Lecture

Climate Risk and Real Estate Markets

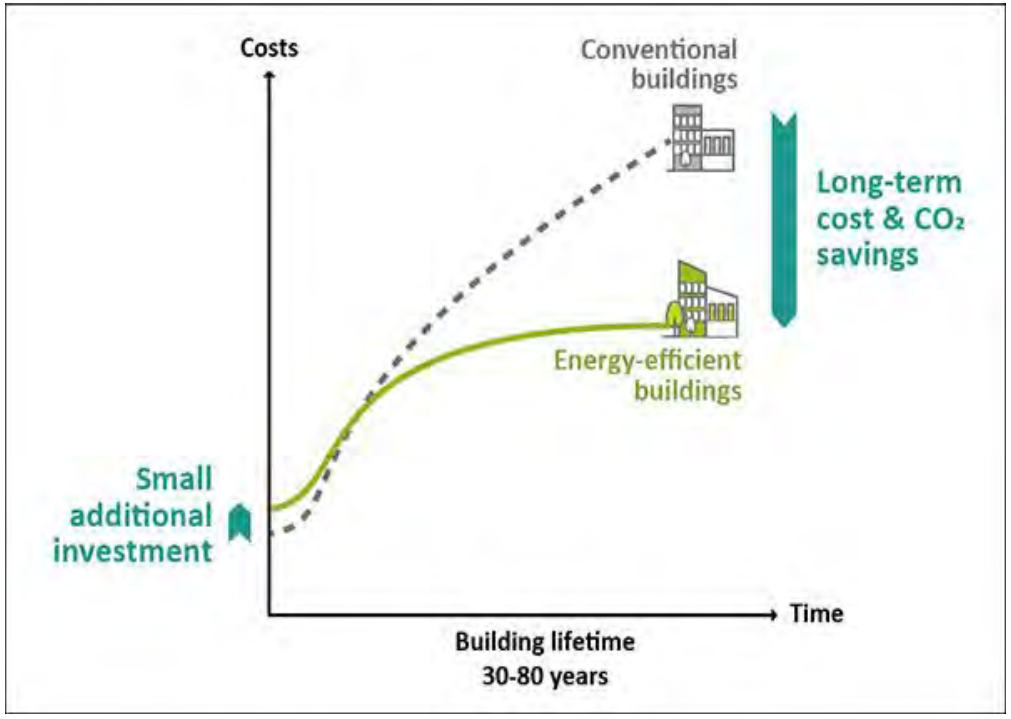
Understanding the basic impacts of climate change on real estate markets

Juan Palacios

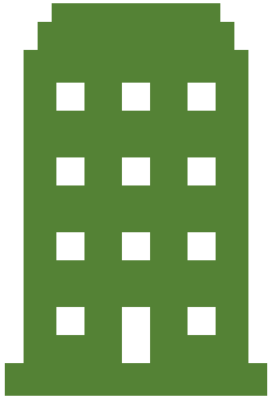
March 2023

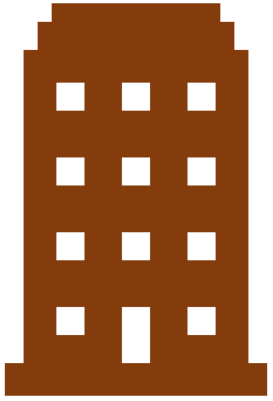
(MIT Center for Real Estate)

Green Building Lectures: Reduction CO2 Emissions



Source: http://sdg.iisd.org/commentary/guest-articles/buildings-vs-the-cooling-challenge-better-building-design-to-curb-the-massive-rise-in-cooling-demand/





Green Building

Brown Building

Outline Today's Lecture

Basic Climate Change

- What is climate change, why and when should we care in real estate?
- Including climate change in the 4Q model

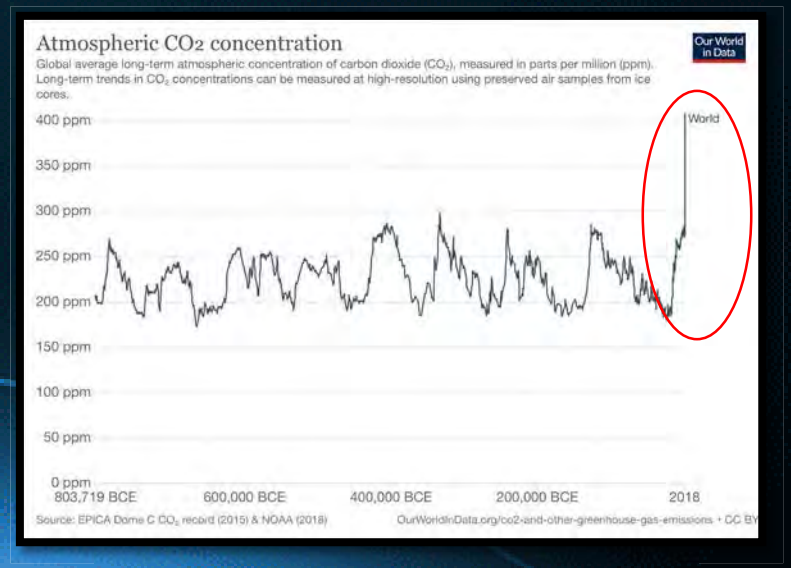
Empirical evidence: How is climate change affecting the value of real estate assets?

- Using hedonic models to estimate impacts of climate events on property markets

Impact of climate risk on real estate markets

- The role of discount rate
- Climate risk and beliefs
- Climate risk in commercial VS residential real estate

The Greenhouse Effect



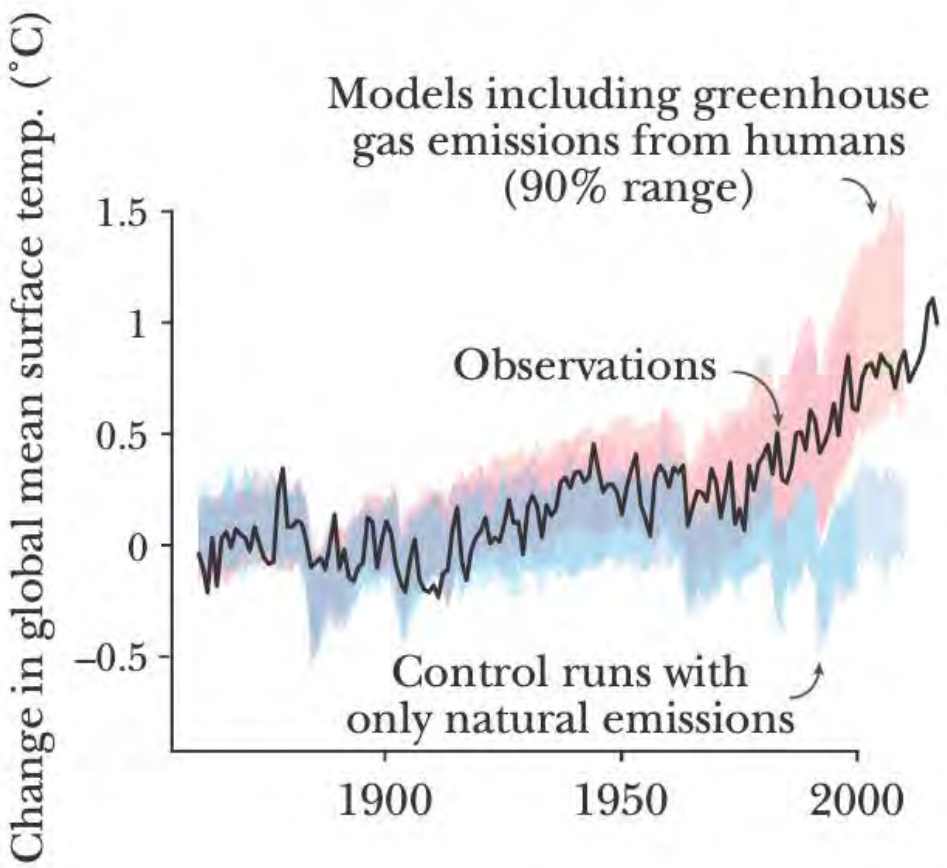
Courtesy of NOAA / Our World in Data. Used with permission.

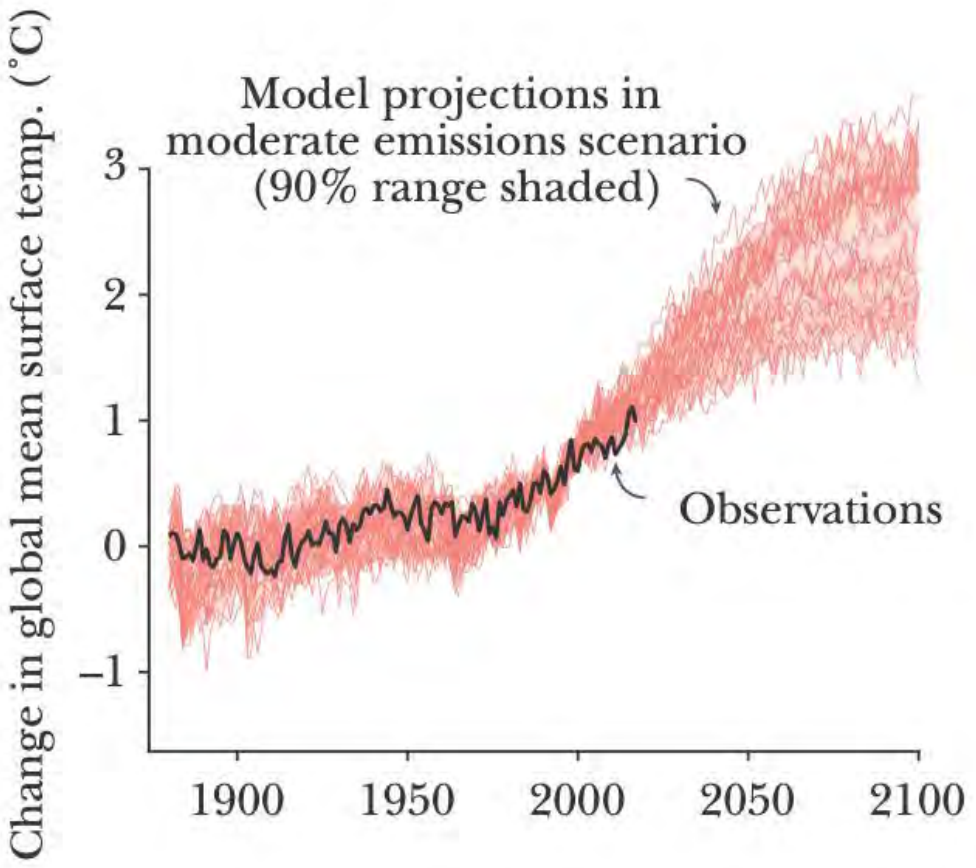
Atmosphere

Public domain image courtesy of NASA/JPL- CalTech.

climate.nasa.gov

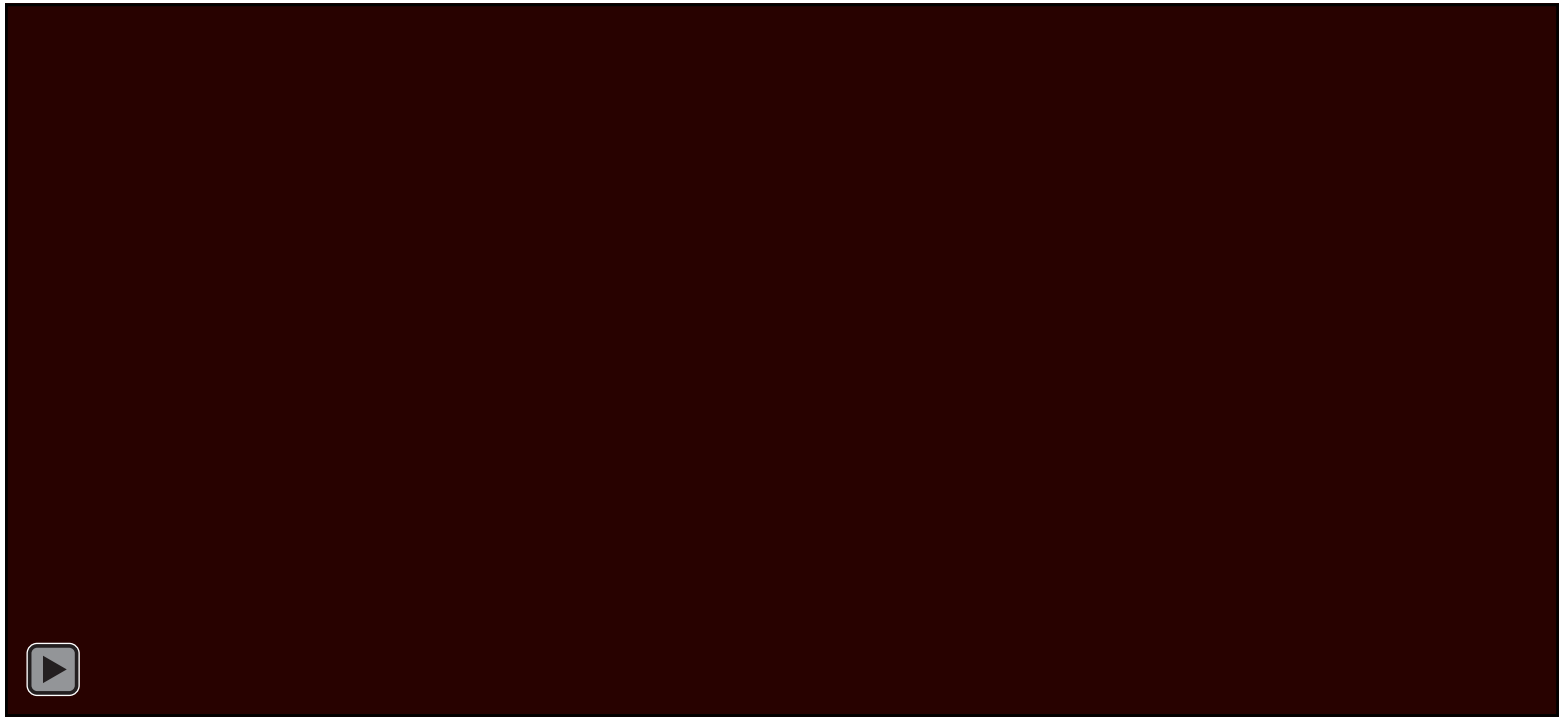
Is Climate Changing?





Source: Hsiang, S., & Kopp, R. E. (2018). An economist's guide to climate change science. *Journal of Economic Perspectives*, *32*(4), 3-32.

