and retention/disposal?
- What other factors affect any observed actions by real estate participants, such as:
  - perceptions and beliefs;
  - governance structures and area-wide investments in resilience;
  - dominance by adjacency or other value-relevant factors;
  - the role of advisors, specifically valuers; and/or
  - availability and reliability of data?

The report summarises the evidence from this literature review, which is presented by type of peril or event to which assets may be exposed (Section 4, and Appendix), as well as thematically according to how and why markets have responded (or not) to extreme weather and chronic climatic events (Section 5). As most literature is based on residential markets, the report discusses how these findings may apply to commercial real estate and how real estate investment markets may see pricing, values and allocation of capital change as a result (Section 6, with commentary on the potential relevance of findings related to individual papers captured in the Appendix). Section 6 also includes a model for the channels by which climate risk translates into value impacts. Lastly, recommendations are offered for next steps by market actors, policy makers and researchers connected with commercial real estate (CRE) to guide future cross-sector engagement and research (Section 7).

2. Method

A systematic, thematic review of primarily academic literature on climate risk and real estate pricing and values was undertaken, focusing on research for developed real estate markets in North America, Australasia and Europe. The search was restricted to English language publications. In addition to academic work, some literature produced by industry, professional bodies or journalists (augmented by some personal discussions) was used to help identify and explore important themes. However, the main findings and conclusions are founded firmly on the academic literature.

At this point, it is useful to distinguish between a valuation, a transaction price, and an assessment of investor worth. The distinction between the three concepts is not always apparent from the literature. A valuation is the opinion by an expert as to a likely sales price, normally based on an analysis of past transactions; it is therefore essentially a backward-looking measure, although it should include a forward look based on an evidenced likelihood of future changes in market sentiments. Price, on the other hand, is what is achieved from sales in the market and, particularly in a residential context, may not have been influenced by professional valuations or advice unless borrowing was required. Finally, an investor's appraisal of worth is based on a forward projection of the likely income flows, capital appreciation and risks over a defined holding period. This point is considered further in Section 5.4.

The review included papers using quantitative methods and others that took a qualitative approach, with more focus on the former. Quantitative evidence on how real estate values and prices have been impacted already by climate change events and known risks was examined, with the aim of informing investors in respect of future strategies. Qualitative studies were equally important, as findings from these studies deepened interpretation of the quantitative results. The review revealed few rigorous, data-informed studies for commercial real estate, with studies of residential real estate more plentiful. This was perhaps unsurprising as the incidence of owner-occupation sales is higher and the availability of large-scale datasets is much greater than for commercial real estate, where academic research is still limited. However, this is rapidly changing. Awareness by stakeholders and by academic researchers in climate risk, in the space of only two to three years, has transformed from the interests of specialists to become mainstream and high priority, creating a situation where more data has been generated and made available for quantitative analysis.

The search covered climate-related hazards whose frequency, intensity and range are increasing as a result of climate change. Based on an initial scoping exercise, these were categorised as fluvial and storm flooding, hurricanes/cyclones and storms, sea level rise (SLR) and wildfires. Section 4 summarises the evidence for impacts on prices or values by type of climate event or risk (with further individual paper summaries by event found in the Appendix), while Section 5 considers themes that emerge from the literature that are relevant to investor analysis and decision-making. Care was taken when drawing inference from studies of residential real estate sales, as decisions made by homeowners tend to be more subjective and less informed by professional advice than decisions undertaken by the real estate investment community, who often adopt formal, rules-driven processes.

Further details on the methods used in the literature is given below.

Quantitative analysis

Quantitative studies typically used hedonic modelling to estimate the impact of climate events or risks on individual property prices in affected areas. Prices were mathematically modelled to be a function of variables that described the attributes of each building (such as size or age), its location, the time of sale, as well as variables capturing the nature of the climate event or risk analysed. These studies then tested whether the occurrence of a climate event or risk of a future event had affected prices in a statistically significant way. In practice, the former may be hard to separate from the latter in that the occurrence of, say, a flood or wildfire event might alert market participants to risks of which they were previously unaware. Most papers studied a single event or small number of events within a particular geography, but some larger studies and meta-analyses (testing effects measured across many studies) were also available.

Results of hedonic studies should be treated with some caution due to two key issues:

- **Data:** Key to establishing a reliable signal of price impacts is the availability of sufficient, high quality data on transactions supported by data on the features of the properties traded. This is challenging for commercial property due to the private, decentralised nature of real estate markets, infrequent trading, and tenure heterogeneity, which inhibits comprehensive and consistent data collection. Ideally, study of a specific event needs to include sales from before and after the event, and of properties affected to different extents. This can be especially difficult if a storm or flood affects not just prices, but also how many sales take place and whether liquidity is affected. Similar issues exist, but to a lesser extent, for residential real estate markets.
- **Many factors contribute to value:** Separating out the impact of one value determinant (climate event) from other influences can be difficult because some attributes of properties associated with climate risk might add value in other ways. For instance, proximity to woodland may increase risk in locations prone to wildfires, but may also lead to higher prices owing to amenity from a woodland location; similarly in coastal areas, there may be a trade-off between a view and risks from flood and storm events. However, such studies often suffer from results which are so location-specific that wider applicability of findings is limited and this needs to be treated with caution. For commercial real estate, central business districts in cities built around rivers may present exposure to flood risk, but still offer value in other ways. This draws attention to the complex and sometimes conflicting motives behind location and investment decisions, considered further in Section 5.2 under the heading of Adjacency and Amenity.

Other types of analysis, such as time-series analysis of assets or markets exposed to climate risks, were rarer. While many aspects of investment performance are tracked for institutional real estate portfolios, asset level data are normally confidential and location-based aggregate data may be insufficiently granular. This is a challenge for improving understanding of the channels through which prices or returns are affected when there is increased exposure to or increasing awareness of climate risk.

Qualitative analysis

The review revealed fewer recent examples of qualitative approaches. Methods used included questionnaire surveys, and interviews; there were some papers where a mixture of quantitative and qualitative approaches were used. As with the quantitative studies, qualitative research concentrated primarily on residential real estate markets, but some studies did consider commercial real estate.

Qualitative methods are commonly used when data availability does not permit robust quantitative analysis or where the research objective is to understand the reasons behind already known results. Samples of participants in such studies need to be representative, appropriate, and sufficient in size to allow robust and meaningful insights to be obtained. Some may consider this approach to be inherently less robust, as it is normally opinion-based and so can be speculative. Yet, despite their perceived disadvantages, qualitative methods are required to explain the why, rather than the what and are therefore widely used to help develop policy. They are also important as they provide insight into the behavioural aspects of decision-making that are likely to be important to climate risk mitigation and adaptation decisions.

3. Key findings from the literature

Property asset valuation and financial modelling require a base of market data and an understanding of the trends and variables that influence pricing and value to owners and investors. Climate risk may already be impacting on values, and it is sure to impact in the future on the trends and variables that affect pricing and investment decisions. Discerning the most relevant information from the evidence available is important. A better understanding of how recent extreme weather and climate events affect values and pricing can support how investors allocate and deploy capital through their buy-hold-sell decisions.

Overall, the empirical evidence on how extreme weather and climate events affect values or prices is limited. It has been skewed towards studies that assess residential rather than commercial real estate markets, although some recent research has begun to examine the commercial real estate sector. The evidence is also skewed towards a handful of countries and regions (e.g., U.S., Australia, and Northern Europe)[2]. Many of the findings come with caveats to the analysis and are sometimes in conflict with similar research. For these reasons, the transmission channels through which pricing and value are influenced by climate risks are unfortunately cloudy. With that in mind, headlines that emerge from the literature review are as follows:

1. **Property prices decline after climate events, but historically the drop has generally been modest and short-lived** in locations where there is strong awareness of, and experience with, extreme weather-related events (particularly flooding and exposure to hurricanes/cyclones). Potential explanations include that climate risk was already capitalised into property values or that pricing was myopic in nature, with participants forgetting that risks are still present in the locations concerned.
2. **There is a small body of recent evidence that certain events can lead to a long-lasting decline in prices or liquidity** in geographies that have heretofore been relatively unexposed to extreme weather or climate events, or where intensity and frequency have appreciably increased. This may be a correction to previous under-acceptance or awareness of risk. This appears as a more identifiable phenomenon in commercial real estate markets, though the range of studies is far narrower than for residential markets.
3. **Trading volumes or time on market may provide early signals of how markets are reacting to climate events and risks through lower liquidity that could ultimately feed into prices.** Evidence is starting to emerge that buyer demand has shifted in response to climate risk exposure, rather than changes in lender or insurer behaviour, although these might follow. While these findings derive from studies of residential housing price and liquidity dynamics, it seems reasonable that the parallel for commercial property could be a thinning of depth of buyer interest in 'at risk' assets.
4. **Proactive public investment and strong governance as risk mitigating factors may contribute to the modest and short-term nature of pricing reductions.** This sometimes is supported by the expectation of public action (e.g. subsidised insurance for high-risk geographies or publicly-funded mitigation works) to minimise losses and/or other moral hazard setting actions. There is some countervailing evidence that a lack of governance capacity or proactive investment may be harming prices, for example in sea level rise studies.

2 Noting that the literature search was limited to English language publications and the results may have been narrowed as a result.

5. **Commercial owners/investors in some geographies are placing a higher risk premium on all properties in metro areas affected by climate events, regardless of whether their individual properties have been directly affected.** There is some evidence that this may extend to areas with similar climate risk profiles, even where events have not occurred. The same evidence does not exist in relation to tenant behaviours.
6. **There is some evidence from residential markets that levels of belief in climate change and its impacts may result in differing levels of price impacts of climate risk.** In areas with high levels of climate change 'deniers' the price impacts may be muted. This observation is most likely where the risks lie primarily in the future, such as sea level rise.
7. **For areas affected by wildfires, floods and storms, significant short-term value drops may, in part at least, be offset by amenity value.** Further, the very limited number of commercial studies points to greater persistence of urban agglomeration benefits offsetting perceived climatic risks.
8. **Access to information on risks and on mitigation measures is a contributing factor in value assessment and pricing.** The evidence suggests that better information leads to greater awareness, belief acceptance and integration of climate impacts on prices achieved.
9. **Valuation practices, which are largely driven by lagging indicators, suffer from a paucity of climate risk-related evidence and available data.** Some papers also claim that valuers may lack the necessary specific interdisciplinary skills and professional standards to enable or require them to fully integrate climate effects. These factors may contribute to value and price heterogeneity.
10. **There is evidence in the U.S. context of lender concerns about climate risk being manifested through a shift in mortgage originations to loans that are able to be securitised.** Evidence was found that some lenders are proactively shifting the composition of loan originations in order to sell the loans and transfer risk to government sponsored enterprises (GSEs) through the MBS (mortgage-backed securities) market, rather than hold the loans on their balance sheets and face climate risk.
11. **There is little evidence in recent literature that quantifies the financial performance benefits from asset-level risk mitigation expenditure.** Although the costs of improving asset resilience can be quantified, it seems neither the heightened climate risk nor the benefits of mitigating that risk are currently clearly evidenced in commercial real estate values. There is also a lack of evidence that insurance pricing reflects owner investment in resilience.

4. Hazard exposure and evidence on asset values

This chapter summarises the evidence from the literature based on asset exposure to individual climate hazards or perils: flood, hurricanes/cyclones, sea level rise, and wildfire. The report Appendix provides an additional reference source through a summary of each of the main papers considered, also organised by climate risk.

4.1 Flood

Property exposure to flood risk is not a new consideration, though climate change will impact the prevalence, intensity, and frequency of flooding, as well as increasing the pool of properties with exposure. Roberts *et al.* (2015) identified an increased likelihood of extreme climatic events and thus increased frequency and intensity of flood risk as significant to depreciation in property values. There are several channels through which impacts on value might occur. Bhattacharya-Mis *et al.* (2011) summarised the main concerns of stakeholders in commercial properties in the UK, which related to physical, economic and social losses as a result of flooding. These included:

- potential risk of disruption to business, including lack of essential services and loss of profit;
- higher cost of relocation to other properties, even for a temporary period;
- higher repair, replacement and reinstatement costs;
- potential increase in the cost of insurance, particularly in light of improvements to data held by insurers on flooding; and
- more difficulty in obtaining mortgage finance resulting from higher risks and reduced insurance cover.

There is a body of quantitative work that has examined the impact on property prices from flooding. The results vary greatly. This reflects that the impact of flooding can vary significantly between areas given differences in meteorological factors and physical characteristics such as topography and geology. It also reflects differences in the nature and intensity of land use across areas, as well as variations in the dynamics of real estate markets.

Beltrán *et al.* (2018) examined 37 published studies conducted for residential properties at risk of flooding. They reported results that ranged from a -75.5 percent discount to a +61.0 percent price premium for properties located on a floodplain. They then conducted a meta-regression using the 364 separate point estimates that were reported in these studies to establish a price discount of -4.6 percent associated with properties located on a 100-year floodplain. Their results also indicated that price discounts were larger immediately following a flood but started to decay afterwards. It extended the work of Daniel *et al.* (2009), whose previous meta-analysis focused solely on studies from the U.S.: in that study the authors found that a 0.01 increase in probability of flood in a year amounted to a difference in transaction price of an otherwise similar house of -0.6 percent. The study also found counter-effects on prices from amenity, an issue that is returned to later.