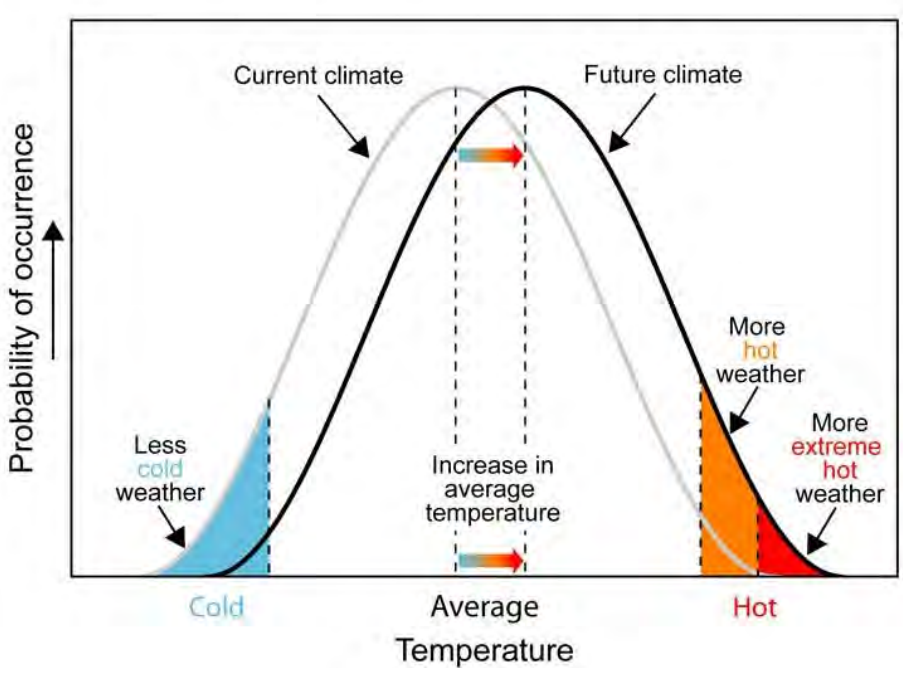
Weather, climate, and climate change



Weather, climate, and climate change

- **Climate** describes long-term status of the atmosphere, ocean, and freshwater systems (including ice) and their complex interactions
  - Common measure: 30 year averages of weather (surface temperatures and precipitations)

- Climate change refers to changes in **long term trends**:
  - Change in **expectations/forecasts/beliefs**: Key for real estate investments, with holding periods usually covering several decades



Is Our Climate Changing? Roadmap of Uncertainty in Climate Models

Statements of the Intergovernmental Panel on Climate Change (IPCC) on Detection and Attribution of Global Climate Change

First Assessment Report (1990)	"Unequivocal detection of the enhanced greenhouse effect from observations is not likely for a decade or more."
Second Assessment Report (1995)	"The balance of evidence ***suggests*** a discernible human influence on global climate."
Third Assessment Report (2001)	"Most of the observed warming over the last 50 years is ***likely*** to have been due to the increase in greenhouse gas concentration."
Fourth Assessment Report (2007)	"Most of the observed increase in global average temperatures since the mid-20th century is ***very likely*** due to the observed increase in anthropogenic greenhouse gas concentrations."
Fifth Assessment Report (2013)	"It is ***extremely likely*** that human influence has been the dominant cause of the observed warming since the mid-20th century."
Sixth Assessment Report (2021)	"Climate change ***is already affecting*** every region on Earth, in multiple ways. The changes we experience will increase with additional warming."

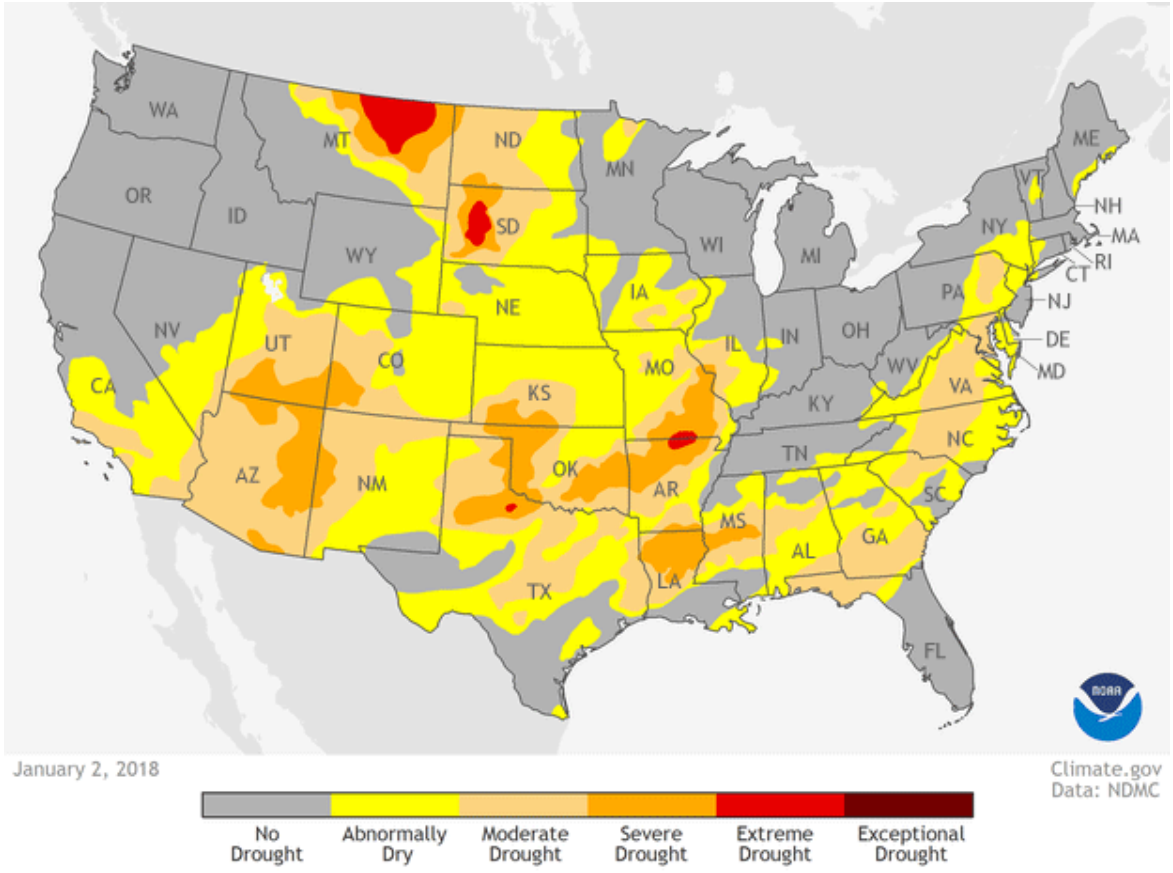
Source: Hsiang, S., & Kopp, R. E. (2018). An economist's guide to climate change science. *Journal of Economic Perspectives*, *32*(4), 3-32.

Weather, Climate, and Climate Change

Increase in frequency and severity of heat waves:

Weather, Climate, and Climate Change

Increase in frequency of droughts:



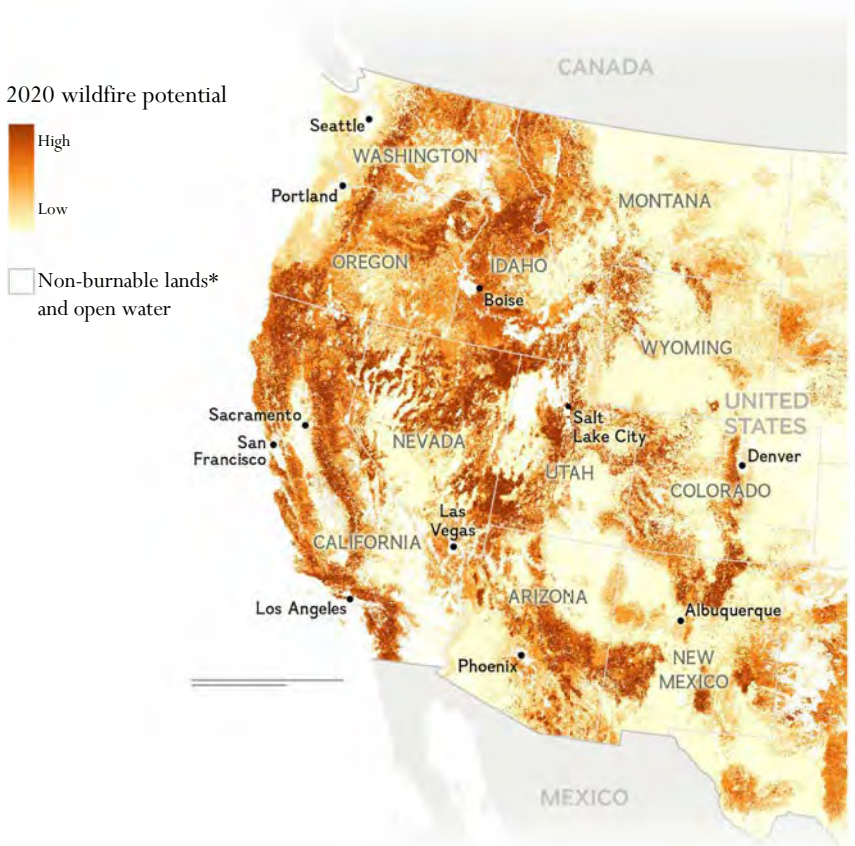
Weather, Climate, and Climate Change

Increase in frequency of wildfires in regions like California:

These Big Plans to Protect California Homes From Wildfire Fell Short in the Legislature

By Lauren Sommer Sep 26, 2019

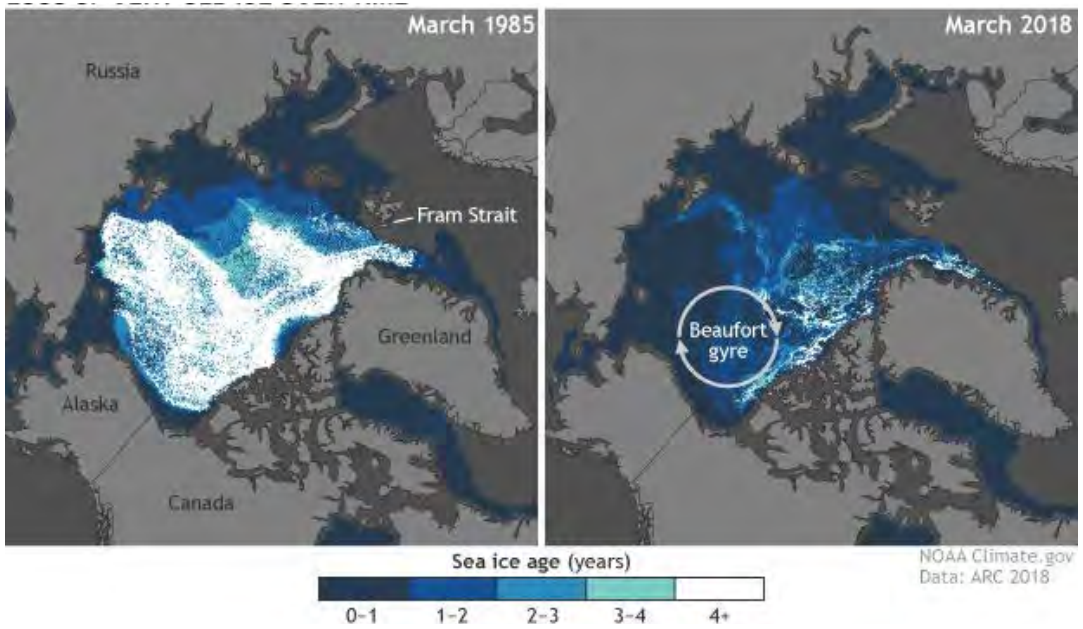
Efforts to retrofit homes against wildfires like this 2013 blaze in Southern California stalled in the state Legislature. *(David McNew/Getty Images)*

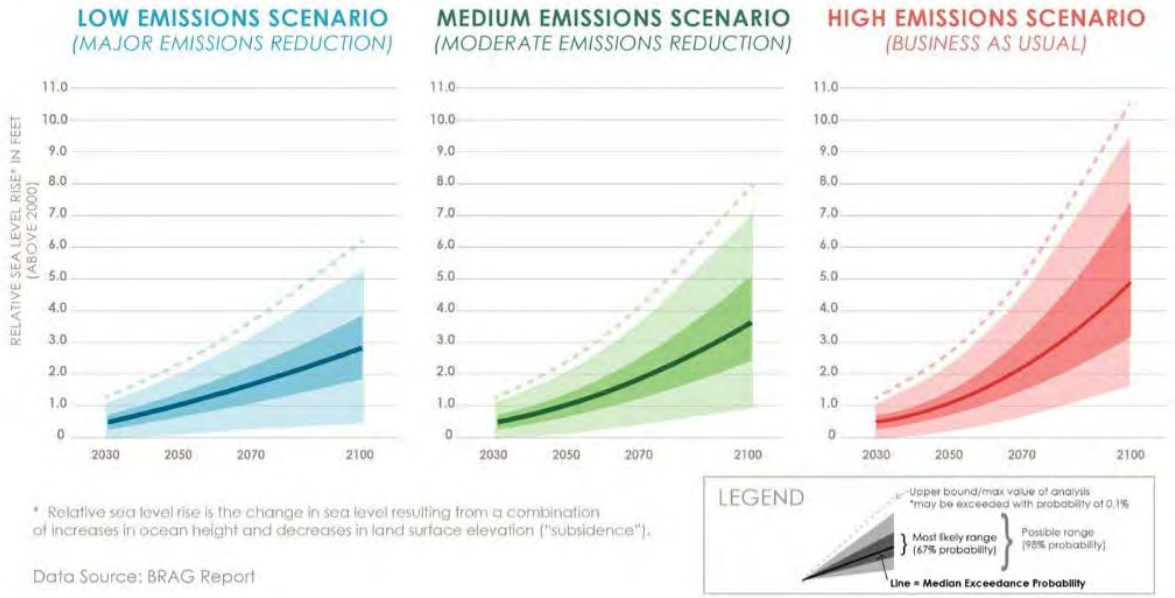


Weather, Climate, and Climate Change

Global warming is causing soils in the polar regions that have been frozen for as much as 40,000 years to melt

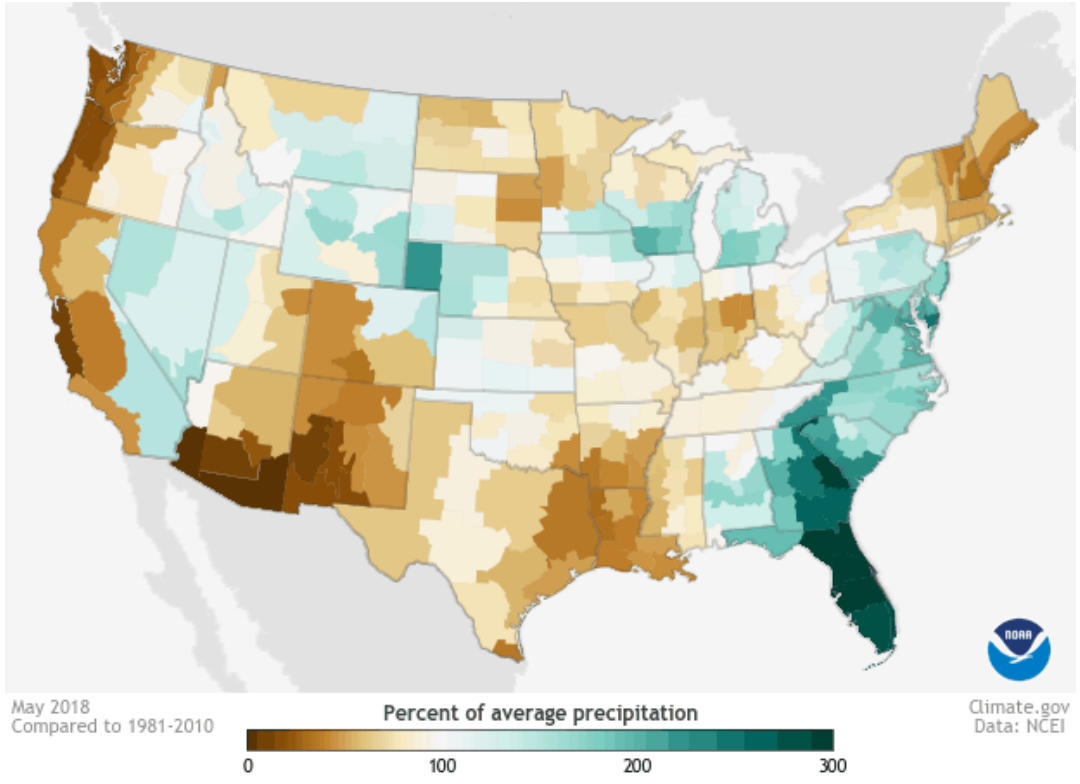
- Some of the sea level rise is due to melting glaciers and ice sheets which add water to the oceans that was once trapped on land.

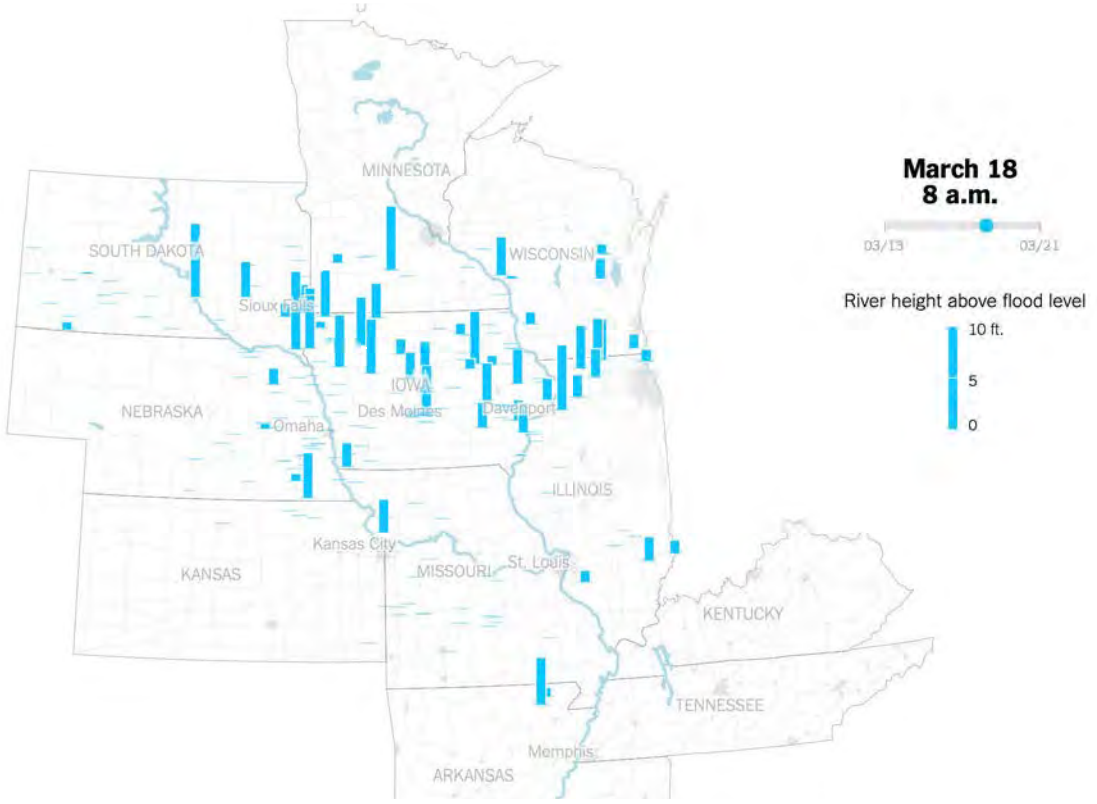




Weather, Climate, and Climate Change

Extreme rainfall accumulations have increased by a factor of 2-4 in the Northeast United States:



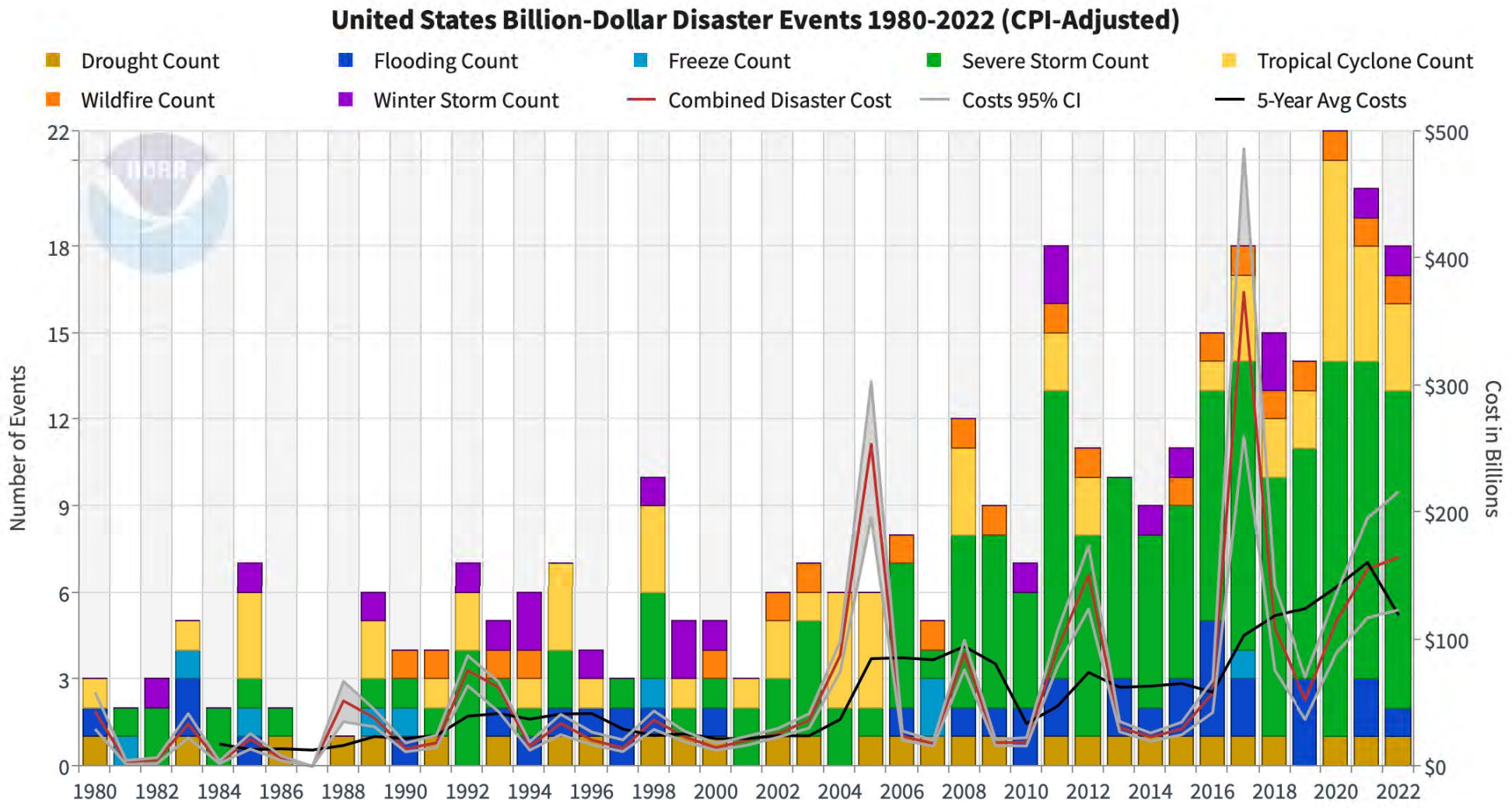


Weather, Climate, and Climate Change

Zhengzhou (China)
July 21, 2021

Germany
July 15, 2021

Evolution of Damages Climate Disasters



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Public domain content courtesy of NOAA.

Climate Risk in Real Estate Markets

Physical risk

Capable of ***directly affecting buildings***

- **Acute Climate Risk: Catastrophic events**.
- **Chronic Climate Risk: Changes in weather patterns**.

Transition risk

Indirect risk for buildings: Economic shifts, regulatory changes, and the changing availability and price of resources.

- **Market risks**
- **Reputation and market position**
- **Policy and regulation**
- **Resource availability**

Physical risks: Acute vs Chronic Physical Risks

Capable of ***directly affecting buildings & occupants***

- **Chronic Climate Risk: Changes in weather patterns**.
  - Rising sea levels
  - Rising average temperatures

Average changes in weather [experience]:
Frequent events, affecting our daily life now
Damages are not catastrophic

- **Acute Climate Risk: Catastrophic events**.
  - Wild fires
  - Heat waves
  - Storms
  - Floods

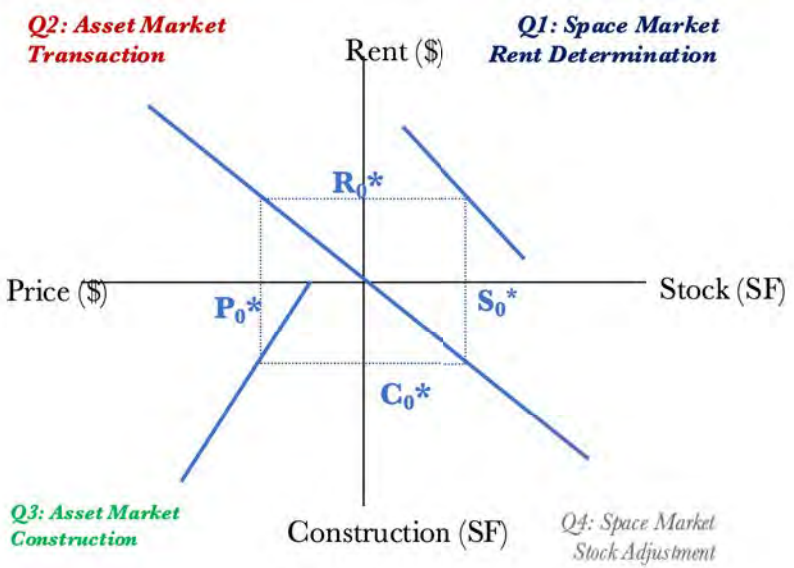
Tail Events [expectation]:
Infrequent events, often projected to happen in the (far) future by climate models (e.g. 100 years):
Damage are extreme

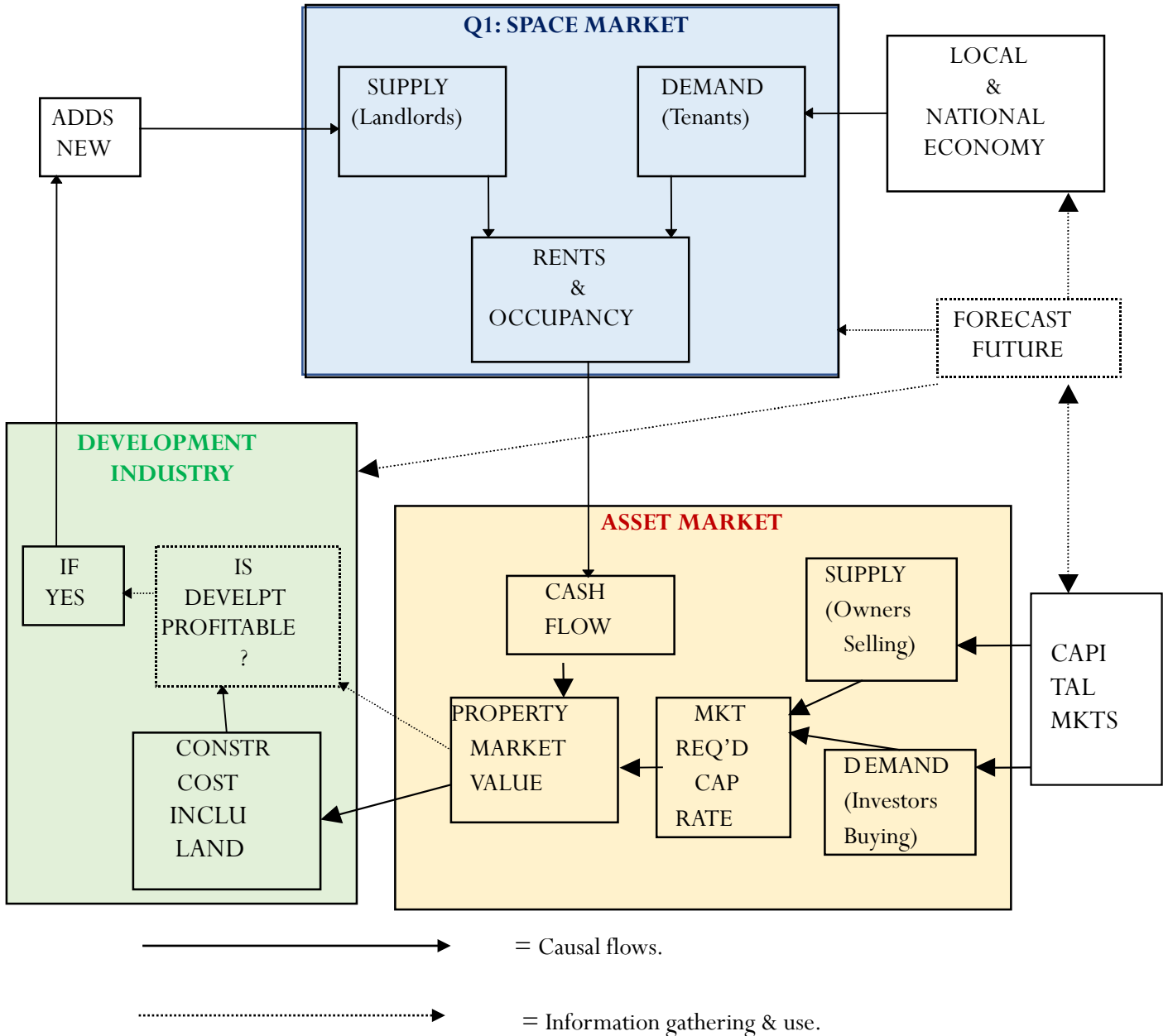
Transition Risks

Transition risks: regulatory changes, economic shifts, and the changing availability and price of resources.

- **Market risks**: markets vulnerable to climate change will **become less desirable over time**. Rising capital costs to pay for building and maintaining infrastructure to manage climate risks.
- **Reputation and market position:** Growing **stakeholder preference** to work with companies incorporating climate risk into investment decisions, and consumer preference for real estate products incorporating climate mitigation.
- **Policy and regulation**: **Regulations to address climate change**—e.g., climate risk disclosure, tougher building standards, carbon pricing, emissions caps, changes to subsidies—as well as changing policies for providing funding for infrastructure or rebuilding after major events.
- **Resource availability**

The "Real Estate System": Interaction of the Space Market, Asset Market, & Development Industry



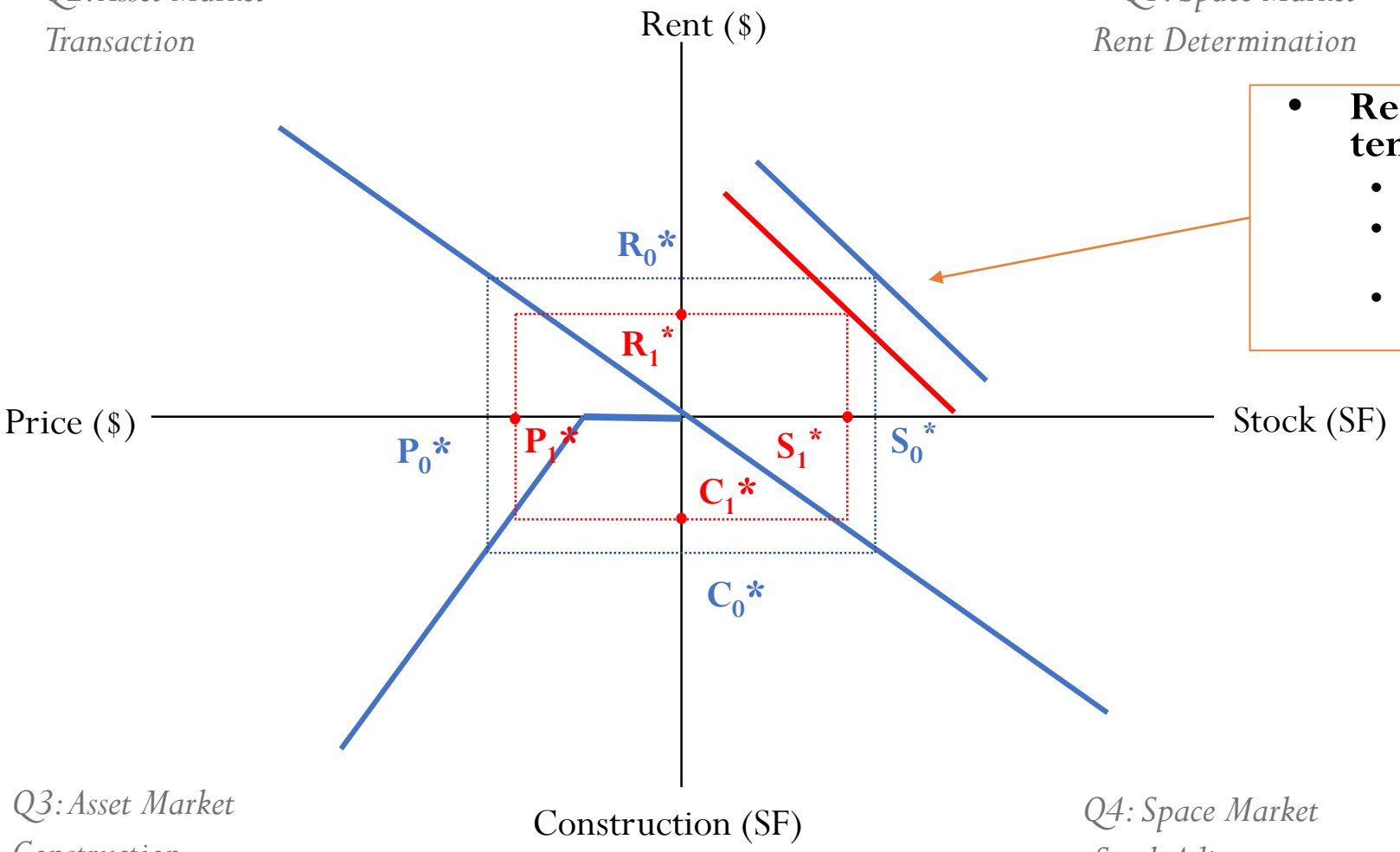


Geltner, D., Miller, N.G., Clayton, J. and Eichholtz, P., 2001. Chapter 2. *Commercial real estate analysis and investments* (Vol. 1, p. 642). Cincinnati, OH: South-western.