Subsequently, Miller *et al.* (2019) undertook a comprehensive investigation of the impact of proximity to water on U.S. residential property prices, including price differ-

ences arising from the likelihood of being affected by storm surges and sea level rise. In the absence of coordinated climate risk mitigation, they investigated whether housing markets were adapting to such risks. While many previous studies focused on a single metro area, they examined transactions in 19 U.S. states over 2000–2017. Rather than a discount, the authors found significant price premiums for waterfront proximity, suggesting that the positive effect of waterfront amenity outweighed the negative impact associated with risk from flood or other water-related events. They also found that single-family home prices rebounded quickly to prior trends after the occurrence of major storms, with little persistent negative impact. Only for extreme events that were large enough to displace employment, such as Hurricane Katrina in 2005, was a longer-term depression in prices observed. The authors suggested that their results implied either a short-term horizon for buyers of coastal properties at risk, or a moral hazard problem whereby residential owners are dependent on and subsidised by government and the failure of insurers to reflect the risks adequately.

Hirsch and Hahn (2018) analysed the effects of flood risk on the rents and prices of residential properties in Regensburg, Germany. They found that the impact on both variables was negative, but with a smaller impact on rents than on prices. They attributed this to the different commitments of tenants versus owners to specific properties, with the former having only a transient interest.

The accuracy of data on flood risk is an important consideration. CBRE (2019) compared Environment Agency flood maps in the UK with their own site-specific analysis. They contended that official flood maps overstated flood risk in 62 percent of the sample. They suggested that properties classified as 'high risk' could be at low or very low risk instead and could be under-valued by between £15bn to £31bn. While further research is needed in this area, it highlights the potential for mispricing where flood data is not accurate.

In the absence of quantitative data in some markets, researchers have studied how perceptions of flood risk impact on commercial property values. Bhattacharya-Mis & Lamond (2016) found no clear evidence that property owners saw a direct link between flood risk and value and this is corroborated by interviews with built environment professionals reported in Lamond *et al.* (2019). The latter study highlighted a temporal element, where a recent flood event can create a disproportionate reaction with impacts on value, property insurance and desirability of locations, but that people tend to forget over time. Businesses at risk, but not recently flooded, could have low awareness of risk or not perceive such risk as a significant concern. Lamond *et al.* (2019) also identified locational factors that could offset risk in the commercial sector. For instance, waterfront location could be seen as important in some commercial sectors and not just in residential markets.

Prior to these papers, Pottinger and Tanton (2014) found evidence of increasing flood risk due diligence among major UK investors when making acquisitions, driven by tightening regulation and the occurrence of major flood events. The availability and accessibility of insurance were also identified as issues for occupiers. Yet, the authors found no evidence that valuers were making rent or yield adjustments to reflect changes in investor and occupier sentiment. Roberts *et al.* (2015) suggested that surveyors should look at local probability of floods and historic evolution of flood maps. Lamond *et al.* (2019)

found that low perception or lack of awareness, as well as a lack of guidelines and common practices on the threat of flood risk explained why any discount in market value was inconsistent. They identified that without reliable and accurate data and projections of risk, interviewees were also reluctant to disclose flood risk to buyers.

4.2 Hurricane/Cyclone

For coastal locations in several parts of the world, hurricanes are a fact of life and can be anticipated based on historical patterns. There is mounting evidence that the frequency, duration, and intensity of hurricanes has increased over recent decades, driven by global climate change. During this review, the only papers examined related to storms in the U.S. These are mainly recent, possibly triggered by the significant increase in costly storms experienced in this century, notably Hurricane Sandy. Highlighting this shift in frequency and intensity is the fact that 14 of the top 20 costliest mainland United States tropical storms occurred since 2000 (Fisher and Rutledge, 2021). In addition, the geography of hurricane paths has changed, with locations further up the U.S. East Coast that were traditionally thought to be out of harm's way now affected.

Consistent with the literature on flooding, early studies of the impact of hurricanes on property prices focused on single-family homes and typically documented a temporary negative reaction that ultimately dissipated as the event became a distant memory as highlighted by Below *et al.* (2017). They conducted extensive analysis of house price reactions to hurricanes on the North Carolina coast over the period 1996–2012 and found a price discount of roughly 3.8 percent in the 60 days following a storm, but which became unobservable beyond 60 days post-storm. Severe storms do not seem to have a lasting impact on the prices of residential properties in this severely threatened subject area, likely because the threat was realised and hence risks were already being capitalised into prices of these properties.

Fisher and Rutledge (2021) conducted one of a limited number of empirical studies focused on the commercial property sector. The authors investigated the impact on commercial property values and returns from all the significant hurricanes that occurred during the past 30 years in the U.S. They found on average an immediate price impact that worsened over time, taking three years to bottom out, then prices reverted back to 'normal'. That is, there did not seem to be a permanent price discount, consistent with previous findings based on the single-family residential sector.

A potential limitation with both the Below *et al.* (2017) and Fisher and Routledge (2021) studies is that that there was no consideration of the potential for increasing climate risk, and recognition of it, over time. The hurricanes and their associated time-period are grouped together in a single analysis, essentially forcing the adjustment coefficients to be time invariant. A number of recent studies that examine the impacts of Hurricane Sandy, that hit land in October 2012 (the first major storm in recent times to impact New York City), provide insight into a potential re-evaluation and rethink of climate risks.

Ortega and Taspinar (2018) examined the reaction of house prices using an extensive property level dataset comprised of all New York City house sales from 2003–2017 combined with Federal Emergency Management Agency (FEMA; U.S. government) geo-coded data on building structure damage. They compared price trajectories of housing units impacted by Sandy to similar units not impacted but also in a flood zone, plus a 'control' sample. They reported that damaged properties suffered a large immediate drop in value following the storm (17–22 percent), followed by a partial recovery that likely reflects their gradual restoration. A key finding is the gradual emergence of a price penalty among flood zone properties that were not damaged by Sandy, reaching 8 percent in 2017 and showing no signs of recovery, consistent with a learning mechanism related to heightened perceived risk of large-scale flooding episodes in the area, aka 'belief updating'.

Gibson and Mullins (2020) reported that Hurricane Sandy-related flooding decreased home values by 3–5 percent, and inclusion of homes in the floodplain by new FEMA maps post-Sandy decreased sale prices by 7–8 percent. However, the effect of new flood plain maps on properties flooded by Sandy was zero, while the effect on properties not flooded as a result of Sandy, but now in the floodplain, was estimated to be between 12–23 percent. This implies that updated maps provide no new information for properties flooded as a result of Sandy, as they were already at risk, but they do lead to reassessment of risk for homes previously outside of the floodplain. Cohen *et al.* (2021) show that the 'surprise' of Sandy-induced flooding that extended beyond the FEMA flood zone at the time, impacted house prices beyond, but close to, the area of flooding. They report a short-run negative effect on New York City (NYC) housing prices of 6–7 percent for each mile difference between the property distance from the flood zone and the distance to actual flood locations. However, for homes outside the flooding area, the negative 'surprise' effects on housing prices tended to disappear, as residents' memories of the incident faded.

Addoum *et al.* (2021) wrote the second of only two academic papers on the impact of hurricanes on commercial real estate (CRE) investment, and the only one focused on the implications of increasing climate risk for CRE values. The authors examined the impact of Hurricane Sandy on property prices using CRE transactions from 2001–2017 found from CoStar data, matched with flood risk data. The authors add controls by expanding their sample to include Boston (likely now higher perception of risk) and Chicago (placebo). Further, they report a permanent price discount for impacted properties, with properties exposed to flood risk experiencing slower price appreciation after the storm than equivalent, but unexposed, properties. Their analysis supports an impact channel primarily via an increased risk premium as opposed to revised downward strength of leasing fundamentals.

Finally, in a rare paper examining the impact on CRE tenants, Meltzer *et al.* (2021) found that the effects were concentrated among retail businesses with more localised consumer bases, and that they were long-standing with closures persisting four years beyond the storm event.

4.3 Sea Level Rise

Of the academic papers considering impacts of impending sea level rise (SLR) on real estate from 2009 to 2020 (which were completely or primarily related to residential properties), two main categories emerge:

- those published up to and including 2016 were all in the nature of predictive and theoretical models of how real estate was likely to be affected by sea level rise; and
- those published from 2017 are primarily empirically based analytics and consider the extent that price or value impacts are already observable. In some cases, these papers also consider associated storm damage; e.g., Ortega and Taspinar (2018) which, as noted above, considered Hurricane Sandy, and Miller *et al.* (2019) which examined the impact of various types of flooding, including SLR.

The early studies, which tended to be geographically diverse, recognise that the climatic impacts of SLR were, at the time, uncertain, both in terms of when inundation would be likely to occur and the level of rise (and hence extent of land impacted as determined by elevation above sea level).

Both Bin *et al.* (2011) and Almås and Hygen (2012) studied the potential costs of SLR to North Carolina, the U.S. and Norway respectively. While Bin *et al.* sought only to model and predict residential value losses, Almås and Hygen quantified total losses to infrastructure; both studies concluded that there were inherent uncertainties as to the size of financial impacts due to potential mitigation measures, a point that relates to consideration of the role of governance (see section 5.3 below). Elsewhere, Kontogianni *et al.* (2014), studying the impact on Greece's low-lying delta lands, put forward suggestions for real option modelling of values. Fu *et al.* (2016), in their Florida study, went further by suggesting that a pure economic cost analysis failed to account for wider socio-economic costs, such as loss of amenity and loss of wetlands, with the associated biodiversity impacts. Heberger *et al.* (2011) similarly argued that human dislocation costs should also be factored in.

These papers underscore that uncertainties in the underlying scientific predictions and unknown levels of future mitigation lead to an inevitable inability to calculate precisely any impact on prices. Their inclusion in this review is to demonstrate the rapid trajectory of academic research from identification of the identifiable and quantifiable, at least in cost/property loss terms, to attempts to consider potential price impacts of SLR predictions. The clear gap in this literature has been the lack of commercial real estate studies.

Most of the papers that were published within the last five years show a geographic shift towards the U.S., with only two being non U.S.-based, both of which related to Australia (Warren-Myers *et al.,* 2018; Fuerst and Warren-Myers, 2019). No recent quantitative studies in Europe were identified, even though the European Environment Agency indicates that SLR in Europe will be similar to the global average (except for some areas still seeing land rise consequent on post-glacial rebound and changes in the Greenland ice sheet gravity field).[3]

3 Predictions quoted by the European Environment Agency (https://www.eea.europa.eu/data-and-maps/indicators/sea-level-rise-7/assessment) from work by Slangen *et al.* (2014) and Oppenheimer *et al.* (2019).

It proved difficult to discern consensus findings from the literature. The range of estimates of SLR and the range of timescales over which it was expected that this would feed into purchase decisions clouded the ability to make meaningful comparisons (Bernstein *et al.,* 2019). Furthermore, a lack of knowledge as to the full (including indirect) costs, likely degree of inundation, and presence (now or in the future) of mitigation measures continue to be argued as issues that can influence results (Scott *et al.,* 2012; Conyers *et al.,* 2019; Warren-Myers *et al.,* 2018; Walsh *et al.,* 2019; Murfin and Spiegel, 2020). Further influences on the results may be the level of belief in climate change or expectation of state protection. These views are developed further in sections 5.1 and 5.3.

Nonetheless, knowledge of the potential impacts from SLR is growing and with it, higher price discounting (Beck and Lin, 2020) or lower rates of price appreciation as found by Tyndall (2020), who looked at the impact on multi-family blocks. This increasing level of knowledge led McAlpine and Porter (2018) to conclude that some quantifiable level of price adjustment could be discerned in coastal Florida, although the price adjustments found were small. However, the main inference that can be drawn from this is that moving forwards value preservation is dependent on collective action by communities, individuals and government officials as these stakeholders can reduce risks through reasonable adaptation measures.

Owner-occupiers may well not have access to, or consider, information regarding long-term impacts. This could be a matter of lack of knowledge or data, but beliefs as to whether SLR will/will not occur can influence whether prices are negatively affected (Bakkensen and Barrage, 2021; Baldauf *et al.,* 2020; Murfin and Spiegel 2020). In contrast, investor owners are more likely to factor in long-term impacts. They may discount long-term values in much the same way as, in non-risky locations, a long leasehold will command a lower value than a freehold (Bernstein *et al.,* 2019). Those with short-term interests, such as tenants (or older purchasing homeowners), will be less concerned with long-term risk altogether. Therefore, rental values are less likely to be impacted than capital values (Bernstein *et al.,* 2019; Miller *et al.,* 2019). A lack of liquidity can be an early sign that SLR is starting to impact on markets, before prices move negatively, but eventually a tipping point for prices will occur (Keys and Mulder, 2020).