Four Quadrant Model: Drop in Demand

Q2: Asset Market Transaction

Q1: Space Market Rent Determination



- **Reduction in demand of assets by tenants**
  - Impacts on attractiveness of the asset
  - Impacts on occupants (health, behavior, performance)
  - Impacts on amenities

Q3: Asset Market Construction

Q4: Space Market Stock Adjustment

Impact of Climate on Demand for Assets

Introducing the problem of households using the hedonic-model:

$$\text{Price}_h = B' \text{House Characteristics}_h + B' \text{Location (physical) Amenities}_h + \mathbf{B' \text{Climate}_h}$$

- Household value the access to physical amenities within and ''around" the house
- Individuals sort to locations based on their preferences for ***climate amenities*** (e.g. warm and cold weather)
  - As climate changes, the weather also changes introducing new sorting (**migration**), and changing the demand for cities

Impact of Climate on Demand for Assets

Roback (1982): Housing Price (Rent) is the ticket to a city

$$\Delta Rent_i = \Delta Wage_i + \Delta Quality\ of\ Life_i$$

How much more people are willing to pay to live in city i

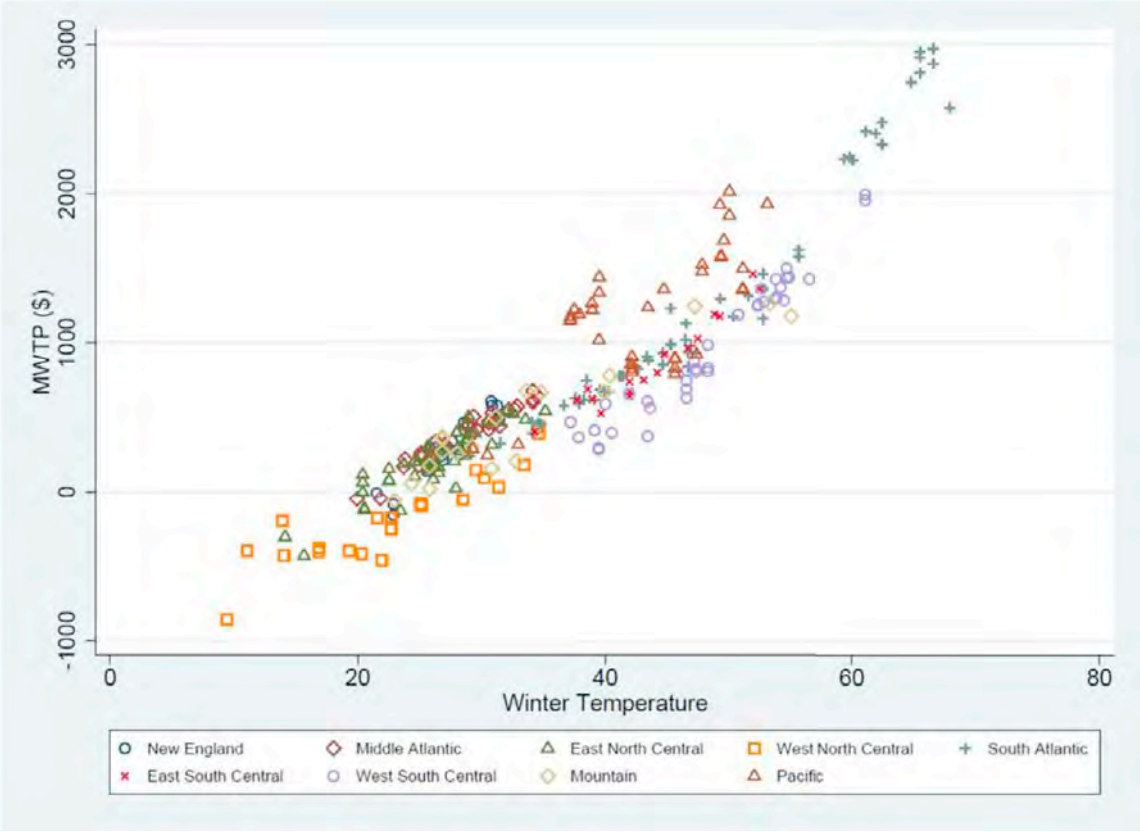
How much more people earn here

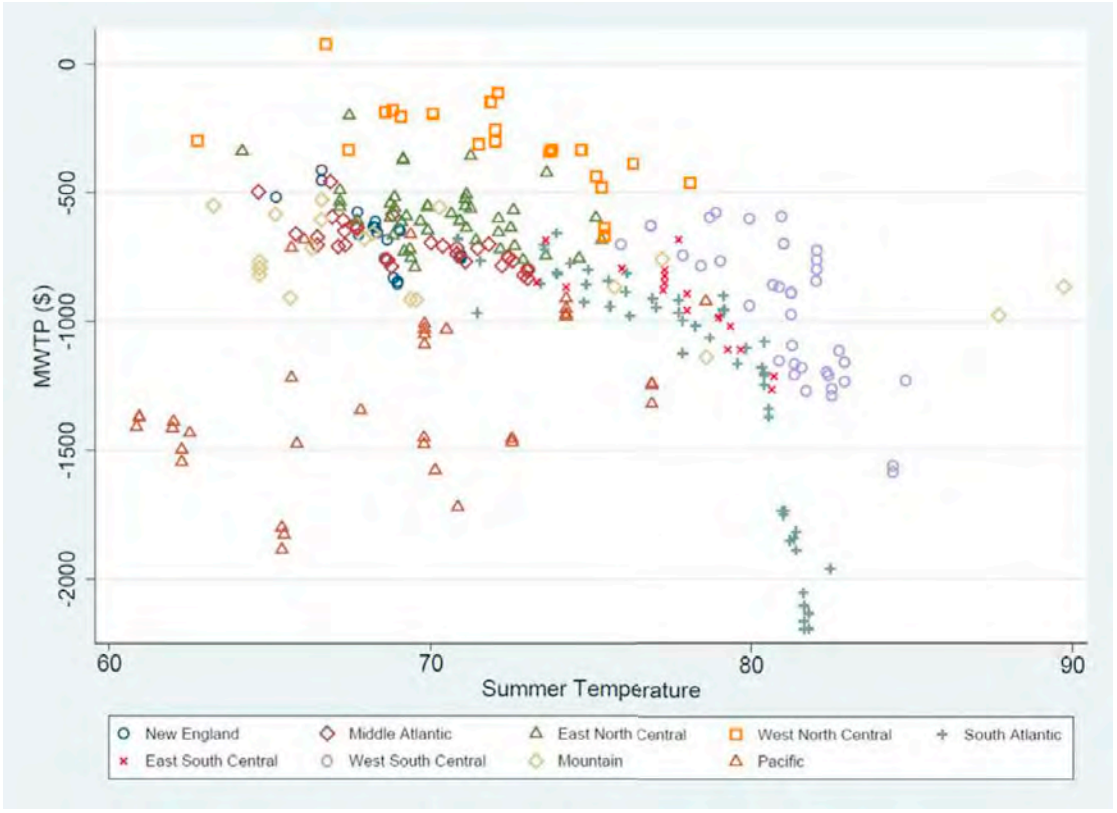
How much more people value the quality-of-life here

$$\Delta Quality\ of\ Life_i\ (\uparrow \text{temperature exposure}) = \uparrow \Delta Wage_i + \Delta Rent_i \downarrow$$

Δ: Premium relative to benchmark level

Impact of Climate on Demand for Assets

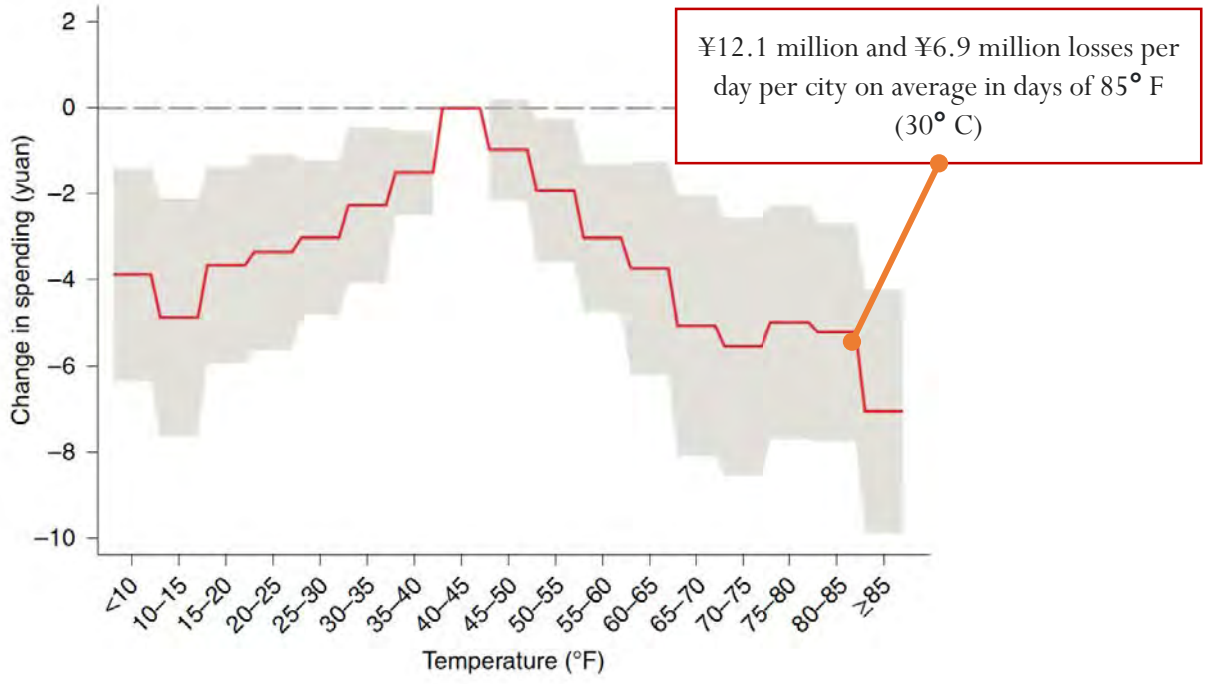




Source: Sinha, P., Caulkins, M.L. and Cropper, M.L., 2018. Household location decisions and the value of climate amenities. *Journal of Environmental Economics and Management, 92*, pp.608-637. Courtesy of Elsevier, Inc., https://www.sciencedirect.com. Used with permission.

Impact of Climate on Demand for Assets

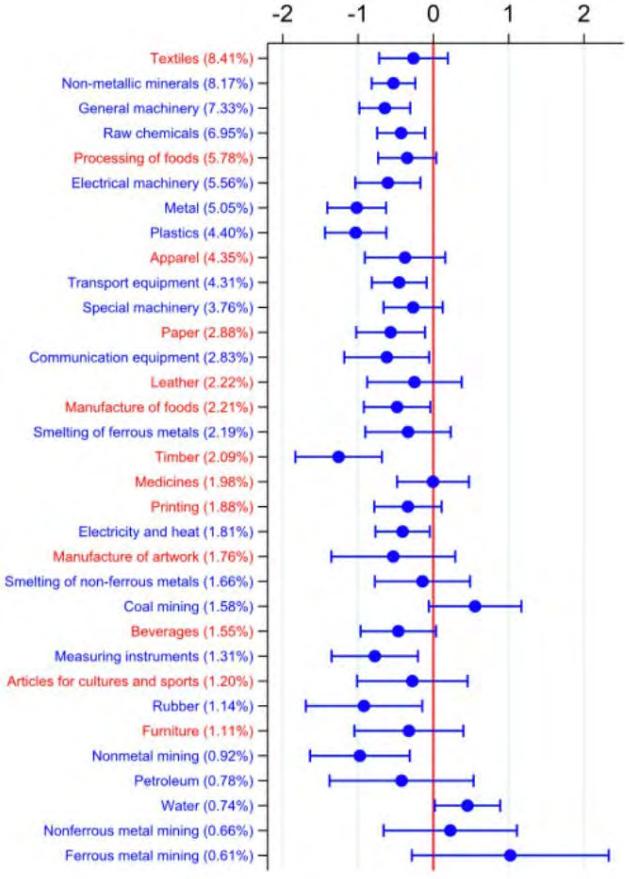
Retail Sector: Changes in Demand



Lai, W., Li, S., Liu, Y., & Barwick, P. J. (2022). Adaptation mitigates the negative effect of temperature shocks on household consumption. *Nature Human Behaviour*, *6*(6), 837-846.

Changes in productivity

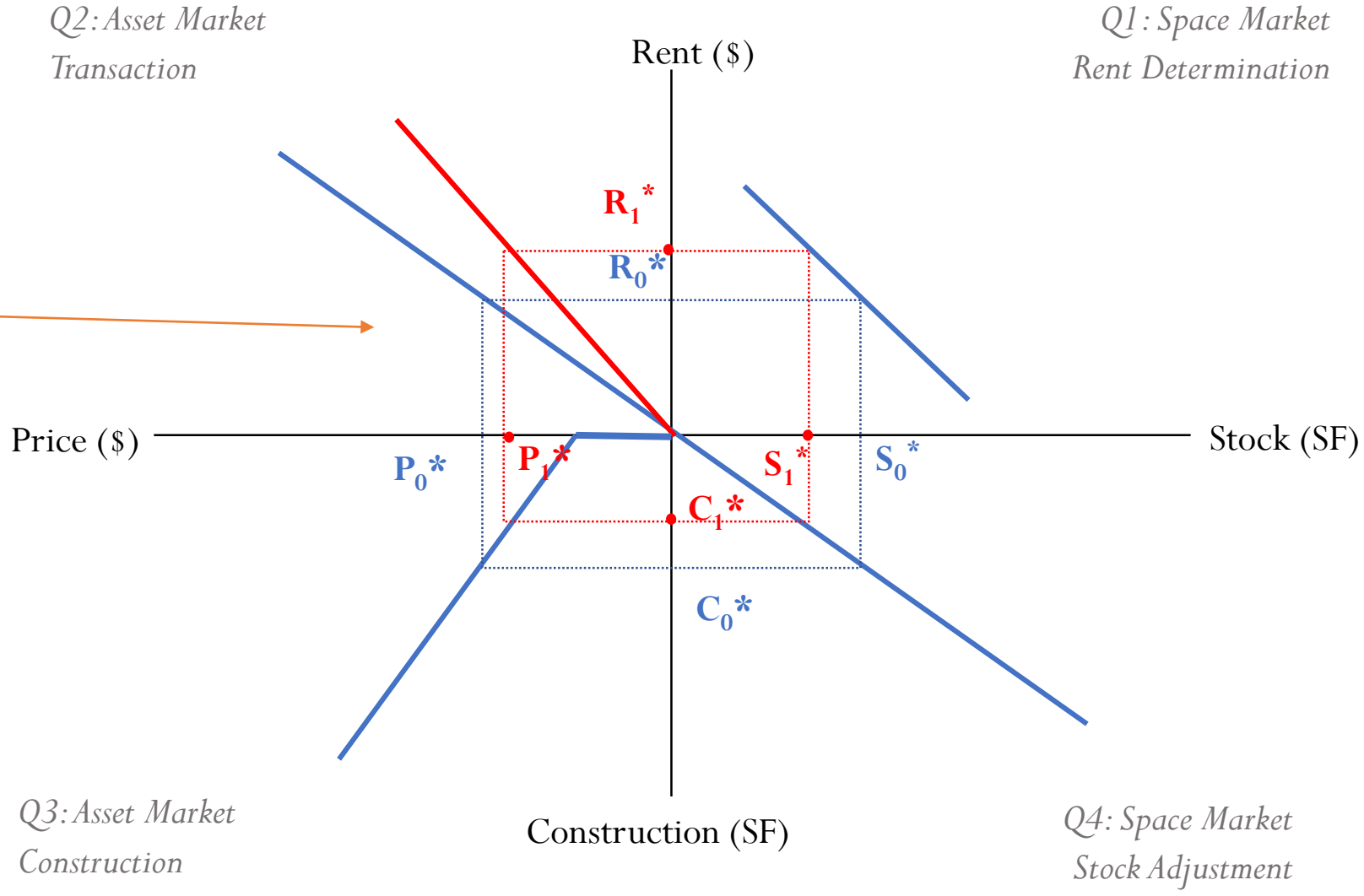
Estimated effects (in %) of a day with temperatures above 90 °F on output for each manufacturing subsector.