Finally, the impact of SLR is only one risk among many climate risks. Being 'chronic' (and in fact not presently 'realised' in most cases), other acute climate factors, or positive factors such as amenity, may outweigh the risk, making isolation of SLR as a separate price influence hard to isolate (Keenan *et al.,* 2018). The authors provided empirical evidence that the rate of appreciation of house prices since 2000 is negatively related to elevation; appreciation in the lowest elevation locations has not kept up with the rates of appreciation of higher areas. The authors conclude, albeit tentatively, that this shift of preferences and perceptions may be anticipatory of further climate change effects which will affect both marketability and valuation of properties where their resilience and exposure to SLR varies.

In summary, the still seemingly 'far off' nature (even if inevitable in scientific evidence), leads to a view that it is still early to find backward-looking literature. Nonetheless, for investors, there is some evidence of early price movement in high-risk areas where there is limited confidence in municipality ante-event mitigation schemes and insurance or public bail-out protection.

4.4 Wildfire

The review examined ten empirical studies of the impact of wildfires on real estate markets, mostly from the U.S. and secondarily from Australia. The majority considered the impact on real estate markets (and mostly on house prices) of specific wildfire events, while three articles examined whether risk factors or risk ratings impacted on market outcomes.

Some studies framed wildfires as a natural hazard to which some locations were more prone because of their climate and landscape. However, through increases in temperature and changes in rainfall and aridity, climate change is making wildfires more frequent and more severe (Hansen and Naughton, 2013; McCoy and Walsh, 2018) and this will increase climate risks in regions that are currently prone to wildfires and create risks in new areas where there is no, or limited, experience of such events.

Estimates of the short-term price impact from specific wildfire events range from:

- 10 percent fall following a first wildfire for homes in Southern California (Mueller *et al.,* 2009)
- 7–14 percent fall for homes in Montana depending on proximity to the fire (Stetler *et al.,* 2010)
- 5–7 percent fall for homes proximate to smaller wildfires in Alaska (Hansen and Naughton, 2013)
- 6–13 percent fall in affected areas in the case of Colorado (McCoy and Walsh, 2018)

Long-term price effects are more complicated. Factors influencing this include the nature of changes to the landscape (with contrasting results in the Montana and Alaska studies), whether houses have a view of affected landscapes (McCoy and Walsh, 2018) and the value of the houses concerned (Mueller and Loomis, 2014). Mueller *et al.* (2009) also show that exposure to repeated wildfires had greater price impacts. Echoing comments above for other types of climate event, the extent to which falls in prices reflect reductions in amenity versus increased perceptions of risk is not easy to identify. In the absence of a specific wildfire event, Athukorala *et al.* (2019) found that proximity to woodland had a positive effect on house prices in the suburbs of Brisbane, Australia. However, as shown by Donovan *et al.* (2007), this relationship can change if awareness of wildfire risks increases.

There are two clear gaps in the literature on wildfires. First, analysis of residential property has focused on prices and has often not considered related aspects such as sale rates and time to sell, or the ability to obtain finance or insurance for properties, although Issler *et al.* (2020) is a recent exception that has considered both insurance and mortgage finance. Second, as with other events discussed here, there is an absence of evidence on commercial real estate prices or performance.[4] While institutional-grade CRE assets may not be in many areas at direct risk from wildfires, they could be impacted through the effects on local economies, fiscal policies and infrastructure from risk or incidence of wildfire events.

4 While Walters and Clulow (2010) consider the effects of wildfires on tourism in Victoria, Australia, their work did not examine the impact on occupancy or value of hotel, commercial or leisure assets.

5. Market factors and evidence on asset values

This section presents conclusions and inferences from the literature thematically, that is considerations of 'how' and 'why' the market is (or is not) correlating climate risk and exposure to climate hazards, and CRE values and pricing. These themes are:

- Perceptions and beliefs
- Adjacency and amenity
- Governance
- Valuation practices
- Short-term and bounce-back, or sustained value erosion
- Liquidity
- Lending behaviour and securitisation
- Insurability
- Asset level investment in resilience

5.1 Perceptions and beliefs

Key messages

- There is some evidence to support the view that pricing of residential properties which are subject to identifiable climate risks are influenced by beliefs.
- Owner beliefs are not static and are a product of experience, knowledge of the scientific data and confidence in governments to mitigate future risks and insurers to compensate losses.
- Far fewer commercial research papers study the role of climate change beliefs, though intuitively where markets are well-informed and confidence in governments is strong, then pricing will more accurately reflect the risk. The extent to which this is presently the case remains unanswered.

Throughout Section 4, references have been made to the impact of perceptions and beliefs in climate change on observed prices. It is perhaps not surprising that a link should exist: if there was no belief that climate change is happening, *ceteris paribus*, it would be reasonable to expect that markets would be unaffected. However, where belief exists, depending on the level and type of perceived risk presented by climate events, logic would suggest that price impacts should result. The evidence that perceptions and belief affect pricing mostly sits within U.S. residential market literature and much of this relates to SLR, which is a future risk—not an experienced event.

Baldauf *et al.* (2020) undertook a large-scale quantitative study using Gallup poll results on beliefs in the risks of global warming to respondents' ways of life. They then sought to establish whether these beliefs were revealed in the transaction prices of properties at high risk of future climate impacts (i.e., potential SLR inundation) rather than those properties that had seen value change as a result of past events, such as a storm surge, wildfire or flood. The findings pointed to a variation of more than 7 percent between homes situated in 'believer' and 'denier' neighbourhoods but declined to conclude whether deniers underplay the risks or believers over-estimate them.

Bernstein *et al.* (2019) found that investors who, they claimed, were better risk-informed than owner-occupiers, discounted values to a greater extent in reflection of risk from SLR. They also suggested that greater information tended to lead to a greater belief in SLR. Meanwhile, Bakkensen and Barrage (2017, revised 2021), using a combination of hedonic analysis and door-to-door surveys in Rhode Island (U.S.), found that properties at risk of coastal flooding were overvalued, but the amount of over-valuation was sensitive not just to climate beliefs, but also to whether buyers perceived that future policy measures might mitigate any impacts. This may point to trust in government action, and future insurability might also influence the perceived significance of the risk. These findings support those of Bhattacharya-Mis and Lamond (2015), who concluded that those with flood experience were more tolerant of the risk, but also had enhanced knowledge of, and belief in, the impact of mitigation activities.

In a similar vein, Hamilton-Webb *et al.* (2016) in a study of English farmers found that direct experience of extreme events (in this case, increasingly frequent flooding) led to a greater belief in, and concern for, climate change. However, climate risk was still deemed to be low compared with other business risks, a point also made by Lamond et al (2019).

The ability of events to change beliefs was underscored by Ortega and Taspinar (2018) in their study of New York house sales both before and after Hurricane Sandy. They concluded that, while increases in knowledge and information may lead to incremental behaviour change, a sudden extreme event can produce a more extensive and persistent change in beliefs, in this case with resultant negative price effects. Their findings pointed to how almost total denial of a risk can, when it materialises, create sudden and permanent reassessment of risk and prices. In contrast, Murfin and Spiegel (2020) found less clear evidence of impact when studying SLR price effects. They suggested that the price effect will not be found if those at most risk generally are non-believers, while those who believe choose to live in less exposed locations.

5.2 Adjacency and amenity

Key messages

- For the residential sector, adjacency to the amenity offered by being in areas known to be at risk of climate events can still add value. Evidence is emerging, however, that greater climate risk awareness and belief in climate change are countering this premium in some markets.
- The limited evidence for commercial real estate points to greater persistence of proximity premiums for assets close to business centres, whatever the risk. This may imply investors' view that such areas are more likely to attract funding for risk mitigation and post-event restoration work or simply the dominance of agglomeration value impacts.

Locational characteristics are fundamental to real estate values. However, within a location, there may be conflicting drivers of value and that is apparent through the literature examined here in the context of physical climate risks. Notably, properties that are most exposed to climate risks are often those which enjoy 'amenity adjacency' value.

There is a large literature for residential properties that recognises the premium value of proximity to natural amenities, be that a view, waterside, or access to open space or forests. Chen and Hua (2019) conducted a meta-analysis of value impacts from the amenities and dis-amenities of proximity to urban rivers. Their analysis revealed a range of value impacts from -12.2 (from pollution etc.) to +63.6 percent (river views). Their review deliberately sought to exclude flood risk, but it provides an indication of the challenge to researchers in separating out the negative impact of climate risk on prices or values from the undoubted benefits of amenity adjacency. Meanwhile, Beltrán *et al.* (2018) noted that amenity effects could not only neutralise a discount from flood risk but might result in higher prices. Yet they also found that the knowledge base of purchasers in relation to risks could be influential; this has been observed in Florida where house price increases slowed and liquidity reduced as knowledge of SLR increased (Keys and Mulder, 2020).

In a study of potential impacts of predicted SLR along Australia's Gold Coasts Cooper and Lemckert (2012) concluded that, as adjacency to the sea was so critical to the tourist industry, property values would be maintained owing to the likely state preventive adaptive action; this was in contrast to other at-risk areas where tourism was not important.

Athukorala *et al.* (2019) found that proximity to woodland had a positive effect on house prices in the suburbs of Brisbane, Australia, despite the wildfire risk. However, the visual analysis by Gill *et al.* (2015) established that any value effects were influenced by the density of the immediate vegetation, which influences the likelihood of total loss: open landscape settings were preferred. Donovan *et al.* (2007) found that amenity effects can also be tempered by greater availability of information on (wildfire) risks.

There is far less literature on this issue for commercial real estate, where the key driver of location value is influenced, not by landscape amenity but proximity to the central business district (CBD) or established commercial location. Cooper and Lemckert (2012) concluded that this might relate to the likely greater acceptance of city or state government to protect properties within the CBD through mitigation versus properties elsewhere; this they argued might be critical in supporting the adjacency premium. Lamond *et al.* (2019) also found that the business imperative for proximity may outweigh the known flooding risks, although they concluded that other factors such as the governance context were relevant to any discounting of values.

5.3 Governance

Key messages

- There is limited evidence that the approach, and expenditure, of local and national governments towards physical climate change measures influences values directly.
- Where evidence does suggest a relationship between good governance and values, it appears influenced by the level of trust of those affected in the local government to prevent catastrophe or/and repair and compensate those affected.

Governance in this context refers to the implementation of policies and investments in resilience by state or local governments in respect of land use, taxation, infrastructure provision or loss prevention that can address the societal issues and market frictions raised by climate risk. Direct state-funded preventive measures are more deeply embedded in policy in some countries than others and are directed at economic, as well as human or environmental, protection measures. Cooper and Lemckert (2012) argue that, while the Netherlands take a whole country approach out of necessity, in other countries it is more likely that direct state action will be aimed at protecting specific key cities.

A recent qualitative study of experts across Europe (McEvoy *et al.,* 2021) found that some 75 percent of coastal countries in Europe are planning to undertake adaptation measures to protect against, on average, a 1 metre rise in sea levels and associated storm surge inundation up to 2100. Most recently, a major review of U.S. flood alleviation projects by Rasmussen et al (2021) found that government flood mitigation schemes have often been hindered by social conflict, laws, politics and governance structures, While these papers do not provide any evidence of direct linkages between governance and price impacts, they lend weight to the inference in value price papers that price effects have been examined and found more readily where strong public action is less likely.

In place of directly funded and initiated schemes executed for future protection,[5] governments can, for example, seek to proactively socialise adaptation costs through well-regulated insurance markets and amongst the widest possible set of payers, or alternatively take a more laissez-faire route where responsibilities for climate-related defence infrastructure are offloaded onto private individuals with associated cost implications. It is important in any discussion of governance to recognise that public actions might not always be effective and can have unintended consequences. Nonetheless, actions that are well designed, based on good science and well-executed, can serve to mitigate the negative impacts on property values from increased climate risks in the short- to medium-term, even if some negative impacts cannot be avoided in the short-term.

5 As an example, the Thames Barrier, opened in 1982 was designed to protect London from storm surge flooding, both as a response to devastating floods in 1953 and as protection against the then known climate risks up to 2030; but now there are plans for future strengthening in the light of greater evidence (see for example Lumbroso and Ramsbottom, 2018).

Lamond *et al.* (2019) identify that in Germany, following amendments in the Federal Water Act 2009, property owners are expected to put private precautionary measures in place in accordance with their resources and capabilities. Through a questionnaire, the authors identified that the terms of insurance cover issued by the industry could be influential in simulating companies to take more active steps to mitigate against flood risk; such stimuli, it is suggested, result in a higher take-up of insurance policies and premium incentives to spend resources on mitigation. They also suggest that, in the absence of repeated events, people tend to forget flood risk even if a property is in a floodplain. One insightful response suggested that commercial property values could even increase in response to a severe flood if there is a high likelihood it could lead to increased mitigation spending by government.

The finding of a confident assumption that governments would take preventative action or/and pay for losses was considered by Bakkensen and Barrage (2021). They suggested that, where this existed, it might go some way towards explaining why residential prices were less adversely affected by flood risk than might have been expected. However, where such strong preventative governance is not in place, price reactions to events are more likely to be very significant, as was the case with hurricane Katrina (Miller *et al.* 2019).

5.4 Valuation practices

Key messages

- Evidence from the studies reviewed shows links between valuers' due diligence and the prevailing governance, datasets, insurability and regulation.
- Valuers are increasingly aware of heightened climate risk but are generally not explicitly incorporating it into market valuations prepared in compliance with client instructions and professional standards.
- Addressing climate risk gaps in valuation practices where they exist—particularly in data availability—plus enhanced valuation professional body advice, will improve valuer contribution to overall market functioning where assets are exposed to physical climate risk.

Valuers are responsible for advising clients as to the market value of assets for many purposes, including sale, loan security (collateral) and as input into portfolio or asset management and monitoring. Normally, such valuations are prepared through a process of due diligence, taking due account of market transactions and other evidence before arriving at their considered, expert opinion. They are bound to comply with standards, most commonly those of the IVSC (International Valuation Standards Council) as

enforced and monitored by their own valuation professional body.[6] Of these, the body with the biggest global reach is the RICS.[7]

The role that valuers can, or do, play by building in physical climate risk assessments was examined. If valuers do not specifically consider climate risks, is this due to lack of skill, professional body requirements, or both?

The IVS currently do not mention any requirement by valuers to consider climate change specifically. Indeed, a consultation document, IVSC (2020: 14) acknowledged that they are only now consulting as to how they should, or could, include matters pertaining to ESG, including climate change, in their valuation standards. Since 2014, RICS have mentioned sustainability in their mandatory standards. Yet even in their extant 2020 standards (RICS, 2019), there is only limited specific reference to climate change as a sub-set of the wider sustainability agenda, with valuers being advised that

> **"Only where existing market evidence would support this or where in the valuer's judgement market participants would expressly reflect such matters in their bids, should sustainability characteristics directly influence value(s) reported."**
>
> **(RICS, 2019: 113)**

Other bodies such as the Australian Property Institute (API) provide similar guidance, but do not mandate specific approaches (Warren-Myers and Cradduck, 2021).

From this, the inference can be drawn that, from a regulatory viewpoint, valuers are not yet under an obligation to be forward looking in respect of physical climate risk.[8] This might explain why, in the academic literature, valuers are often considered to be backward looking and not building in forward risks. Meins *et al.* (2010) concluded that due to a 'valuation lag' and 'black box' approach to data analysis, climate change could not be explicitly and sufficiently accounted for by valuers. They recommended a model based more on forward projection using discounted cash flow (DCF) methods, rather than a strong reliance on current market data as informed by legislation and regulation. However, within the Market Value requirements, valuers are advised to be cognisant of, and build in for, impending or sudden actual change, though only to the extent that this can be evidenced from market participant behaviours.[9]

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6 The IVS (International Valuation Standards) are set by the IVSC (The International Valuation Standards Council) but such standards are not enforceable by individual valuers; it is the bodies who belong to IVSC who have an enforcement role. The IVSC currently has some 160 member organisations operating in 137 countries; most are valuation professional organisations but some are major consultant valuers www.ivsc.org/about/members/our-members

7 RICS (the Royal Institution of Chartered Surveyors) is one of the world's largest valuation professional bodies. Through its own Valuation Standards (colloquially known as the 'Red Book') it enforces and expands on the IVS.

8 However, RICS have commissioned both an independent review of investment valuation methodology and a review of their best practice guidance on sustainability and commercial valuation.

9 For example, within a UK context, valuers are expected to reflect published but still impending change to mandatory minimum energy standards imposed on investment property (see RICS (2018)).

Michl *et al.* (2016) conducted a survey of UK and European valuers to understand how far valuers were taking account of environmental factors in valuations. They found that few clients were instructing valuers to consider sustainability characteristics, although valuers were routinely collecting some environmental data (notably published flood risk data). The investigation did not reveal whether any forward projections, or specific climate events, formed part of the due diligence process. What it did draw out was that, while there was little discernible evidence of valuers reflecting sustainability in market values, when advising as to investment worth using DCF techniques, some recognition of emerging sustainability factors was evident. Both Meins *et al.* (2010) and Michl *et al.* (2016) therefore identify an inherent inability of conventional market valuation techniques to adequately support building in for increasing climate change risks.

The skill base of valuers was examined by Le and Warren-Myers (2019). They interviewed Australian valuers and found a lack of knowledge in how to reflect climate change in their valuation practices. This runs somewhat counter to Fuerst and Warren-Myers (2019) study, which used hedonic analysis to compare professional valuers' opinions of the risk of SLR with market prices achieved. They found that professional valuers were more likely to quantify flood risk than market players. Yet, while identifying progress in the valuer knowledge base in Australia, Warren-Myers and Cradduck (2021) found that climate change risks remained inadequately identified, considered and reported. They concluded that this was largely due to a lack of guidance from professional bodies as to what is required, as well as inadequate data sources with which to evaluate the risks.[10]

5.5 Short-term and bounce-back, or sustained value erosion

Key messages

- There is substantial evidence that property prices revert to the trend following extreme weather events, with commercial property prices taking longer to revert than residential. Whether this suggests that markets already price the risk, or that investors are taking a myopic, short-term view, is unclear.
- Some evidence is emerging that sea-level rise alters this dynamic due to its permanence, and that prices may be softening in the most exposed areas. Increase in extreme storm and wildfire event severity and frequency may also create this more sustained value erosion.

A central theme that emerges from the academic literature is that, while historically, major weather events have had an immediate, and sometimes prolonged, negative effect on property values in impacted areas, prices tend to eventually revert to trend. The short-

10 Consistent with these characterisations and findings, Rivera (2020) provides a call to action in the U.S. institutional valuation context, suggesting that commercial property valuations are not currently reflecting climate risks, owing in large part to a lack of industry-wide consensus on education and standards. He emphasizes the crucial need for "those of us in the real estate industry to work together to create industry-wide norms that contemplate and quantify climate risks in decision-making and valuations."

term finding is particularly robust in studies for water-related hazards (floods and hurricanes), but less so with wildfires where one might argue there is more uncertainty. There is evidence, albeit limited, though consistent across hazards, that repeated experience of hazard impact does impact risk assessment, but only for a time, unless the frequency remains high. In addition, results in recent studies, while based on specific localised events and so not necessarily generalisable, suggest that homebuyers, commercial property investors and lenders are increasingly paying attention to climate risk and that this is leading to an erosion in property values, or has a real potential to—as evidenced by reduced liquidity and mortgage lender behaviour—see sections 5.6 and 5.7.

Below *et al.* (2017) and Miller *et al.* (2019) found that single-family home prices rebound quickly to prior trends after major storms, with little persistent negative impact on value. Fisher and Rutledge (2021) documented a similar dynamic for institutional-owned commercial properties in the NCREIF Property Index (NPI), with prices declining for up to three years after major hurricanes before reverting to 'normal'. The transitory nature of pricing impacts in areas known to be at risk could imply that the threat is realised and hence the risks are already being capitalised into prices of these properties. The storms are not a surprise per se. Alternatively, it could derive from a myopic or short-term view, or a blend of both. The question is, is this now changing and/or will it in the future as the risk of higher frequency and severity plus broader geographic impact become better documented?

Graham *et al.* (2007) provided potential early impact into the question of awareness and refined assessment of likelihood. They found a pattern of increasing home price declines in response to successive event hurricanes in their study of the impact of four successive major hurricanes in North Carolina. However, this ultimately gives in to full price recovery and a return to pre-storm market stability over the following three years, in the absence of another major hurricane landfall. Mueller *et al.* (2009) examined the impact of repeated wildfires and found that successive exposure to fires affects prices for proximate homes more than exposure to a single event or to no fire at all. Similar to the hurricane dynamic, recovery in real house prices is prolonged but does ultimately take place without continued events.

As noted earlier in section 4.2, a potential limitation with both the Below *et al.* (2017) and Fisher and Routledge (2021) studies is that that there is no consideration of the potential for increasing climate risk, nor recognition of it, over time. Recent studies of Hurricane Sandy and its impact on pricing in New York City (Ortega and Taspinar, 2018 and Gibson and Mullins, 2020 for residential property values and Addoum *et al.,* 2021 for commercial)—as well as a select group of recent studies testing whether sea level rise (SLR) is priced into property values (Baldauf *et al.,* 2020; Bernstein *et al.,* 2019 and Keys and Mulder, 2020) collectively provide evidence to suggest a more sustained value erosion.[11]

11 The findings, though suggestive, are not necessarily conclusive. The results were U.S. only and weighted towards one major hurricane episode hitting a major city (NYC) location for the first time. Miller *et al.* (2019) suggested that Bernstein *et al.* (2019) overestimated the discount attributed to SLR due to inadequate detangling of property quality and waterfront location amenity. Murfin & Spiegel (2020), also tested whether house prices reflect differential SLR and found limited price effects; not statistically different from zero. Fuerst and Warren-Myers (2019) found no price effects of SLR in their study of residential property pricing in Melbourne, Australia.

The extent to which the empirical evidence demonstrates that the market has (or has not) in recent times priced in extreme weather and climate change is of paramount importance to this study. An important finding in both in both Ortega and Taspinar (2018) and Addoum *et al.* (2021) that tends to demonstrate this in the affirmative is that post-event permanent price discount applied not only to properties impacted by Hurricane Sandy, but also to those that were not impacted, but which could be in the future. McCoy and Walsh (2018) found a similar dynamic with wildfires. Prices in areas directly impacted fell in the year after a fire and only partially recovered. Prices in unaffected but high-risk areas also fell, though recovered in 2–3 years.

Further evidence in relation to commercial properties is given by Addoum *et al.* (2021) who found that prices in Boston have been impacted by Hurricane Sandy, presumably as institutional investors, certain to have a broader geographic and portfolio view than more localised homeowners, have reassessed the risk of a hurricane hitting. This may provide limited early indications that investors are factoring future effects into their purchase decisions, but it is too early to say anything conclusive. What can be concluded is that, if the sustained increase in frequency and severity of extreme weather events and SLR materialise as scientists forecast, then the awareness and recognition (more 'believers'?) should heighten, and lead to climate change event-related risks being reflected permanently in property prices in high risk areas.

5.6 Liquidity

Key messages

- Extreme climate events and/or increased awareness of climate risk may affect: which properties are offered for sale, the cohort of interested buyers, and, consequently, sale times and sale volumes.
- Pricing tends to be a lagging or post-hoc indicator of how markets are absorbing physical climate risk. Trading volumes or time on market may be better leading signals of how markets are reacting to climate events and risks, though the research into this is sparse.
- The availability and cost of lender financing and re-financing, as well as insurance, are likely to be key determinants of investor behaviour and liquidity going forward. However, there are instances of downward shifts in buyer demand in high-risk areas that cannot be attributed to changes in lender and insurer practices.

Low liquidity relative to other financial assets is a fundamental feature of private real estate markets. This is manifested in higher transaction costs, longer and more uncertain transaction times, and less frequent trading. Variations in the liquidity of private real estate arise both over time and across locations, and prices do not always adjust sufficiently to equalise liquidity across locations or through market states. This reflects different numbers of buyers relative to sellers and different pricing responses by buyers and sellers in response to economic conditions or other factors such as exposure to climate risks.

The influence of climate events such as floods on the beliefs and perceptions of market participants was considered above. If the occurrence or risk of a climate event reduces the number of buyers relative to the number of existing owners, this should affect prices and selling times. Allied to this, if buyer valuations of properties in affected areas respond differently to owner valuations, say through a more rapid mark down in what buyers are prepared to pay, this will also affect prices and trading times. As sales must occur for price effects to be observed, indicators such as trading volumes or time on market may provide early signals of how markets are reacting to climate events and risks.

Despite this, there have been very few analyses in the academic literature of how climate risks affect transaction activity. Turnbull *et al.* (2013) argued that liquidity must be studied alongside prices to fully capture the effects of flood risk on housing markets. They found longer selling times as well as price discounts for houses in the highest risk areas of Baton Rouge, Louisiana. Keys and Mulder (2020) examined changes in house prices and volumes for coastal areas of Florida exposed to sea level rise. From 2013, they found that sale volumes declined in more exposed areas relative to less exposed areas, while prices exhibited similar trends until c. 2018. They state that the results show how "*increasing salience of SLR risk can first result in a decline in market liquidity rather than[…]prices*" (Keys and Mulder, 2020: 6), and conclude that lower volumes in areas more exposed to sea level rise reflected shifts in buyer demand and were not driven by changes in lender or insurer behaviour, a point that may also be implied from the findings of Keenan et al (2018) in relation to price appreciation for properties potentially impacted by SLR.

Similar work on CRE volumes or sale times was not found, though there has been qualitative research and industry commentary on the growing influence of climate risk on stock selection and portfolio composition decisions. In ULI/Heitman (2019), concerns were noted about future liquidity for assets whose climate risk exposure was high, while investors interviewed a year later by ULI/Heitman (2020) cited instances where they claimed that climate risks were beginning to influence market selection. Kanne *et al.* (2017) also provided the specific example of South Florida, which they stated was excluded from investment in the case of National Real Estate Advisors. This implies that some real estate assets are becoming less liquid as greater awareness of climate risks thins the pool of potential buyers prepared to bid on these assets at time of sale based on future financial performance expectations, which may feed back into current pricing.