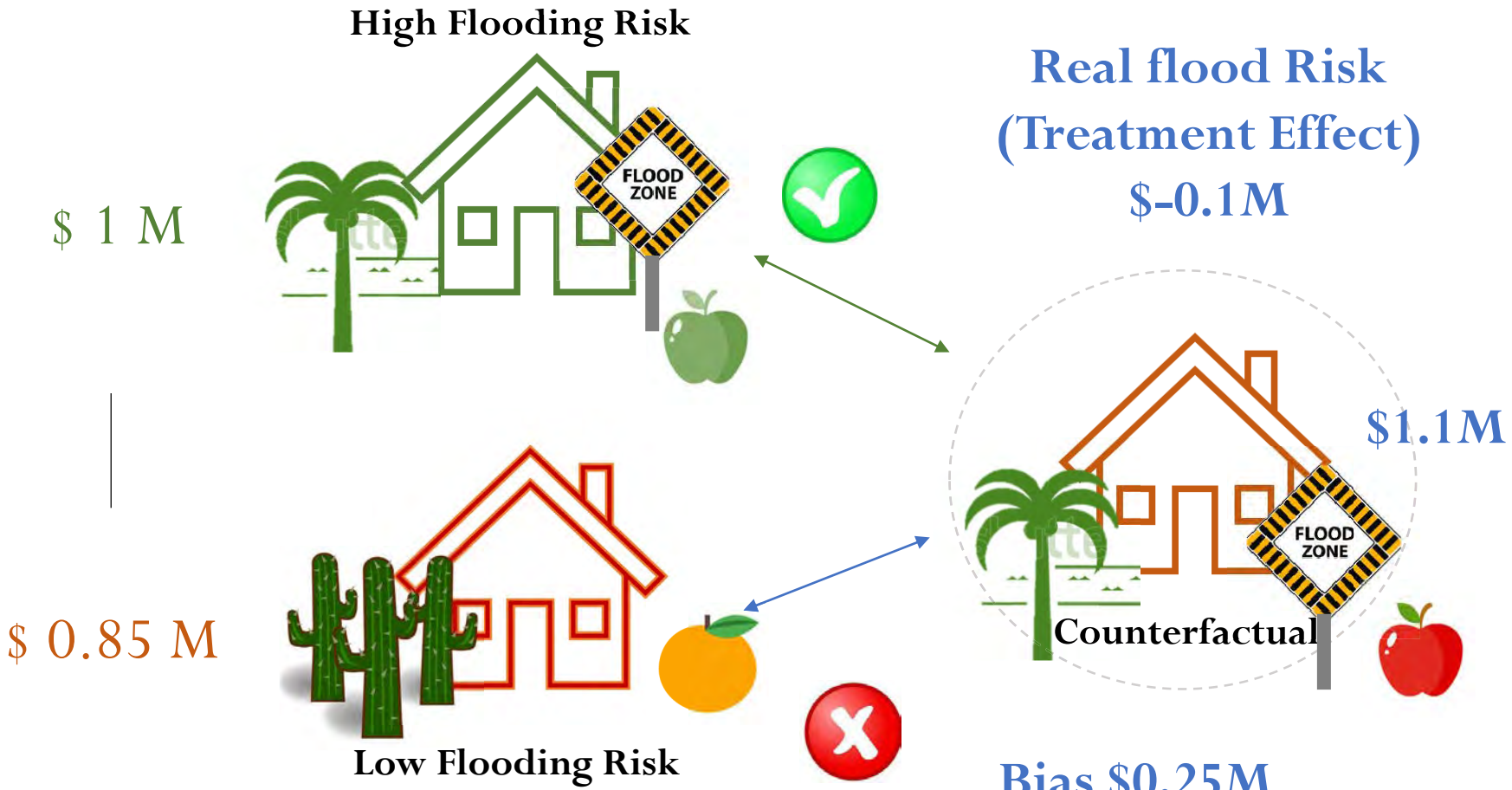
Source: Zhang, P., Deschenes, O., Meng, K., & Zhang, J. (2018). Temperature effects on productivity and factor reallocation: Evidence from a half million Chinese manufacturing plants. Journal of Environmental Economics and Management, 88, 1-17. Courtesy of Elsevier, Inc., https://www.sciencedirect.com. Used with permission.

Four Quadrant Model: Capital Markets

- Increase in asset level risk:
  - **Greater operating expenses due to increases in insurance costs and maintenance cots**
  - Greater awareness by investors and lenders on the risks associated with climate exposure
    (e.g., Task Force on Climate-related Financial Disclosures)



“Apple-to-Apple” Comparison in Flooding Risk Pricing



$ +0.15 M ← Naive flooding risk discount?

Adjustment in Risk Perception of Properties

- Data on the universe of property transactions from Florida, New Jersey, North Carolina, and South Carolina

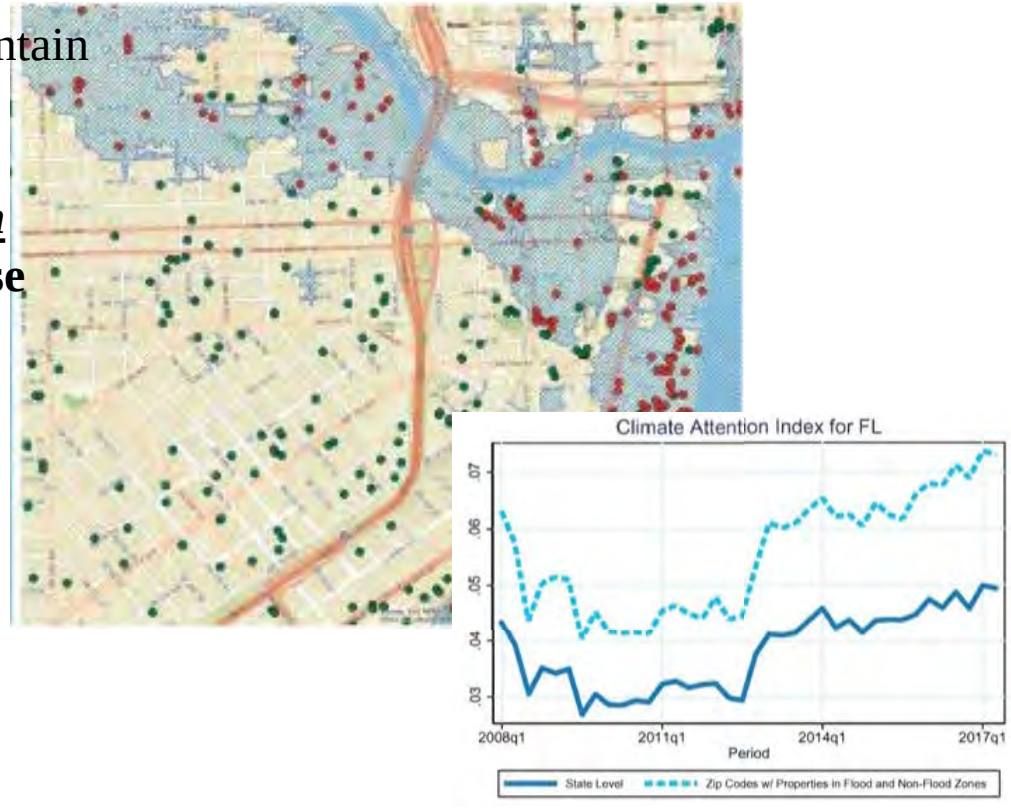
- Measuring submarket attention to flooding risk via "Climate Attention Index": proportion of for-sale listings with property descriptions that contain climate change risk works: "FEMA," "floodplain," and "flood risk."

- Hedonic price model estimating FEMA ***flood zones x Climate Attention Index*** to estimate price discounts associated with **sea level risk on house *prices (long term horizon) and rents (short term horizon)***

	Doubling attention to flood risk in flood zone
Changes in Prices	- 2.9%
Changes Rents	0%

$$\downarrow Property\ price = \frac{\cancel{NOI}}{Cap\ Rate\uparrow}$$

Figure showing properties in the FEMA flood zone (blue shaded area)



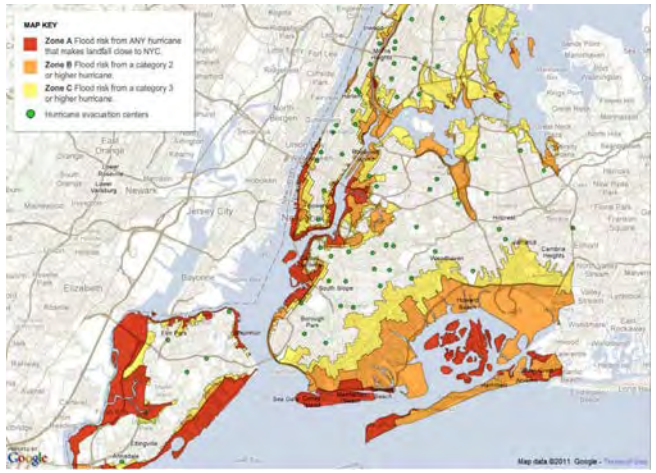
Source: Giglio, Stefano, et al. "Climate change and long-run discount rates: Evidence from real estate." *The Review of Financial Studies* 34.8 (2021): 3527-3571.

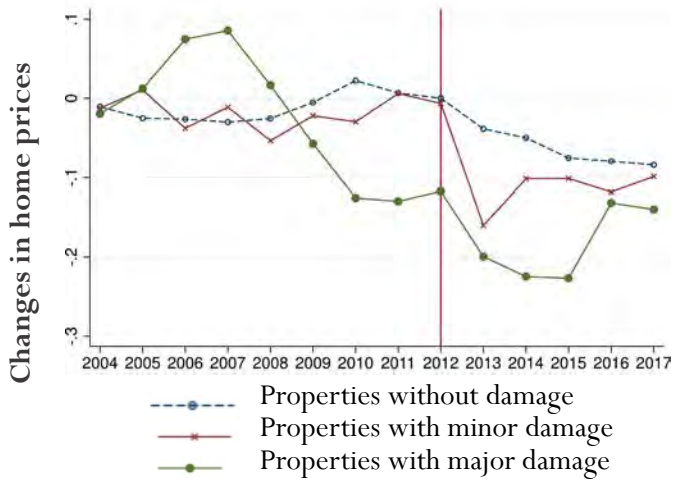
Learning from Hurricane Sandy: Adjustment in Risk Perception of Properties after Climate Disasters

- Hurricane Sandy (2012): a powerful hybrid (tropical/extratropical) cyclone, causing **the highest water level** in at least 300 years in the New York City metropolitan area:
  - Damages amounting to over $19 billion

- Estimation price discounts after hurricane Sandy:
  - **Discounts from 17% to 22%** in properties that suffered ***damage***, that gradually rebounded to ~9% discount as repairs took place
  - Persistent drops in prices by about **9% in flood zones** among properties that suffered ***no damage***
  - Why?
    - Sandy may have led to a change in **beliefs**: increase probability of massive flooding events, reducing the willingness to pay for living in flood-prone areas