How soon any changes in liquidity occur will be influenced by investor behaviour and by how other stakeholders in real estate investment markets respond. For instance, how willing lenders will be to provide finance to potential purchasers (or refinance existing owners) and how willing insurers will be to cover potential losses from climate events. These are both factors that will influence investor interest in particular assets and locations.

5.7 Lending behaviour and securitisation

Key messages

- There is an overall lack of research on real estate debt markets, particularly commercial real estate, focused on physical climate risk. This is surprising given the size of the debt markets; their role in the CRE liquidity equation; and, in certain geographies, the level of residential and commercial mortgage securitisation which relies on standardised underwriting practices and agency rules.
- There is some evidence from residential real estate securitisation markets that assets with higher levels of physical hazard exposure are being securitised as a method to transfer risk from lenders to investors.

The real estate sector relies heavily on debt financing. As large scale, big ticket investments, transactions often require significant debt financing—mortgage funding is part of the liquidity equation. Moreover, credit or debt markets are the largest component of the global financial system. Hence, it seems reasonable to assume that lenders, regulators and credit rating agencies may be even more in tune with potential new risks on the horizon, including physical climate risk.

There has been a lack of academic research on the impact of severe weather events on real estate debt markets and no published academic research that has focused on commercial mortgage markets. However, with the growing recognition of both the importance of climate risk to the financial system as a whole and the large share of mortgage debt within it, it is attracting more attention in the mainstream finance field[12]. Moreover, major credit rating and mortgage analytic firms all have significantly increased their physical climate risk-related analysis of and focus on the mortgage sector, especially the mortgage-backed securities (MBS) markets, and the municipal finance and infrastructure areas that could ultimately impact property pricing in higher risk locations.

Recent research targeting the U.S. MBS market, which plays an outsized role in the U.S. compared to other mortgage systems around the world, has provided evidence of significant changes in lending behaviour following major hurricanes that is consistent with changing perceptions of risk in lending and also the shifting of it from lending institutions to U.S. GSEs. Ouazad and Kahn (2021) document that, in periods following major hurricanes, lenders are significantly more likely to approve mortgages that can be securitised, thereby transferring climate risk to investors.

Keenan and Bradt (2020) provide evidence of a similar shift happening in areas considered to be at higher risk of sea level rise. The authors document a shift in perception of mortgage risk related to information asymmetry or beliefs. They provide evidence that concentrated local lenders are transferring risks in high-risk coastal geographies in the Southeast Atlantic and Gulf Coasts (U.S.) through increased securitisation of mortgages, which is consistent with growing awareness that climate risk could impact defaults. This

12 See Hong *et al.* (2020), who suggest that "financial economists are late to the game" and need to better understand insurance loss distributions, divestment actions relating to potential stranding of assets, municipal mitigation and financing activities and financial innovation.

is the same dynamic as found by Ouazad and Kahn (2021), but in response to a future risk and not an event—signalling that climate risk considerations are impacting mortgage default assessment and origination decisions by local lenders in high-risk areas of the U.S.

While no academic publications were identified that examined commercial real estate debt markets, there has been a surge in research and analytic activity amongst investor, rating agency and mortgage analytics firms that suggests growing awareness of the seriousness of climate risk.[13] Applied research and shifts in underwriting and rating methodologies can be expected to have real impacts in the availability and pricing of commercial mortgage debt in locations at risk going forward.

5.8 Insurability

Key messages

- While there is mounting evidence on the losses borne by insurers from a combination of increasing frequency and intensity of extreme weather, and the relatively high value of assets exposed to hazards, there is little evidence for effects of insurance availability or pricing on asset values.
- Conclusions are further clouded by the varying nature of insurance markets and regulation, which differ by country and sometimes within countries.
- To date, it has generally only been where there were mandatory mitigation requirements through insurance market regulation that owners benefitted from resilience expenditure.

One factor that should influence both the pricing and liquidity of an asset subject to climate risk is the ability to obtain adequate and affordable insurance. An increase in climate risk for an asset in a given location could have several consequences in this regard. Insurance might become unobtainable if the likelihood or magnitude of losses is judged to be very high. It could also lead to variations in the terms of policies, with more exclusions and higher excesses, as well as changes to insurance premiums. There is a body of research that models costs to the insurance industry of natural disasters and the potential impacts on such costs from climate change.[14] However, the focus here is on evidence for the impact of climate events and climate risk on insurability and the insurance premiums faced by real estate owners or occupiers.

13 In July 2019, bond rating agency Moody's Investor Services acquired a major stake in climate risk analytics provider Four Twenty Seven (427), and in August 2020 began including climate risk data analytics in commercial mortgage backed securities (CMBS) reports. In October 2020 CMBS information and analytics firm Trepp announced an integration with Risk Management Solutions (RMS) to provide climate risk scores for properties in CMBS pools. Smith (2021) provides a recent overview of climate risk assessment methodologies of 19 service providers, including 427 residential mortgages suppliers (RMS), for UNEP FI. Blackrock (2019) examined the impact of recent Hurricanes in Houston and Miami on property collateral for commercial mortgage backed securities (CMBS) and illustrate how a warming climate could lead to rising CMBS loan loss rates over time.

14 For recent overviews, see The Geneva Association (2018, 2021) and UNEP Finance Initiative (2021).

Research on insurability is complicated by the fact that insurance regimes vary significantly across national boundaries. In relation to flooding, Lamond *et al.* (2019) set out the contrasting approaches taken in Australia, China, Germany, the UK and the U.S. These nations differ as to public versus private provision of flood insurance, the cost and coverage of such insurance, and whether regulations state that insurance must be held by owners or by occupiers. Where insurance is unavailable or expensive, then self-insurance and under-insurance are potential outcomes, but there will be implications for the value and future prospects of the properties concerned.[15] Hence, the approach of insurers to climate risks and how this evolves in future will influence property investment decisions and outcomes.

The nature of any private provision and its impact on real estate markets depends on whether national or state-based insurance schemes also exist. An example from the U.S. is the National Flood Insurance Program (NFIP). This has facilitated coverage of flood risk in vulnerable areas and subsidised premiums for some properties in such areas, although Bin and Landry (2013) found that take up of these policies was correlated with owners' recent experience of climate events. Nonetheless, the NFIP has affected how market participants assess the risks from and costs of flooding. Miller *et al.* (2019) have suggested that it helps explain why house price discounts did not persist after major storms, as insurance payouts could mitigate the impact on value. In fact, they claimed that federal flood insurance programs prop up markets at higher risk of losses due to climate change. Meanwhile, though Keys and Mulder (2020) found price discounts for houses at risk of sea level rise, they could not establish a relationship with changes to insurance premiums in those areas.[16]

Provision of insurance for commercial properties against climate risks has received less attention. Born and Klimaszewski-Blettner (2013) compared homeowner and commercial insurance provision in a U.S. context and argued that less regulation of commercial property insurance facilitated provision in areas at risk of climate events, as insurers had more flexibility to price and tailor their policies accordingly. However, real estate investors surveyed by ULI/Heitman (2019) claimed that they had seen little impact on insurance availability and costs apart from in the wake of climate events. Nonetheless, these investors anticipated changes in future since (private) insurers could revisit premiums and terms each year, and withdraw provision from higher-risk areas altogether, leading to stranded assets within portfolios. Research in the UK found that increased insurance premiums and excesses were of concern to commercial real estate occupiers as well (Pottinger and Tanton, 2014; Alzahrani *et al.,* 2018).

Could investors improve insurability and reduce premiums by undertaking investments in resilience? If so, this could be a mechanism through which asset values in areas subject to climate risk might be protected. Yet, except where mitigation is a mandatory obligation, there is little evidence to date for insurance benefits from resilience expenditure. Interviewees in Lamond *et al.* (2019) cited the lack of incentives within existing policies and realisation of lower pricing as a deterrent to expenditure on mitigation.

15 Self-insurance describes the use of one's own wealth to cover losses from events such as fires or storms, while under-insurance refers to the retention of substantial exposure to losses despite having some insurance cover.

16 Earlier evidence summarised in Bin and Landry (2013) had suggested that such discounts were correlated with the capitalised value of insurance premiums.

5.9 Asset level investment in resilience

Key messages

- Costs to improve asset resilience may be high and will be compared against the potential benefits in any capex planning and decision-making undertaken by investors.
- There is little quantitative evidence of benefits to guide such planning at present. If climate risk is not properly reflected in asset values, the value of risk mitigation expenditure is unlikely to be reflected either.
- Although there is little evidence of a owners achieving a resilience premium, properties with features that heighten the risks of loss from a climate event may experience a price discount.

As economic activity is likely to persist in many areas exposed to climate risk, can the effects of such exposure be mitigated by making existing properties more resilient or by building new properties with more resilient features? Furthermore, are such actions occurring as awareness of climate risk in the real estate industry increases?

A resilient property might be defined as one that, while still affected by events such as storms or floods by virtue of its location, should experience less damage and disruption than neighbouring assets over a period of ownership because of its design, construction, or the configuration of its structure or site.[17] Investments in resilience will be hard to justify without knowledge of their financial benefits, especially where the proposed measures are costly. Assessing potential benefits is also complicated by the fact that what makes a building resilient today might not be sufficient in the future for locations where climate change impacts are increasing. This makes it challenging to judge what is necessary to future-proof a building against climate risks.

The economics of capital expenditures suggest that resilience or mitigation investments will only occur where the expected financial benefits are large enough to compensate for the costs involved. Survey work by Lamond *et al.* (2019) suggested that flood risk was not properly reflected in CRE market values and so the benefits from mitigation expenditure might not be fully recognised either. Teicher (2018) noted examples where measures to mitigate climate risk for U.S. commercial properties were rejected or only implemented to a limited extent given their cost versus perceived benefits. While this trade-off should change with time, it might be insufficient for many assets until a climate event occurs that necessitates their repair or reconstruction.

Buildings with above-average levels of resilience might command a premium in terms of their rent or price, be easier to sell or be easier and cheaper to insure. However, there is little quantitative evidence for this so far beyond the effects of mere presence in a less risky location, which is not an asset resilience measure. Investors interviewed by ULI/Heitman (2019) indicated that requirements for climate-related expenditures are being

17 Resilience has also been used to describe properties that are simply better located in terms of their exposure to climate risk (e.g. Keenan et al, 2018). Effects such as elevation or distance from a hazard or event are considered in other sections.

factored into acquisition and asset management appraisals more often. This should lead to those buildings that are already resilient commanding a greater value in relative terms if this permeates more widely through industry practice. PGIM (2021) also claims that more resilient buildings experience higher levels of tenant retention, and steadier cash flows as a result. This would be consistent with the model below shown in Section 6, but more evidence is required to demonstrate this conclusively.

Furthermore, assets with lower resilience might become harder to finance or insure, harder to sell, or only sell at a discount. There is some quantitative evidence of price effects for residential properties. For example, Champ *et al.* (2009) found a price discount in wildfire-prone areas for houses constructed from more flammable materials, but not for dense vegetation in proximity to the plot. As noted earlier, some risk factors are correlated with amenity benefits, hence actions to increase resilience must be sensitive to this. However, preferences will change with increased awareness of risk, and, as attitudes to resilience change, the benefits from resilience expenditures may increase.

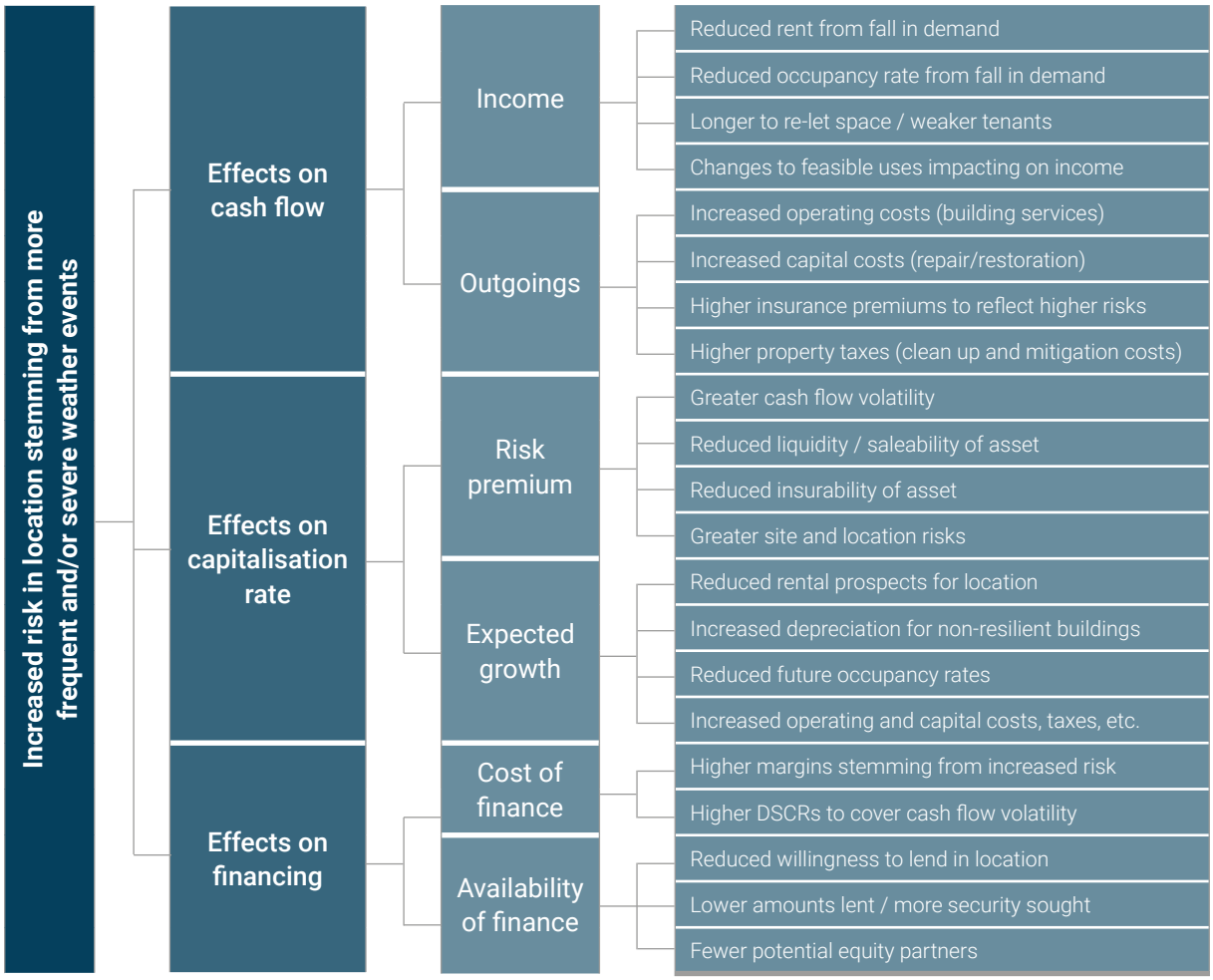
Finally, the interaction with public policies such as building codes, land use planning, and regional and national strategies must be considered. If resilient assets are situated in locations whose infrastructure and planning is insufficiently developed of resourced to mitigate the impacts of climate events, this could undermine the benefits of any asset-level expenditure as noted in ULI/Heitman (2019). In contrast, proactive public policies should help to underpin long-term investment in locations with climate risks by stimulating mitigation expenditure; this underscores the role of governance. This should also reduce the risk of a piecemeal approach to resilience that does not benefit wider society (Teicher, 2018).

6. Conclusions for commercial real estate investors

This review has considered empirical evidence of the impact on real estate values and prices from climate events and from greater awareness of climate risks. While the goal of this paper was to assess the effects for commercial real estate assets, much of the available evidence was for residential real estate and indicated that, historically most price impacts were relatively short-term. However, this review has shown that the breadth and depth of research has improved over time, and it highlights more recent studies that have examined commercial real estate. This recent research is appearing both in real estate and in broader economics and finance journals, and it indicates that awareness of climate risks may be starting to have a more sustained impact on pricing and on investor decision-making. Much of this recent literature is U.S.-focused, possibly because of recent dramatic events which have pushed the risks higher up the investor agenda, whereas such events have been lesser in number and severity (Europe) or impacted less people and city centres (Australia).

To conceptualise the potential effects of climate risk on the value of commercial real estate assets and the channels of impact discussed in this work, Figure 1 demonstrates how, in theory, climate change physical risks could feed through to income-property pricing in a discounted cash flow (DCF) appraisal framework. At a general level, it is expected that climate risk could be incorporated in conventional valuations via an impact on three primary valuation components: 1) cash flow—leasing fundamentals (rent, rent growth and vacancy) net of operating expenses and capital expenditures; 2) capitalisation rate—capital market conditions including the overall required return that embeds the required risk premium and also expectations of cash flow prospects (including exit price) and liquidity within a conventional multi-year pro forma; and 3) financing—the cost and availability of funds from both equity partners and mortgage debt providers are directly related to return requirements and indirectly to property liquidity. While some of these factors are more easily identified in a DCF, they are matters which should be considered in any capital market valuation.

Figure 1: Anticipated effects on commercial real estate asset performance of increased exposure to climate risk



Developed with reference to de Wilde and Coley (2011)

Clearly, the effects are not all evidenced equally by the literature, and there is rather limited evidence therefore on the validity of some of the 'sub-channels' of impact shown on the far-right side of Figure 1. The overwhelming body of evidence is on sale prices without further decomposition of the components of pricing or value. Yet, the breadth of evidence has expanded, and for the three main elements or aspects of pricing, the following findings can be identified.

Effect on cash flow

As many of the existing studies were focused on owner-occupied residential assets, income effects were not substantially proven. Yet, pricing studies that found that 'bounce-back' was more muted were beginning to recognise reduced occupier demand and some increase in void periods. In terms of outgoings, evidence from flooding studies in particular shows that wealth and ability to pay for clean-up are important, but that the ability to insure is also critical. It is here that the role of governance comes into focus: insurance cost and availability are dependent on actual and potential risk levels and,

critically, mitigation measures. From this, a tentative connection between insurance and outgoings can be viewed as part of cash flow.

Effects on required returns and capitalisation rates

Capitalisation rates are the product of many influences, but the two main drivers are perceptions of risk, including risk of vacancies, and expected property cash flows, including rental growth. Effects on the risk premium is perhaps where the expectation of price change stemming from climate events and risks is most likely; conventionally, this is built into the capitalisation rate applied to rents to find market value. CRE evidence is still weak, and also not granular enough to permit definitive conclusions about which of the components of the risk premium are likely to be impacted—variability of expected future cash flows, including capital expenditures, vacancy rates, asset resilience or saleability/marketability (i.e. liquidity) in the future, or a combination of all. The residential literature demonstrated that, so far, the main emergent conduit to risk is that of liquidity and it seems likely that this is the case with CRE as well. Early indications in areas now established to be subject to largely unmitigated SLR are that lower liquidity is having a negative capital value impact. Whether investors are simply ruling out some locations was not clear from the academic literature, but some market reports, supported by undocumented discussions with institutional investors suggest that some locations are either 'no-go' areas or deemed to warrant extra due diligence processes. Expected income growth and its counter, depreciation, is also critical to capitalisation rates. Given the dominance of owner-occupation studies, this is not clearly evidenced. However, in the wider sustainability literature, the presence of price differentiation is well established, both in regard to performance benefits attributed to more 'sustainable' (often regarded as synonymous with certified) buildings and, increasingly, 'brown' discounting linked to accelerated depreciation due to an inability of buildings to keep up with escalating sustainability requirements. A more extreme outcome may be potential stranding of less resilient or sustainable stock, especially those buildings that might also be at greatest transition risk.

Effects on financing

Without capital there are no transactions; real estate markets will stutter, causing values fall. Although many transactions are fully funded by equity, many are dependent on borrowed funds. The availability and cost of finance are conduits which will influence values and potential investor actions. The review revealed that, with the exception of residential securitised mortgage-backed (RMBS) lending in the U.S., there has been a relative lack of academic research on the impact of severe weather events on real estate financing.

Evidence from the literature, while inconclusive on financial effects through the above channels, does suggest the following conclusions for commercial real estate market participants:

- Investors will be affected by how other market participants respond to climate risk. In specific locations, the nature and perspectives of the marginal buyer/investor may influence how quickly any changes to pricing or transaction activity occur, but climate risks will still present a long-term challenge for investors around future asset values and exit strategies. In other locations, the process could take longer as differences in beliefs and/or investment horizons may imply that climate risk is only slowly reflected in pricing. It seems reasonable to expect pricing of buildings which are nearing a threshold of market participant 'buy-in', or equivalent tipping point, to be affected, similar to that observed with ESG and, in the past, arguments around the presence of a 'green building' premium.
- There is now more interest in how insurers and lenders will behave as knowledge of climate risks increases. It is expected that insurers and lenders will respond through the availability and pricing of insurance and loan products, with impacts on asset pricing in turn. These organisations may also have exposure to climate risk through their own investments as well as through policies and loans. The divergence between investor holding periods (typically 8–10 years) and the shorter horizons over which insurance (annually) and to some extent secured lending agreement loans (3–7 years) are repriced and provision reassessed is an issue that will increasingly add to cash flow and financing risks, exerting downward pressure on prices where physical climate risks are identified or found to increase. Alternative structures for insurance contracts could be a potential solution.
- Arguably there needs to be more understanding of how occupiers respond to climate events and risks, as it is occupiers that generate the cash flow that underpins commercial real estate values. At present, empirical evidence on factors such as rents or occupancy is limited. Most studies to date are based on analyses of prices, but not the channels through which prices are determined.[18]
- Consideration of climate risks in the investment process and portfolio risk management is an imperative. Institutional investors may need to embed better planning and management of uncertainty within their internal appraisals, asset location, stock selection (buy-hold-sell) decisions, and external disclosure, particularly as the market shifts to more forward-looking climate risk analyses.
- Inadequate consideration of climate risks raises the prospect of the misallocation of capital, both for individual investors and for the investment community generally. To avoid this, the evidence base needs to increase and investors should consider whether or not current prices fully capitalise climate risks.

18 The importance of understanding the occupier side is underscored by global investor PGGM in its recent position paper on assessing climate risk in real estate. Schlmetschek *et al.* (2019) suggest that the major channel of physical climate risk impact is the potential for lack of tenant demand for a specific location.

- Other stakeholders in the real estate investment market will also influence change. Advisors and valuers may have been unable to emphasise climate risks historically, based on the available data and professional body requirements, but awareness has risen and with this, the potential, if not yet actual, ability to integrate climate risks more fully into appraisals and, in due time, market valuations. To elaborate, the contrast between market value (reporting what people will pay now based on transactional (pricing) evidence) and worth or fundamental value is important—a greater reflection of climate risks in the latter should ultimately lead prices, and thus market values, to reflect climate risks as well.
- The role of government agencies, national or local, can potentially be beneficial in increasing the resilience of built-up areas to climate change and this can provide confidence to invest. However, how costs and risks should be shared across private and public sectors is still an area for debate, and public policies need to be well-designed to avoid unintended consequences that can occur if decisions are made for the shorter-term political cycle rather than the long-term sustainability of the area in question.

7. Recommendations for next steps

The research was undertaken to address a perceived gap in market participants' in-depth understanding of pricing signals and value at risk from the physical impacts of climate change. Without a foundational understanding of the empirical evidence for how markets have responded to extreme weather events, it is hard to make assertions on how modelling practices should be structured or investment/portfolio allocation decisions weighted to best balance risk and return. The shallowness of the evidence base also suggests further research is needed to better understand the transmission channels through which pricing and value impacts are revealed, and to inform policy makers, regulators and practitioners in their efforts to increase resilience and advance socially equitable markets.

As a global organisation working with investors, banks and insurers to create a sustainable finance sector—but with the neutral status to engage with regulators and policy makers for alignment with the global sustainability objectives of the UN—UNEP FI offers a convening platform to bring together market setters and market actors for thought leadership and best practice development dissemination. To that end, it and its collaborators from the Henley Business School (University of Reading) and Schulich School of Business (York University) propose the following to strengthen the field of physical climate risk and real estate investment. These suggested programme elements can be viewed as complementary and may run concurrently with overlapping stakeholders or constituents, but can equally be undertaken as discrete elements based on capacity, resources and interest from the market.

1. Market surveillance and improving data flow on hazard exposure and asset pricing

A structured engagement with regulators, lenders, insurers, and owners/investors on a national or local/regional level can be initiated to discuss voluntary and/or mandatory practices so that information on current and projected climate hazard exposure, asset damages and losses, insurance pricing, and sales volume and pricing can be catalogued and shared between market setters and participants. How this surveillance and data sharing is structured will depend on, amongst other issues, the nature of proprietary research and data collation and analysis. However, the literature-based evidence of how data, knowledge, and beliefs affect markets—including in lending, securitisation, and insurability decisions—suggests a need for improved information practices that can support individual asset and sustain area-wide value. This may be particularly challenging in countries where property data collection is already inconsistent and fragmented. Programme outcomes should include an agreed set of data points and data collection and dissemination practices that serve as a universal guide for multiple geographies and market contexts.

2. Asset-level financial and valuation modelling

As demonstrated by the graphic presented in Section 6 above, there are multiple ways in which pricing and value may be affected by climate risk. This points to impacts across a wider range of variables than commonly acknowledged when institutions undertake, for example, cash flow modelling of assets or calculation of exit or terminal values within their investment horizons—which in turn affect estimates of market value. To improve such modelling practices—principally by institutions internally for making their buy-hold-sell decisions, but also to potentially influence formal valuation practices of external practitioners—a working group of asset owners and managers is proposed to conceptualise modelling practices to: derive an agreed (expanded) range of variables; undertake

modelling and sensitivity testing against key variables based on research- and experience-informed parameters (e.g., cost of capital, cost of insurance, cost of taxes, void periods, etc.) set against future climate scenarios; assess how decisions of other market actors may influence these variables (e.g., lenders and insurers); and share and publicise findings on exemplar practices and results generated.