Hurricane Flood Risk Zones in NYC





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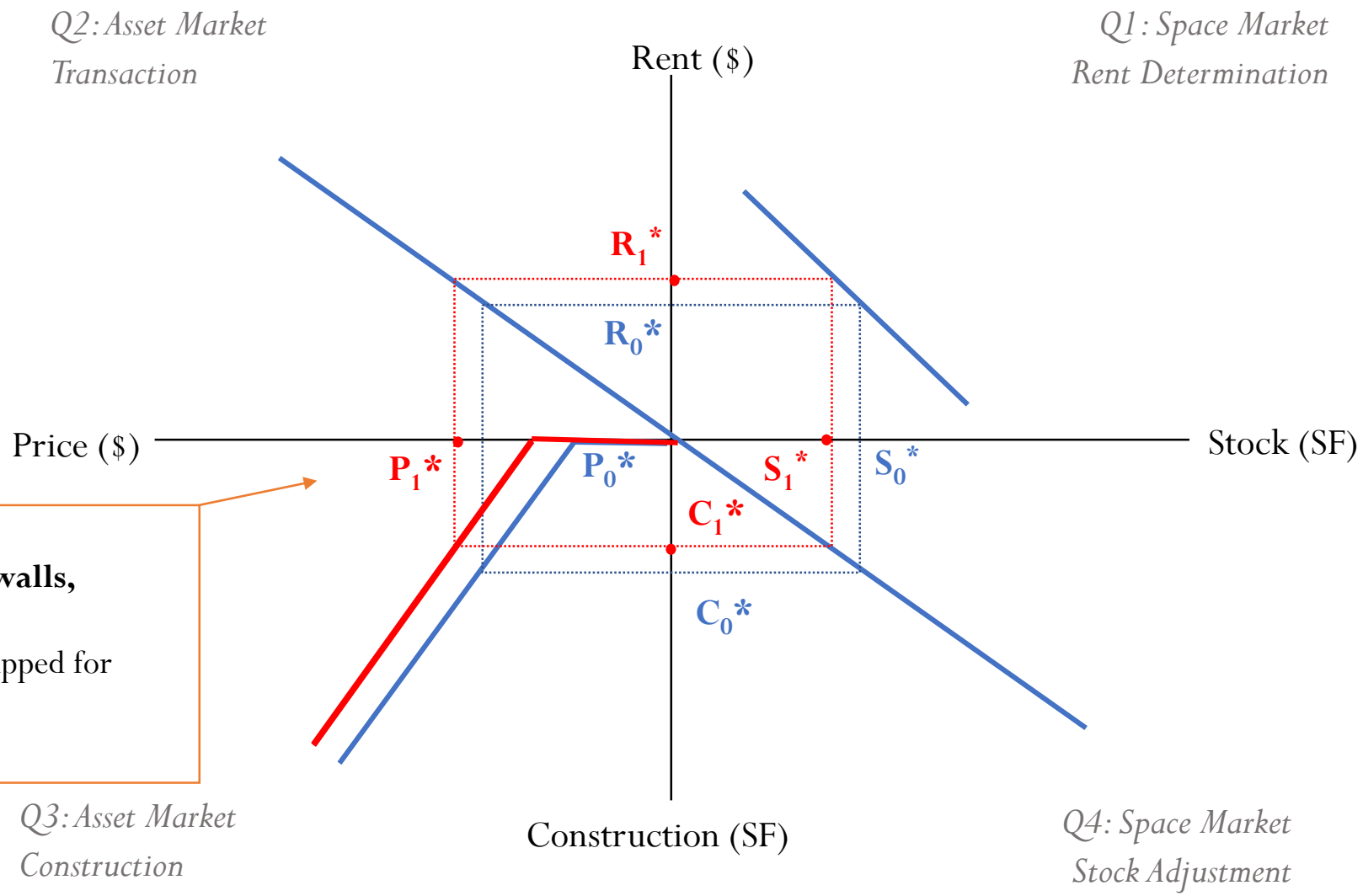
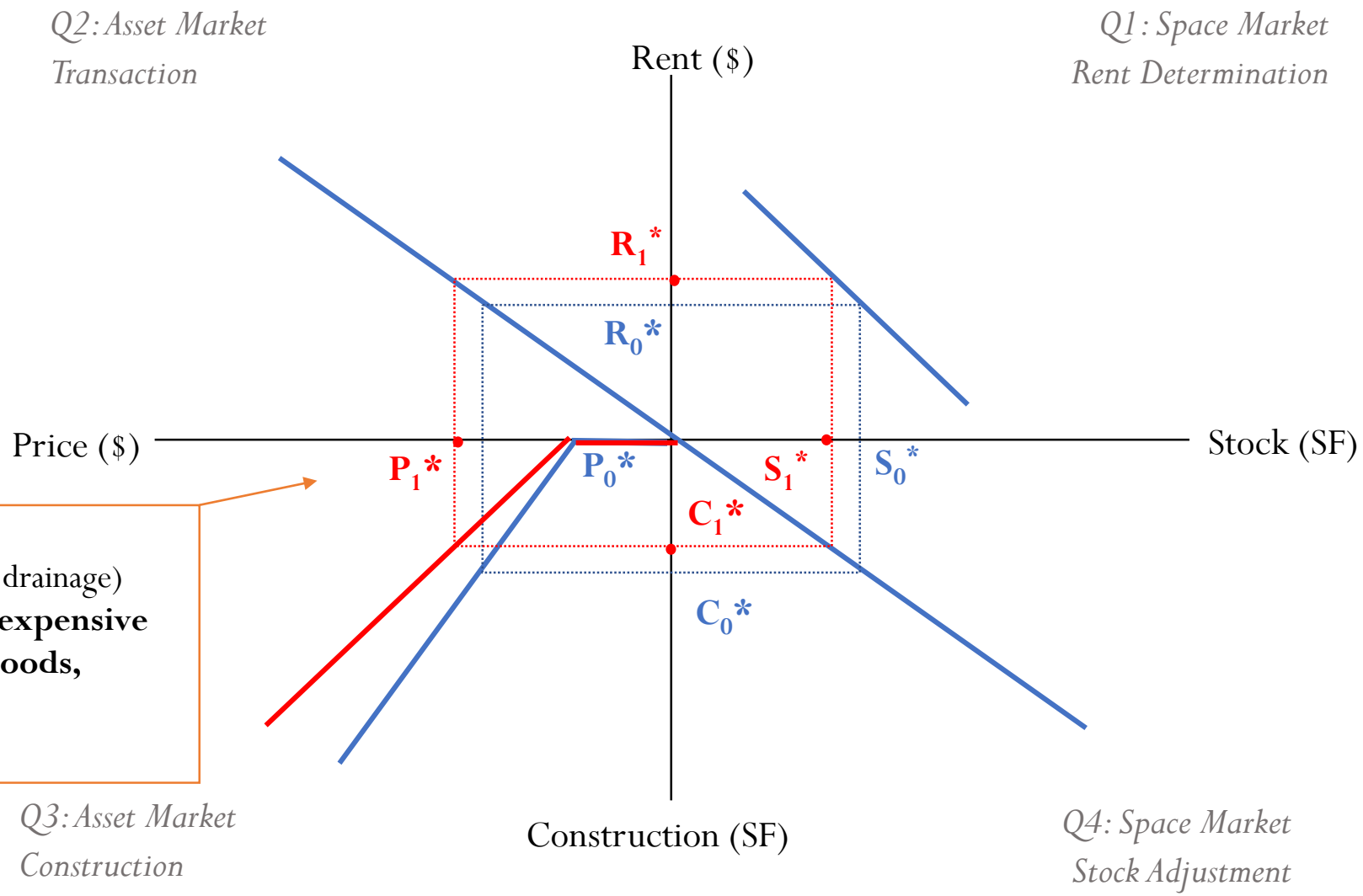
Source: Ortega, F. and Taşpınar, S., 2018. Rising sea levels and sinking property values: Hurricane Sandy and New York's housing market. *Journal of Urban Economics*, *106*, pp.81-100. Courtesy of Elsevier, Inc., https://www.sciencedirect.com. Used with permission.

Impact of Climate on Development Market



- Increase in cost of construction:
  - **Greater site remediation (flood walls, drainage)**
  - More expensive materials (better equipped for floods, storms, wildfires, etc.)

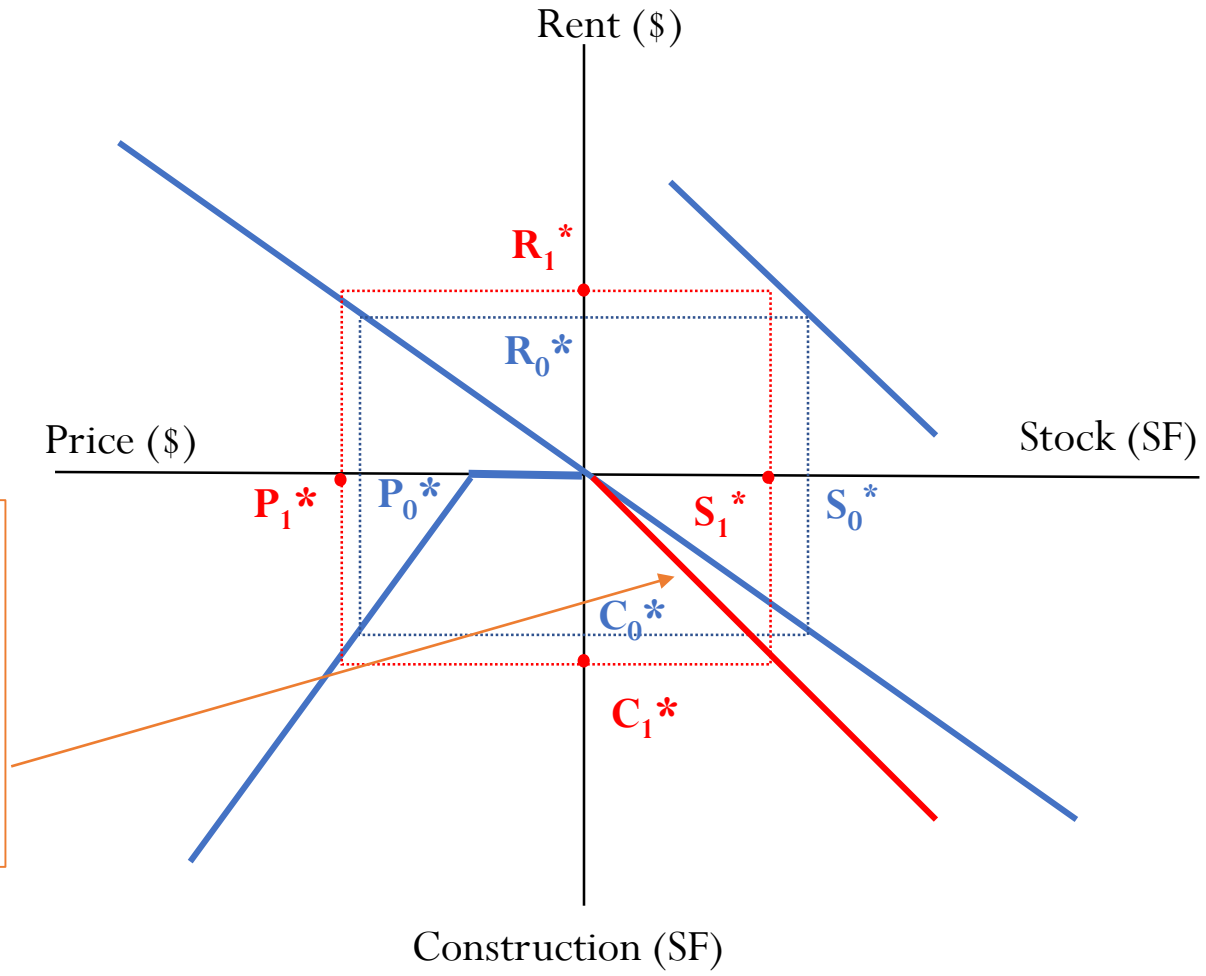
Impact of Climate on Development Market



- Increase in cost of construction:
  - Greater site remediation (flood walls, drainage)
  - **Supply chain disruptions: More expensive materials (better equipped for floods, storms, wildfires, etc.)**

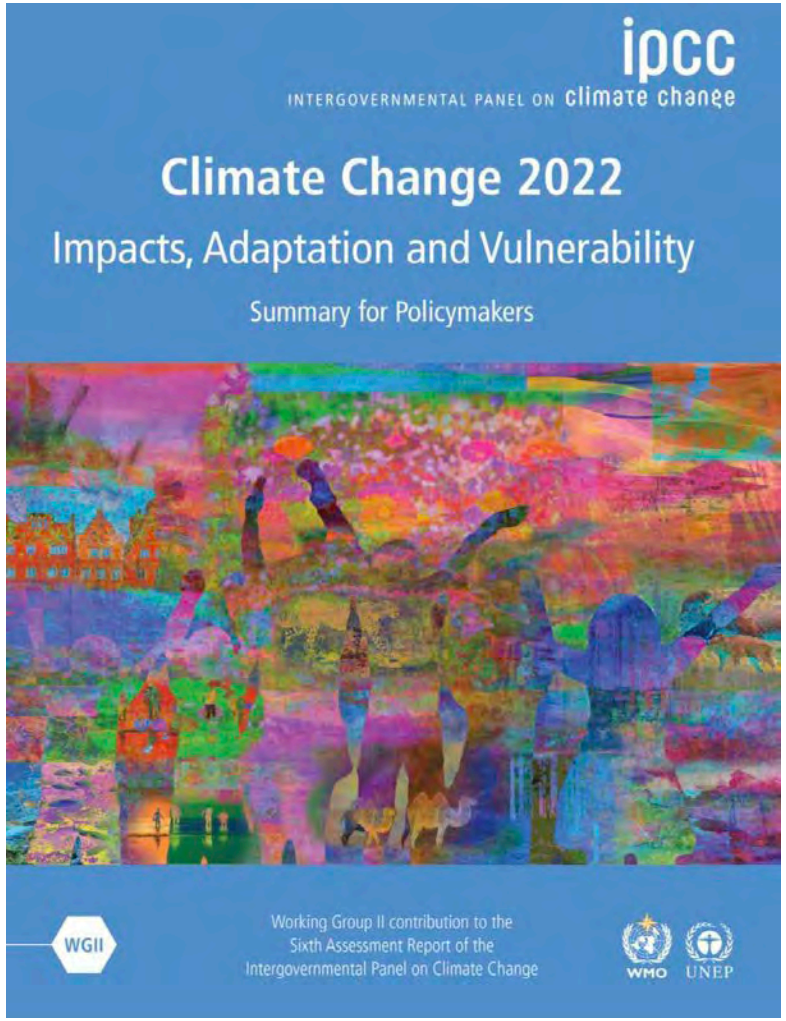
Depreciation: Impact of Climate on Supply of Assets

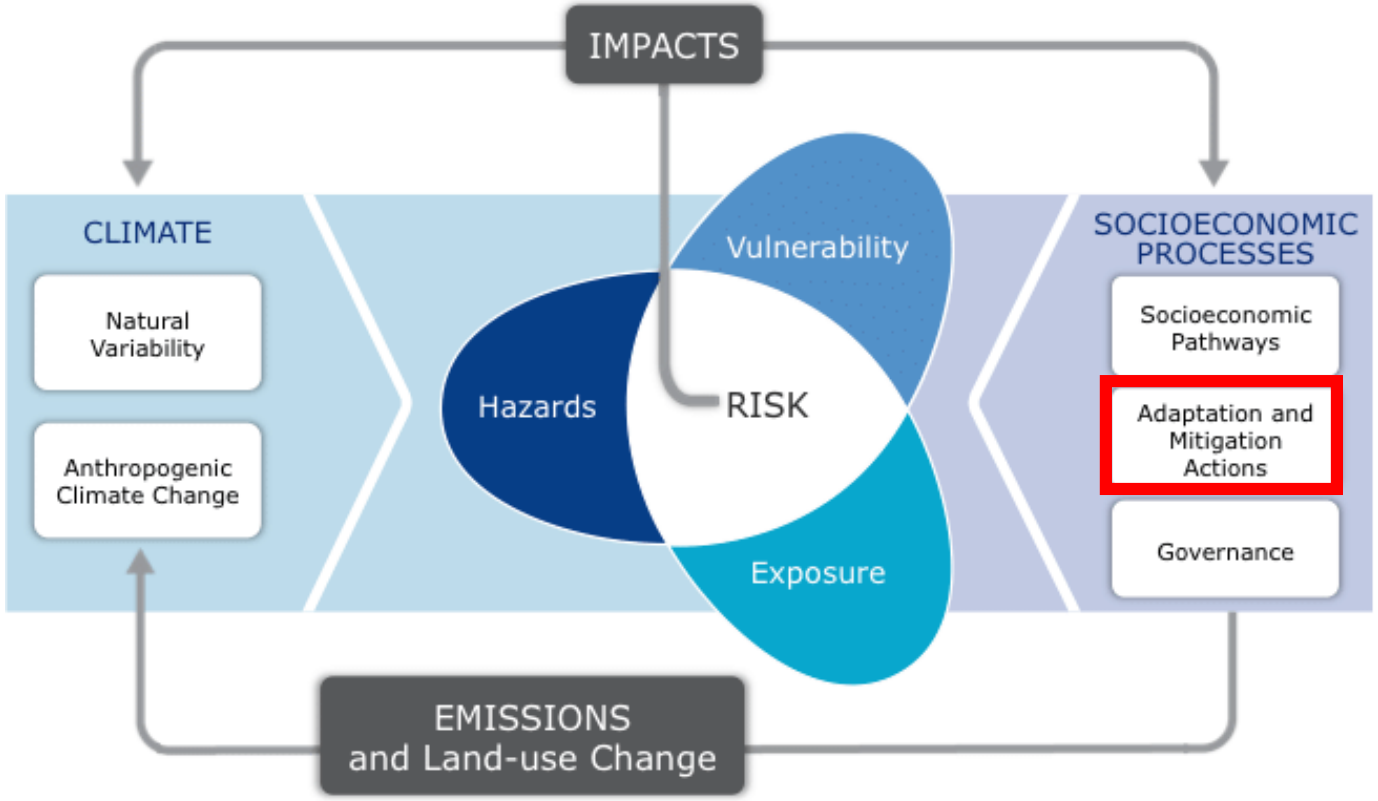
- Climate change shrinks the probability that the infrastructure and the land survive each year:
  - Build less-durable capital
  - In equilibrium, any particular building will spend less time in the maintained state after climate change
  - This results in higher stock depreciation