3. Governance and resilience investment planning

The academic research on governance is limited but suggests stronger action is being taken by some governments to compel asset owners to harden assets against climate impacts, or to provide financial or other support to strengthen protective infrastructure. Non-academic literature—not specifically presented in this paper—also indicates that public governance and public-sector planning for and managing climate risk exposure is a factor in investor capital allocation decisions and in the cost of capital via credit rating agencies analyses of sovereign and sub-sovereign issuances. Other literature (not covered here) also indicates a growing range of hazards and potential financial effects to assets economy-wide, and a need for increased investment in resilience at the asset and area-wide scales. This creates a need to allocate capital for these uses and a 'virtuous' investment opportunity for investors with exposure to real estate, infrastructure, and sovereign/sub-sovereign debt, i.e., investment in infrastructure to improve area resilience supports individual property asset values in the same markets. Meanwhile, government borrowing for investment in resilience infrastructure may be recaptured in part or in whole through land and property owners via rates or other value capture instruments. Therefore, an engagement and dialogue exercise is proposed that involves local/regional/national government actors, asset owners and investors, lenders, insurers and credit rating agencies to support understanding of the dynamics between strategic resilience investment and asset values, the need for strategic investment planning, and capital raising and capital repayment channels. Findings can be captured to inform stakeholder engagement and capital planning/capital raising innovation between public and private actors while informing policy prescriptions.

4. Considerations for future Research

The paucity of commercial real estate-focused literature revealed by this review has affirmed the need for open, or shared, access to data to better enable rigorous academic investigation. Detailed property level data is crucial. Information in relation to asset-specific data, including, for example, capex and retrofit investment, and transaction details that capture not only price but holding period and even identification of buyer and seller investor type, leasing agreements and insurance data would provide a platform to assess more extensively the impact of physical climate risk on investment performance.

There are several potentially fruitful areas for further research that can be taken by individual firms, industry organisations, policy makers and/or academics which are presented below. The list is not exhaustive, merely indicative.

- **The size and longevity of pricing effects of climate events and risks on commercial real estate:**
  Further empirical investigation is needed of the impact of recent notable weather events on CRE pricing and adjustment over time—to what extent is this a permanent price erosion and to what extent do values bounce back?—as well as the pricing of

SLR and wildfire risk should be a top priority. There is now a growing body of literature focused on single-family residential, largely owner-occupied, housing. However, institutional CRE market players have very different motivations for making purchase and lending decisions and tend to be far more sophisticated in a financial sense compared to homeowners. Moreover, the value of CRE assets is linked in part to tenant decisions that are driven more by locational and CBD adjacency requirements than visual amenity factors such as waterfront. An exception tends to be hotels, hospitality and possibly multifamily properties, for which amenity remains a critical factor. Hence, the capitalisation of risks and adjustment to extreme weather-related shocks could be quite different. How does the liquidity impact channel work, both in terms of available indicators and the investment processes (external and internal) in which decisions on purchase, retention and sale are made?

- **The impact of climate events on income and income growth:**
  While some evidence of CRE capital value changes was revealed, there was a dearth of literature on how climate events impacted the landlord and tenant relationship and, in turn, whether such events led to temporary or long-term reduced income, cessation of leases, or/and uninsurable losses for the building occupant. An important consideration in this respect is how the measured impact can be captured, e.g. based on performance of assets before and after the event, as well as whether any impacts are sustained over time as revealed in robust time series data. For assets exposed to chronic hazards such as sea level rise, is this exposure impacting on lease terms or type of tenants?

- **The potential costs and benefits of resilience expenditure on existing stock:**
  The business case for asset-level investment in resilience was largely absent from the literature, as was evidence of a 'resilience premium'. The lack of evidence of costs and benefits from resilience investment suggests opacity on the return such expenditure would generate at the individual asset level and creates risk for a mis- or under-allocation of capital. Research into the value effects of technical upgrade options, not simply their costs or efficacy, is needed, as well as integrating these expenditures with the business case for carbon neutrality. There are additional questions around how resilience features or investments may be captured through valuation and appraisal processes, as well as how these can be recognised by insurers and factored into policy pricing. Such a focus on resilience investment and associated building improvements may also yield benefits in terms of tenant attraction and retention, e.g., they provide scope for moving beyond the concept of a 'green' lease to a 'climate resilient' lease.

- **The required and possible response of insurers and lenders to support of 'at-risk' assets:**
  If real estate cannot be insured against adverse events and cannot be used as loan security, it will lose value and potentially become 'stranded'. This research has uncovered some evidence of this, either in terms of actual value loss or, as a lead indicator, lack of liquidity. Given these linkages, creating effective mechanisms to ensure continuing market liquidity facilitated by insurance and finance is in the interests of all stakeholders, and especially those who may have a diminished ability to fund high premiums.

Appendix: key paper summaries

Flood

Authors (date)	Geography & Hazard/ event	Summary of findings	Implications for inves-tors
Beltrán *et al.* (2018)	Global	Reviews 37 studies covering U.S. and non-U.S. markets that report a range of price impacts from -75.5% (discount) to +61.0% (premium) for resi-dential properties located on floodplains. Meta-regression establishes a price discount of -4.6% on average associated with locations in a 100-year floodplain.	As well as revealing significant variation in results, they also find that price discounts are greater immediately following a flood, and that the discount then decays afterwards. States that changes in subjective risk assessments and objective measures can influence results.
Bhattacha-rya-Mis *et al.* (2011)	UK	Examines flood risk, insurance and related factors affect-ing valuation of commercial property; also different models of flood damage estimation across the world.	Authors identify spatial and temporal specific attributes for damage estimation models, while valuation models consider market factors.
Bhattacha-rya-Mis & Lamond (2015)	UK	Survey of commercial prop-erty occupiers and experts in Wakefield and Sheffield in UK. Respondents identified a lingering effect on activities and income resulting from reduced usability and utility of property as business units.	Value of properties perceived to be vulnerable to flood risk. Study concludes that there is a knowledge gap between experts and property holders regarding operational factors that affect value.

Daniel *et al.* (2009)	U.S.	Based on analysis of results of pre- and post-flood events, they found that a 0.01 increase in flood risk in a year amounts to a difference in transaction price of an otherwise similar house of -0.6%.	Negative price effects from flood risk are countered by positive effects from amenity, which reduces the ability to draw conclusions. Willingness to pay for flood risk is less in wealthy areas.
Hirsch & Hahn (2018)	Germany	Finds a large and significant asking price discount, and a small, significant rent discount for houses located in the 100-year flood zone, while controlling for other factors.	Study provides evidence of the cash flow channel for a partial explanation of price discounts in residential investments. A bigger impact implies that there are also cap rate effects.
Lamond *et al.* (2019)	Australia, China, Germany, UK, U.S.	Interviews with 72 built environment professionals across five countries. Finds inconsistencies in information about and understanding of flood risk, as well as implications for the insurance, management, and valuation of commercial real estate.	Authors advocate a greater shared understanding of flood risk as a precursor to actions on valuation and mitigation. Market value impacts may be short-lived, generating volatility in values. A cost-based approach to assessing impacts may be helpful.
Miller, Gabe & Sklarz (2019)	U.S. also hurricane impact and sea level rise	Examined c. 1.2 million sales of waterfront homes and c. 6.5 million sales of non-waterfront homes in the same ZIP Codes for 19 U.S. states over 2000–17. They found price premiums for waterfront location and that prices rebounded quickly after major storms occurred.	As observed price discounts after such events dissipate quickly, this suggests that changes in risk perceptions are short-lived. The results also highlight the continued influence of amenity in supporting prices for locations with higher climate risks.
Pottinger & Tanton (2014)	UK	Finds that UK institutional investment funds are paying greater attention to flood risk due diligence when making acquisitions. Tighter regulation and the occurrence of major floods are cited as drivers.	Changes in flood risk within portfolios could still go undetected, due to the assumption that flood risk is unlikely to change post-acquisition or by a reluctance to expose the problem.
Turnbull *et al.* (2013)	Baton Rouge, U.S. Liquidity focus	Drawing on search theory, house prices and sale times are modelled. Authors find that houses in the highest risk areas not only exhibit price discounts, but they also take longer to sell.	Investors need to be conscious of potential risks not only to prices, but also to asset liquidity arising from climate risk.

Hurricane/Cyclone

Authors (date)	Geography & Hazard/ event	Summary of findings	Implications for inves-tors
Addoum *et al.* (2021)	U.S. Hurricane Sandy (CRE)	Find permanent price discount for office properties exposed to flood risk; slower post-storm price growth compared to equivalent assets not at risk. Channel of impact is via revised up risk premium and not leasing fundamentals. Also find price impact in Boston that has yet to experience an event but faces higher risk of one.	Sophisticated or professional investors (at least vs. home-owners) in the U.S. Northeast are incorporating flood risk into risk premiums and hence required returns and property prices
Fisher & Rout-ledge (2021)	U.S. Major hurricanes over past 3 decades (CRE)	Quantifies the impact of hurri-canes on US CRE values, using institutional property level data from the National Coun-cil of Real Estate Investment Fiduciaries (NCREIF) Property Index. Find on average an immediate price impact that worsens over time, taking three years to bottom out, and then prices revert back to "normal"; consistent with much of the literature on the residential sector.	Result of no permanent price discount should be viewed with caution in applying to today. There is no consideration of the potential for increasing climate risk, and recognition of it, over time; single analysis, essen-tially forcing the adjustment coefficients to be time invari-ant. Would be fruitful to study the separate impact of more recent hurricanes that seem to have caused a re-assessment of climate risk. See Addoum *et al.* (2021)
Gibson & Mullins (2020)	U.S. Hurricane Sandy	Estimate the impacts of Hurricane Sandy ("event") plus two flood risk "signals"; Flood Insurance Reform Act of 2012 that increased premiums, and new federal government flood plain maps. On average each signal decreases sale prices by about 5%. Properties for which a signal provides more new information exhibit larger effects. Properties flooded because of Sandy are not impacted by the signals but those not flooded but included in the new floodplain, see sale prices fall approximately 12 to nearly 23%.	Revised flood plain boundaries in (an information signal) induce belief changes broadly comparable to those from insurance reform (a price signal). Consistent with increased awareness and real impacts of risk of future flood damage. Also, Google search data is a useful monitoring metric—document increases in flood-related search intensity coincident with flood risk signals.

Meltzer *et al.* (2021)	U.S. Hurricane Sandy (CRE)	Examined the economic impacts on local business establishments. Controlling for exposure to pre-storm risk, exploit variation in post-storm inundation to identify the impact of storm-induced flooding on establishment survival, employment, and sales revenues. After Sandy, retail establishments exposed to higher surge levels experienced 11% higher closure rates and 9% larger sales revenue declines compared to businesses with less exposure to inundation.	One of the few studies focused on CRE tenants. Results confirm economic losses from Sandy and that these were concentrated among retail businesses with more localised consumer bases. Closures were concentrated among standalone establishments. These losses appear to be fairly persistent, showing no sign of recovery to pre-storm levels by 2016. The evidence for jobs is more tentative—at most, they exacerbated an existing downward trend for retail establishments after Sandy.
Ortega & Taşpınar (2018)	U.S. Hurricane Sandy	Compared price trajectories of housing units in New York City impacted by Storm Sandy to similar units not impacted, but also in flood zone, plus a control sample. The paper found not just immediate, short--term value drop (up to 17%), but a persistent drop in transaction prices (approx. 8%), regardless of level of damage incurred. This they concluded was consistent with collective learning of the increased risks of both flooding and SLR.	A tipping point was triggered in terms of an upward revision of risk. The implication for investors is that, while many climate events may result in only temporary value change, some can constitute a radical re-alignment of risk profiles. While SLR is generally chronic, rather than acute risk, when combined with storm surge, it has the potential to accelerate re-evaluation of the chronic forward impact.
Ouazad & Kahn (2021)	U.S. Lender response	Paper provides evidence that, in the aftermath of hurricanes, U.S. lenders are more likely to approve mortgages that can be securitised, thereby transferring climate risk. Lenders are significantly more likely to lower the sizes of their mortgage loans originated to make sure they are eligible (i.e. at or below the conforming loan limit sizes) to be purchased by Fannie Mae and Freddie Mac (the "GSEs"). Natural disasters increase bunching of loans at the limit, suggesting an increased option value of securitisation.	There is significantly more risk in the U.S. mortgage and hence financial system than may be widely believed. Securitisation channels not fully pricing risk should raise flags for systemic risk similar to the sub-prime crisis. Could the same be happening in the CMBS market or do we assume more sophisticated investors, especially with risk-retention rules added in post GFC?