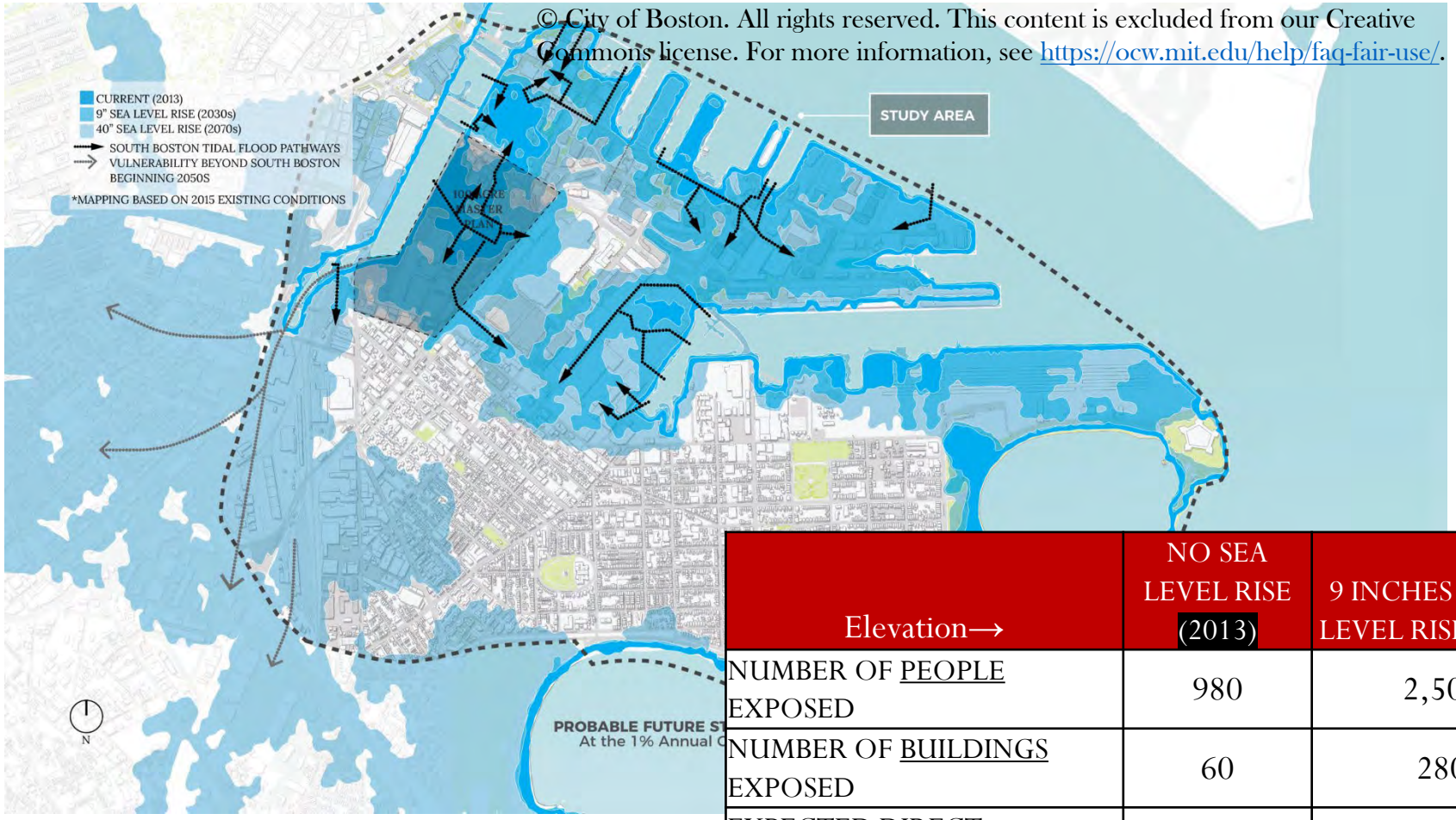
Source: Bunten, D. and Kahn, M.E., 2017. Optimal real estate capital durability and localized climate change disaster risk. *Journal of Housing Economics*, *36*, pp.1-7

Climate Resilience: Adapting to Climate Change





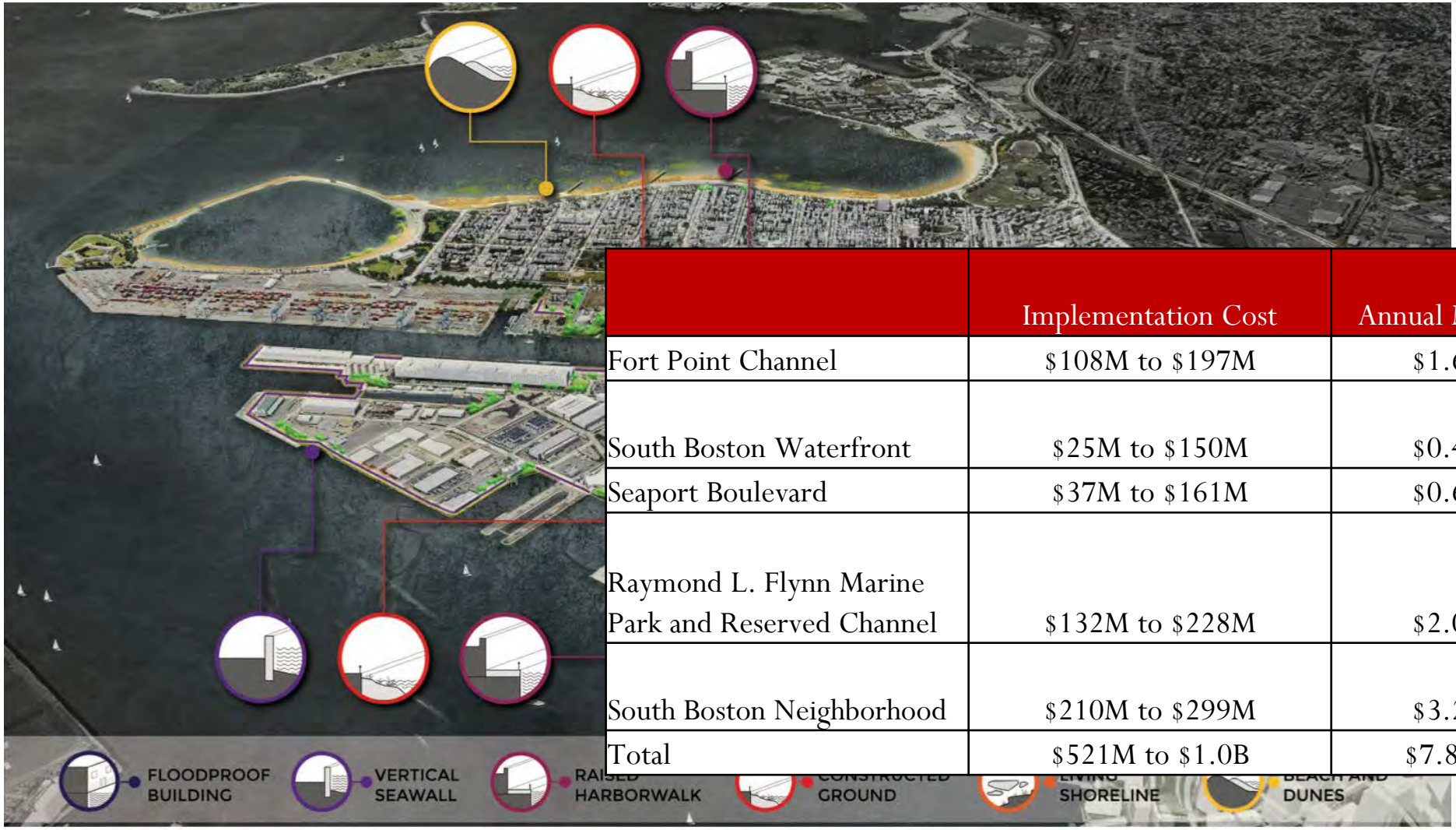
Climate Resilience: Seaport Boston Risks



Elevation→	NO SEA LEVEL RISE (2013)	9 INCHES OF SEA LEVEL RISE (2030s)	21 INCHES OF SEA LEVEL RISE (2050s)	40 INCHES OF SEA LEVEL RISE (2070s)
NUMBER OF PEOPLE EXPOSED	980	2,500	7,300	40,200
NUMBER OF BUILDINGS EXPOSED	60	280	920	5,140
EXPECTED DIRECT PHYSICAL DAMAGES & RELOCATION COSTS	$140 million	$1.2 billion	$2.8 billion	$8.1 billion

Source: City of Boston (2018). Coastal resilience solutions for Boston

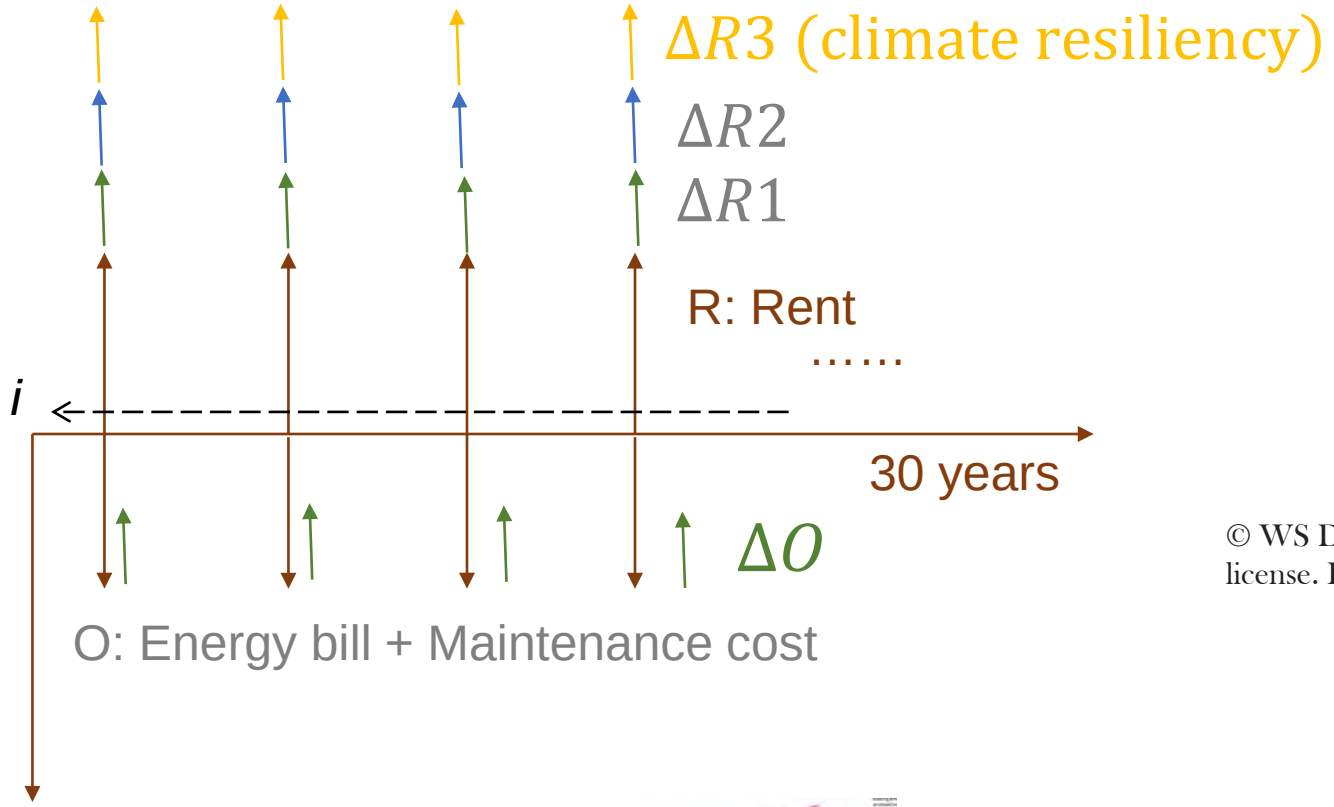
Climate Resilience: Seaport Boston (Costly) Investments



	Implementation Cost	Annual Maintenance Cost
Fort Point Channel	$108M to $197M	$1.6M to $3.0M
South Boston Waterfront	$25M to $150M	$0.4M to $2.3M
Seaport Boulevard	$37M to $161M	$0.6M to $2.4M
Raymond L. Flynn Marine Park and Reserved Channel	$132M to $228M	$2.0M to $3.4M
South Boston Neighborhood	$210M to $299M	$3.2M to $4.5M
Total	$521M to $1.0B	$7.8M to $15.2M

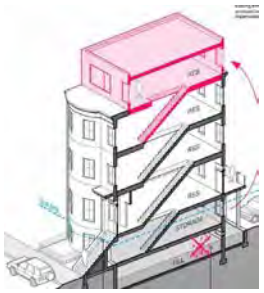
Source: City of Boston (2018). Coastal resilience solutions for Boston

Decision Making for Climate Resilience Investments



[Image: courtesy of Boston Seaport by WS Develop ment]

$$\sum_{t=o}^{T} NPV_i(\Delta R3) > \Delta V3$$

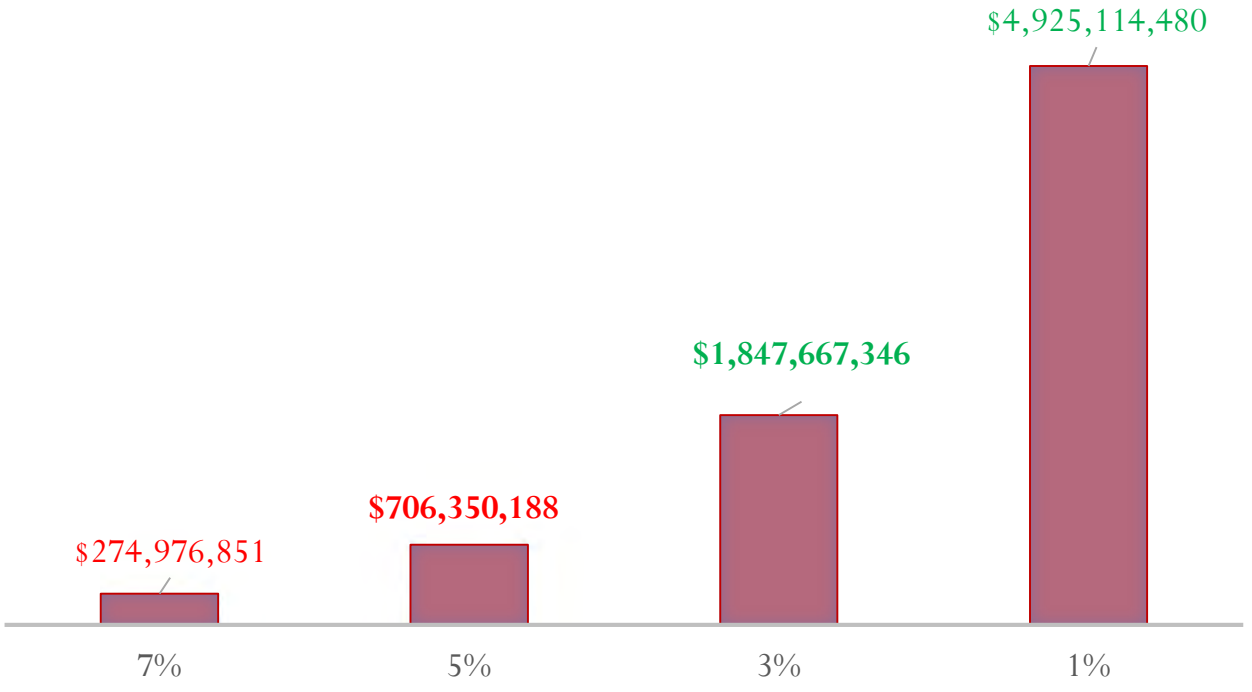


1. Profits occurring in very long term (60 years, 100 years,…)

2. Profits are uncertain (i.e. likelihood hurricane hitting Boston,…), based on climate model predictions

Discounting Climate Risk: Case Seaport in Boston

- As an example, assume that an investment to avoid flooding costs $1 billion, and is expected to avoid environmental damages worth $8.1 billion in 50 years.
    - At a discount rate of 3%, the present value of those damages is $1.8 billion and the project seems appealing.
    - At a 5%, the present value of the investment drops by an order of magnitude to $700 million, and the project no longer appears attractive.
- Long run discount rates observed in housing markets are around 2.6% (Giglio et al., 2021)



Sources: (1) City of Boston (2018). Coastal resilience solutions for Boston
(2) Giglio, Stefano, et al. "Climate change and long-run discount rates: Evidence from real estate." *The Review of Financial Studies* 34.8 (2021): 3527-3571.

Lecture

Climate Risk and Real Estate Markets

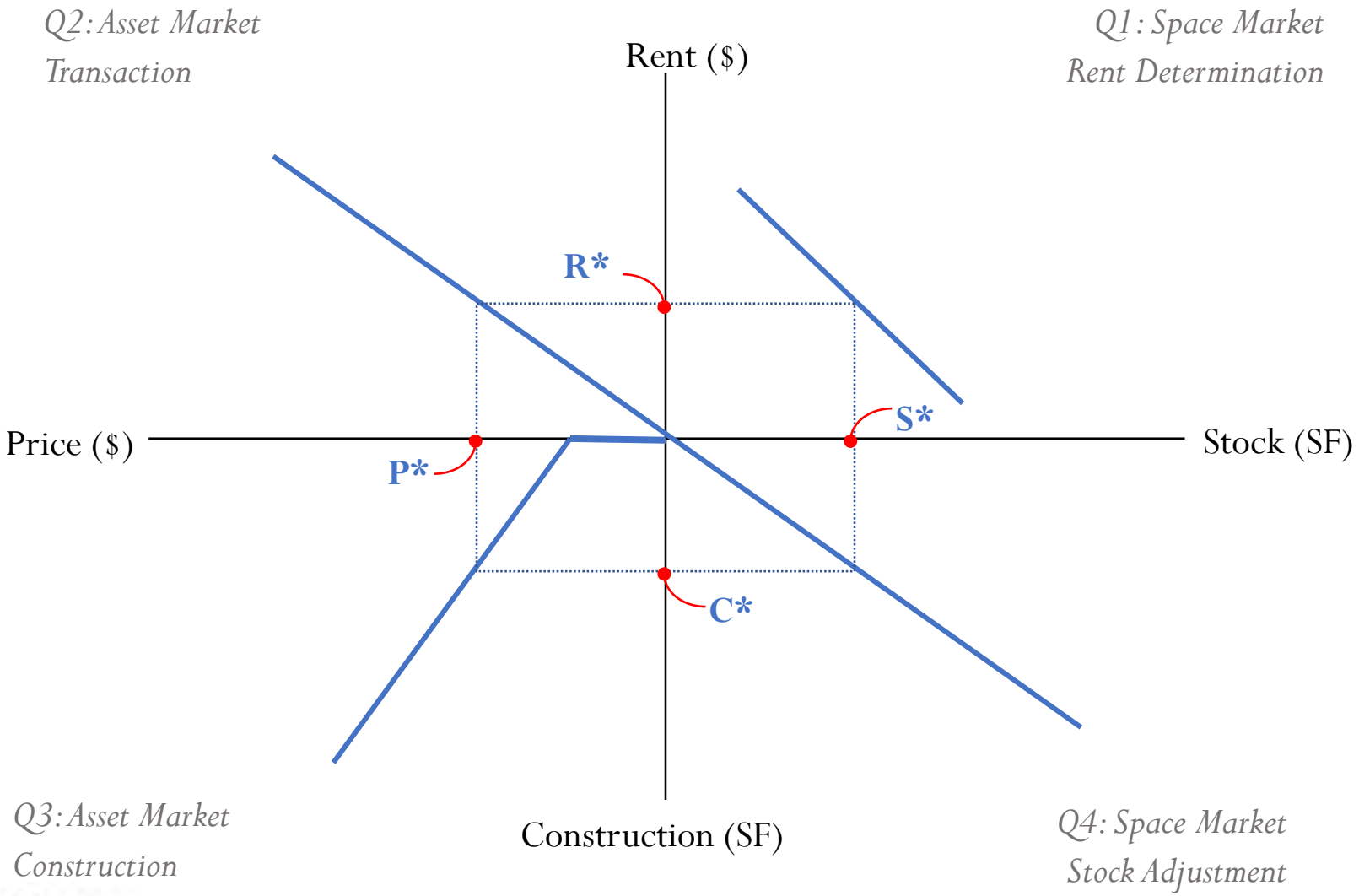
Understanding the basic impacts of climate change on real estate markets

Juan Palacios

March 2023

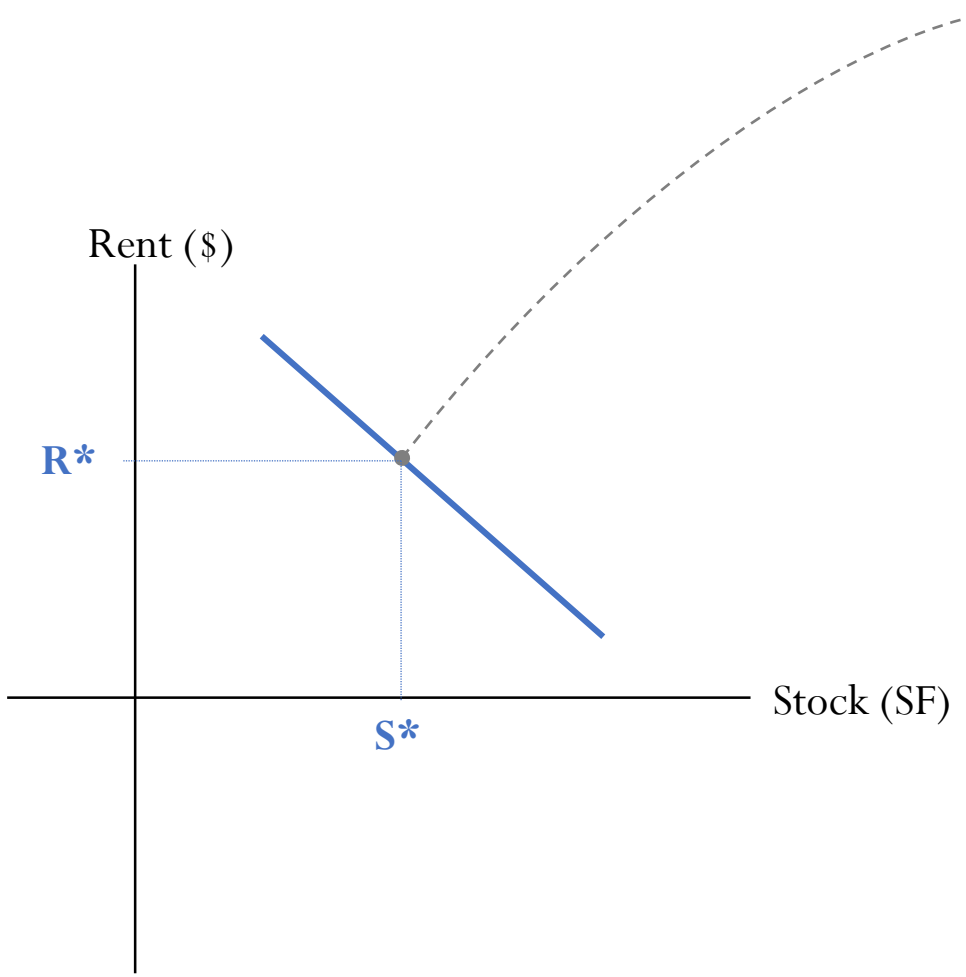
(MIT Center for Real Estate)

Four Quadrant Model



Geltner, D., Miller, N.G., Clayton, J. and Eichholtz, P., 2001. Chapter 2. *Commercial real estate analysis and investments* (Vol. 1, p. 642). Cincinnati, OH: South-western

The Space Market: Demand Effects



Tenant **demand** for space is a function of:

- Rent per square meter (changes within demand curve)
- Willingness to pay (WTP): Desirability (shifts in position of demand curve)
  - Changes in quality of housing amenities (proximity to work, quality of schools, parks, restaurants, neighbors, etc.)
  - Changes in demographics
  - Changes in preferences for assets
  - …

In the short term, supply is fixed at a pre-existing stock, S* resulting in rent at R*

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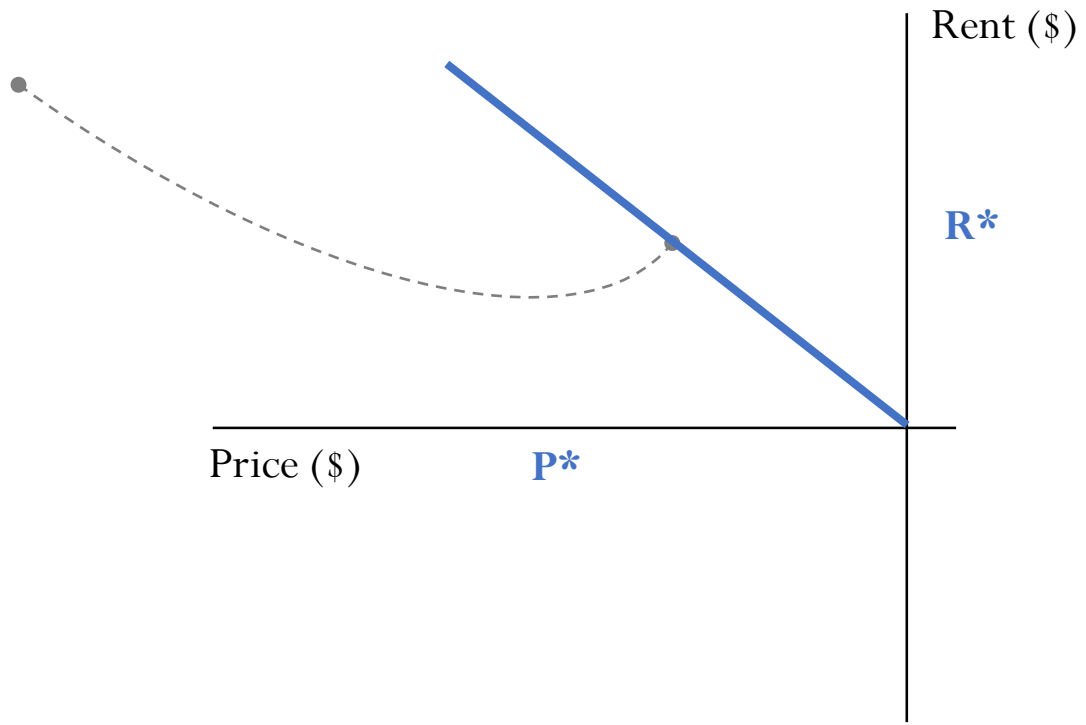
The Asset Market: Owners

Investor **demand** for real estate assets is a function of:

- Net operating income (NOI)
  - Rent (changes along the line)
  - Occupancy
  - Operating expense
- Lenders: Access to capital and cost of capital
- Investor appetite for risk: Cap rate (required rate of return for a particular asset)
  - Asset specific risk (volatility and correlation with market)

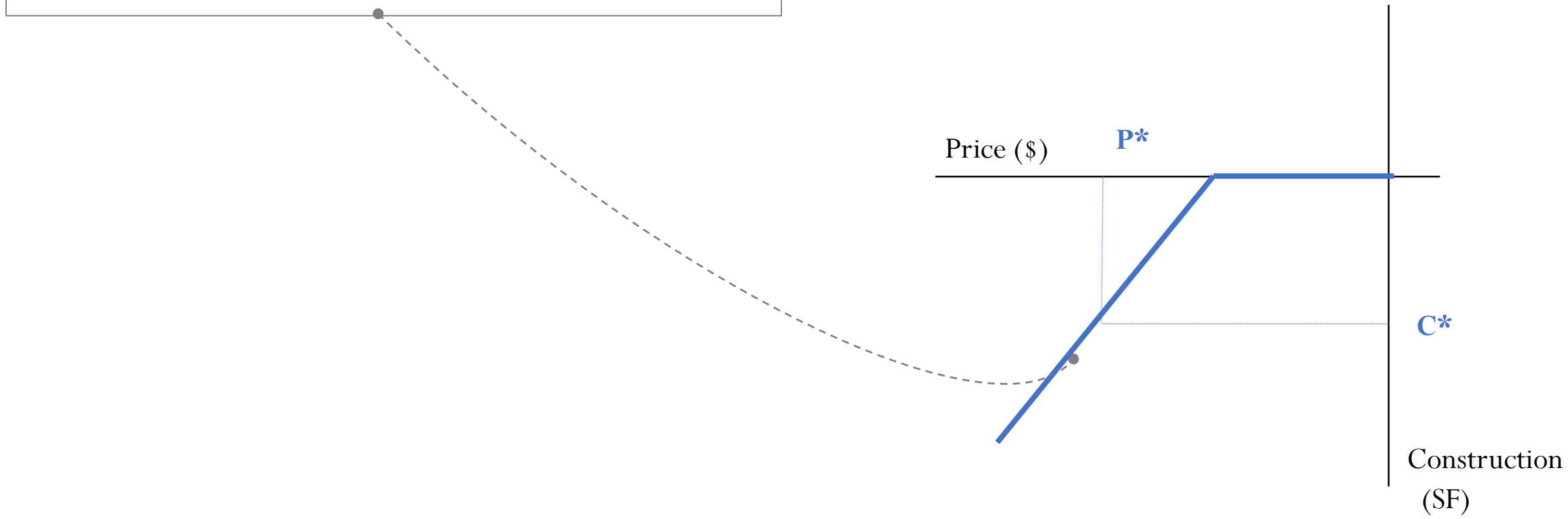
$$Property\ price = \frac{NOI}{Cap\ Rate}$$



Geltner, D., Miller, N.G., Clayton, J. and Eichholtz, P., 2001. Chapter 2. *Commercial real estate analysis and investments* (Vol. 1, p. 642). Cincinnati, OH: South-western

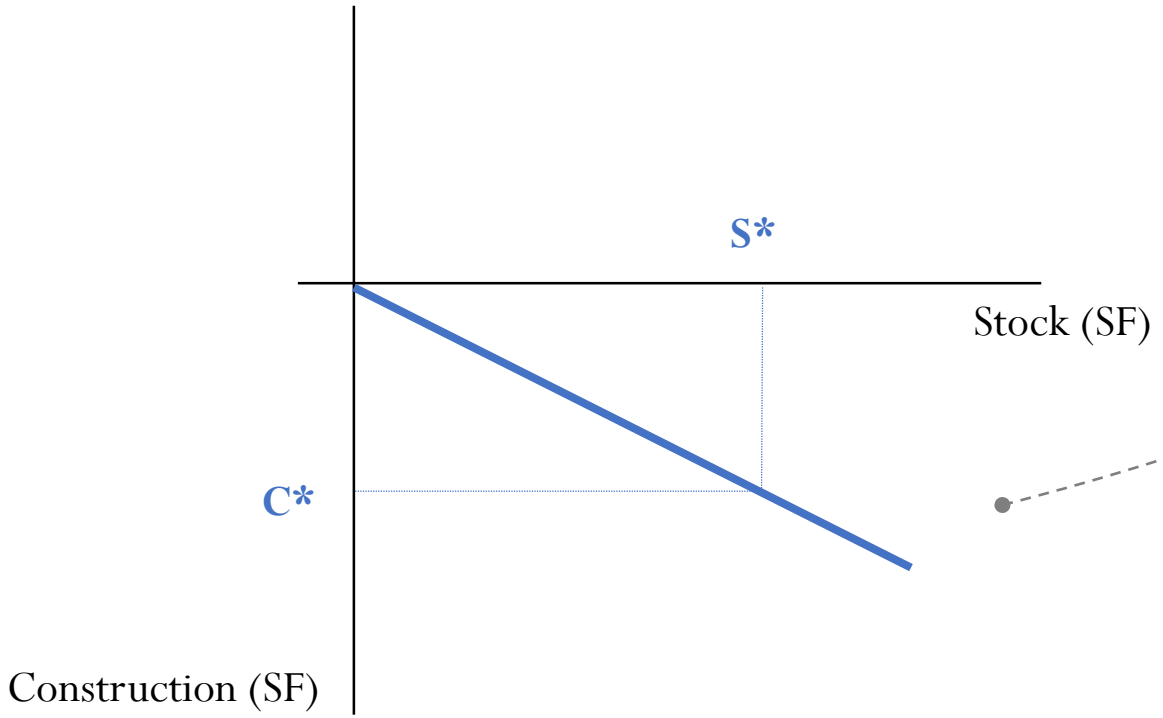
The Asset Market: New Construction

- New construction:
  - Site acquisition
  - Construction Costs



Geltner, D., Miller, N.G., Clayton, J. and Eichholtz, P., 2001. Chapter 2. *Commercial real estate analysis and investments* (Vol. 1, p. 642). Cincinnati, OH: South-western

The Asset Market: Stock Adjustment



- Depreciation of building stock:
  - In the long run, in the absence of new construction, older space will be removed from the market (i.e., depreciation):
    - Abandoned
    - Demolished
    - Repurposed to other usages
  - In the long term, a certain amount of construction is necessary to maintain the stock in the long run

Geltner, D., Miller, N.G., Clayton, J. and Eichholtz, P., 2001. Chapter 2. *Commercial real estate analysis and investments* (Vol. 1, p. 642). Cincinnati, OH: South-western