Sea level rise (SLR)

Authors (Date)	Geography & Hazard/ event	Summary of findings	Implications for investors
Almås & Hygen (2012)	Norway	Paper uses building registration data with historical and predicted climate data to create risk map for country for all property types. Found total costs for Norway to address sea level rises in the construction of buildings in Norway is estimated to be up to 725 million euro—excluding government costs.	The research pointed to the difficulty in predicting any value changes related to SLR due to the complex uncertainties. For investors, SLR remains largely in the future and value impacts, though inevitable, will depend on how far public funds will pay for adaptive infrastructure and insurers cover building cost loss.
Bakkensen & Barrage (2021),	U.S.	Linking owner beliefs in climate and SLR with house prices in Rhode Island revealed that house prices were inflated by up to 13% based against a rational model for values where there was a lack of belief in the effects of SLR moving forward.	The denial of SLR risk may be evidence, as it is less easily linked to specific events in most locations currently. The paper provides useful commentary on the implications for insurance, given that they found many at risk properties in the U.S. are not currently insured.
Baldauf *et al.* (2020)	U.S.	Explores the importance of beliefs about climate risk in the pricing of SLR risk. Analyses the impact of flooding risk projections on house price transactions data based on whether the location was primarily an area of believers or deniers in climate risk. The results showed that the belief or otherwise in climate change was significant in prices prevailing in high SLR areas—up to 7% lower in believer areas.	Translating findings to commercial real estate could be difficult, as it would be harder to track motivations/ beliefs in investment property. Nonetheless, it underscores that, even where scientific evidence is strong, perceptions/beliefs can be equally or more powerful. But it also emphasised that the impacts vary even in small subsample area: there is no substitute for extremely thorough local due diligence.

Bernstein *et al.* (2019)	U.S.	The paper examined price data of residential sales/rental over time along most both East and West coast locations. They found a discount of up to 7% in capital value of properties at risk of SLR, falling to 4% where the risk is 100 years away. No discounts were observed in the rental market.	The conclusions drawn were that sophisticated investors are increasingly pricing in SLR risk—even if it is a long way distant. The analogy with comparing cap values of long leasehold properties with freehold, could be a useful 'shorthand' for expecting decline in value over time. However, as with long leasehold properties, short term income from properties at risk is less likely to be affected as SLR is a long-term risk.
Bin *et al.* (2011)	U.S.	Modelling the loss of residential properties to SLR along the North Carolina coastline by 2030 and 2080 reveals that, without interventions, areas of extreme risk could see a total loss of up to 9.45% of collective values.	To investors, this paper highlights the uncertainties both in terms of whether SLR can be mitigated, and the localised impacts which they found in their model to be very variable. They found no evidence that SLR risk was currently priced in—despite the very strong real risk of loss in even a short-term horizon.
Conyers *et al.* (2019)	U.S.	Using Miami as a case study and compared data on public authority and mitigation measures, vulnerability to SLR with house price index. They found a mismatch with apparent unresponsiveness of house prices to vulnerability levels. They warned this could lead to a sudden 'tipping point' without more municipal interventions.	The research presents some challenges to translate to commercial real estate, as the lack of responsiveness was in high value, fashionable areas, where decision-making may not be based on commercial rationalities. However, it again points to the likely reliance on municipal response in the future.
Cooper & Lemckert (2012)	Australia	The paper considers how the tourist area of the Gold Coast could withstand SLR to maintain attraction to investors, homebuyers and the hospitality industry. Through analysis of SLR predictions and informal interviews, the authors found that future viability will depend on maintenance of the quality of the environment; therefore the level of collective or municipal investment is critical to value retention.	The findings of this early paper may seem obvious: action to create resilience is required. The implication for investors is that it will be increasingly important to channel funds where either individual stakeholder action is possible—or where there is a deep political will to create adaptation infrastructure such that income, insurability and investor/purchaser confidence can be maintained.

Fu *et al.* (2016)	U.S.	Similar methodology to Bin *et al.* applied to local parts of Florida peninsula. Found that economic losses alone were likely to be high ($300–$900 million) but other costs, such as loss of amenity, damage to wetlands etc. are not normally factored in.	The main implications are for policy makers and authors point out the need to take a total socio-economic perspective as factors other than house price loss are critical and should help underpin environmental protection measures.
Fuerst & Warren-Myers (2019)	Australia also fluvial flooding	Regression analysis applied to statutory house valuations over the period 2011–2016 in Melbourne revealed that while river flooding propensity was reflected in values, the implications of future SLR was not.	The authors attribute these results to the better data sets and greater awareness among buyers of flood risk and the far greater uncertainties around timing, impact and knowledge of SLR. To investors, this demonstrates that flooding is far too broad a term of investigation when assessing risk—the nature of the risk needs to be fully understood.
Heberger *et al.* (2011)	U.S.	An early paper that aims to analyse the cost impacts of SLR and associated storm damage in California. It found building costs replacement risk had risen significantly as SLR risk has been modelled in more detail; also projected human dislocation costs.	While the paper did not attempt to analyse any market value effects, the high level of projected individual and collective costs was a call for policy makers, insurers and investors alike to consider the previously unrecognised risks.
Keenan *et al.* (2018)	U.S. Climate Gentrification	By conducting a case study in Florida, and using long-term house price appreciation regressed against elevation, the authors found, albeit tentatively, that higher elevation in coastal high risk locations properties gained more value than those at lower elevation which were already subject to 'nuisance flooding'. The authors recognised that other locational factors could impact, as well as the presence of resilience measures	While this paper demonstrates possible awareness of and price response to SLR risk, investors need to also be aware that other locational 'desire' factors could be at play. As with other papers, there is recognition of the role of municipality as a player in adaptation.

Keenan & Bradt (2020)	U.S. Lender response	Document a shift in mortgage risk related to information asymmetry or beliefs. They provide evidence that concentrated local lenders are transferring risk in high-risk coastal geographies in the Southeast Atlantic and Gulf Coasts (U.S.) through increased securitisation of mortgages	Suggests significant institutional rigidities, variation in and uncertainty of beliefs drive informational asymmetries that may result in assignments of risk that reflect a degree of arbitrariness or inaccuracy which may operate to strand assets and shed (or expand) market share in ways that are inefficient and may lead to negative externalities
Keys & Mulder (2020)	U.S.	Long-term study of house prices (2001–2020) in coastal U.S. Noted that house sale volumes declined from 2013 by 16–20% in SLR high risk areas, but it took 5 further years before sale price growth became negatively affected. However, lender behaviour showed little reaction: securitsation and refusal rates remained unaffected.	Sales activity could provide a first indicator of purchaser risk awareness—rather than pricing signals. However, there is an implication for lenders, that, if they do not act on early signals, they could face increased risk of defaults in the future when a 'tipping point' of SLR risks becomes apparent. The notion that liquidity may be an early indicator—before price signals are picked up—may well apply to commercial real estate as well.
Kontogianni *et al.* (2014)	Greece	Greece is prone to SLR value loss in relation to both low-lying deltas and rapidly eroding coasts lines. Recognising the ongoing uncertainties about scale/timing/impacts, the authors present real options valuation (ROV) as a useful policy tool for the economic assessment of adaptation measures	The paper is of use primarily to policy makers deciding on the level and type of adaptation for maximum impact efficiency. To investors, it is useful in that is considers the impact, not just on households, but all types of property and hospitality.
McAlpine & Porter (2018)	U.S.	Taking a case study in Florida and using regression analysis, the authors found that, over a decade from 2005, SLR predictions had started to be priced in to house transaction prices by up to $3.71 year-on-year on each square foot of living area compared with properties not at risk.	This paper is unusual in that it finds price adjustment has already been factored into some, though small, extent. But as with many other papers, the inference drawn is that value preservation moving forward is dependent on collective action by communities, individuals and government officials to reduce risks through reasonable adaptation measures.

Murfin & Spiegel (2020)	U.S.	An extremely detailed, large-scale study of coastal properties (all coastline) tracking impact of local SLR predictions, elevation and house prices but mitigation measures were ignored. Using a wide range of robust tests, they found an absence of detectable price effects.	This is probably the largest study available. The lack of price effect was suggested to a mix of underestimation of the risk size and/or denial combined with a belief that future mitigation measures will be made by municipality or bailouts provided. The question of knowledge was not addressed, and thus these results may not translate to informed investment-driven commercial markets.
Scott *et al.* (2012)	Caribbean (CARICOM)	A forward-looking study on tourism properties across the CARICOM countries. It found that, depending on the island, between 29% and 50% of properties would suffer partial or total inundation when a 1 metre rise occurred, unless mitigation is taken. Call for better mapping and for preventative policy response.	While the paper does not present empirical evidence of value change, the inclusion is made due to the clarity of implications and because it highlights the extreme results from predictive SLR rise.
Tyndall (2020)	U.S.	Regressing repeat sales prices of both single family and multi-occupancy investor-owned properties in Long Island over the period 2000–2017 revealed that future sea level rise risk had no impact on price appreciation of single family units but that multi-family properties at risk had annual price appreciation 1.4 percentage points below unexposed properties.	The authors attributed the differing results to investor knowledge and sophistication: factors not observed among owner-occupiers. If this translates to commercial real estate it would imply that more sophisticated investors may already be pricing in such risks.
Walsh *et al.* (2019)	U.S.	Aimed to differentiate and measure, through hedonic analysis, the impact of SLR on coastal properties in Chesapeake Bay, U.S. East Coast, by comparing those where local flood mitigation measures had taken place those which had not. The results show that those without mitigation have suffered value loss; those with mitigation measures in place had value enhancement.	The paper provides comfort that even simple mitigation measures (such as bulkheads and ripraps) can support resilience in property prices where local knowledge is leading to SLR risk recognition. It provides a clear message to local municipalities.

Warren-Myers *et al.* (2018)	Australia	The paper found, through predictions of various scenarios of SLR likely to impact Melbourne, that significant value loss will be incurred, not just directly due to inundation total loss, but indirectly due to cost of repair, decreased demand, voids, human casualty and eco-system degradation. It concluded that, despite the clear implications for real estate, there has been little consideration, interaction or action by private property stakeholders. By implication the risks are not yet priced in.	This is a predictive study, so does not help ascertain the extent to which a price effect has taken place. It, however, assumes that it will. The usefulness to investors of this paper is the clear articulation of the costs, other than inundation, that will result, which collectively are likely to render insurance expensive or unobtainable and raise taxes to cover mitigation and adaptation work.

Wildfire

Authors (Date)	Geography & Hazard/ event	Summary of findings	Implications for investors
Athukorala *et al.* (2019)	Queensland, Australia	Houses in bushfire prone areas that are closer to forest had higher values after controlling for other factors affecting price.	Properties in areas with higher climate risks can continue to retain value where amenity or economic advantages remain strong.
Champ *et al.* (2009)	Colorado, U.S.	Most respondents were not aware of wildfire risk before purchase and still under-estimated the risks. Risk ratings were not accessed in advance of home purchase and disclosure by vendors or realtors was not mandatory.	While professional investors may be better informed, it reinforces the importance of due diligence and disclosure in the transaction process.
Donovan *et al.* (2007)	Colorado, U.S.	Before the release of parcel-level risk assessments, amenity effects dominated risks in the prices paid for houses. Afterwards, risks offset amenity effects in determining prices.	Having detailed local level information influences pricing more than general awareness of climate risks.
Hansen & Naughton (2013)	Alaska, U.S.	Small wildfires had negative impacts and large wildfires had positive impacts on the assessed values of affected houses.	Price effects depend on how events shape views of future exposure to risks, e.g., if risk is thought to be reduced after a large wildfire.

Issler *et al.* (2020)	California, U.S.	Mortgage delinquencies and foreclosures are found to increase after wildfire events, although this effect is not so marked for larger fires where there is more co-ordinated rebuilding and renewal of an area in the aftermath, which can have value benefits.	Impact on lenders and insurers of wildfires is discussed. Recent losses have impacted insurance provision and costs, which could affect asset and loan performance in future, with lenders and homeowners having to bear more risk.
McCoy & Walsh (2018)	Colorado, U.S.	Prices of houses in affected areas fell by 6–13% in the year after a fire and these impacts persisted in future years. Prices in unaffected but high-risk areas fell by 9–12% but recovered in 2–3 years. Sale rates suggest shifts in risk perceptions.	Although markets might rebound after climate events, myopic pricing will not safeguard performance against persistent risks.
Mueller *et al.* (2009)	California, U.S.	Repeated exposure to fires affects prices for proximate homes more than exposure to a single event or to no fire at all. Recovery in real house prices is prolonged.	Frequent exposure to climate events suggests heightened risks and reduced utility from properties held in those areas.
Mueller & Loomis (2014)	California, U.S.	Larger impacts on the prices of proximate houses are observed for higher value homes, which may reflect greater loss of amenity value in such cases.	The extent of any value impact depends on the reasons why properties derive value in their locations.
Stetler *et al.* (2010)	Montana, U.S.	Sale prices of homes more proximate to wildfires are negatively impacted. The effects are persistent, but diminish with distance, and are stronger for houses where burned areas are visible.	Pricing reacts to climate events but the size and duration of impacts may not correlate with those areas or structures at highest risk of a future event.

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