Does Climate Change Affect Investment Performance?

Evidence From Commercial Real Estate

Dragana Cvijanović & Alex Van de Minne

UCONN

Introduction (1/2)

- How large is the Commercial Real Estate (CRE) market?
  - Total value of CRE in the US: $16T (Nareit, 2018 estimate)
  - Total mortgage debt on CRE: $4T (Mortgage Banking Association, 2021 estimate)
  - Banks own approximately 1/4 of all mortgage debt, and pension funds invest about $800B in direct real estate.
- Given the importance and size of CRE, it is somewhat surprising that we know very little on the effect of climate on CRE.
- One of the reasons the U.S. pulled out of the Paris accord, was that fighting climate change would hurt businesses. However, how climate change will affect businesses was not addressed. This is the gap we wish to fill in this debate.

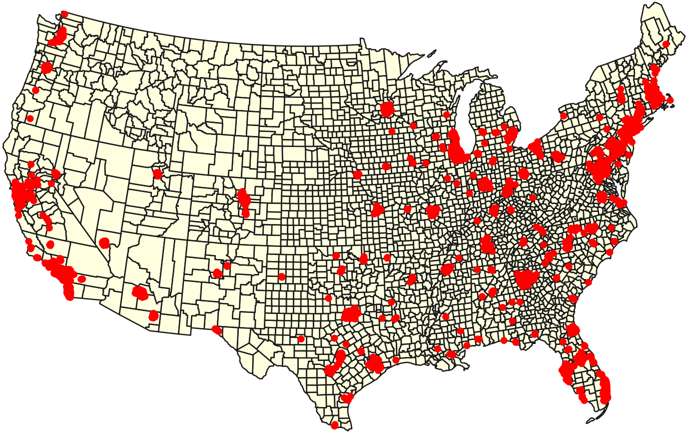
Introduction (2/2)

- To achieve this, we regress total returns on extreme temperature and precipitation in a (total return) repeat sales framework (Geltner & Goetzmann, 2000 JREFE).
- For the definition of extreme temperature, we follow Addoum et al. (2020, RFS), and take the number of days during the holding period that the high (low) temperature was above (below) 30°C (0°C). This is equivalent to 86°F and 32°F, respectively.
- Our data also allows to disentangle the total return into its components: Net Income and Asset. Where net income consists of (1) Income (i.e. rent) - (2) OpEx - (3) CapEx.

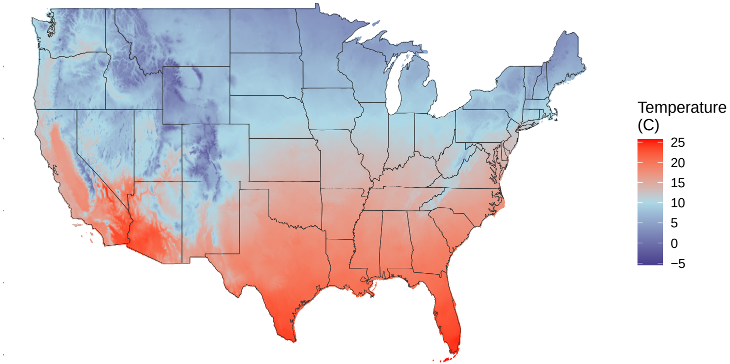
A Tale of Two Datasets

- **NCREIF data:**
  - The National Council of Real Estate Fiduciaries (NCREIF) collects very detailed property level data.
  - This includes data on: Rental income, OpEx, CapEx, sales prices (and appraisals), holding period, as well as the address of properties.
  - We use the addresses to geo-code the data.
  - The data is quarterly and reported between 1980 and 2020.
- **PRISM data:**
  - We obtain daily temperature and precipitation data from the PRISM Climate Group between 1980 and 2020.
  - The PRISM data capture the daily mean ($= (\text{min} + \text{max})/2$), minimum, and maximum temperature, as well as level of precipitation in mm, in each of 481,631 16-sq-km (or 4×4 km) grids covering the continental United States.
  - We merge this data with NCREIF to obtain measures like the # of days during the holding period that were over 30°C, etc.

Location of Properties



Mean temperature between 1980 and 2010.



Descriptive Statistics

Statistic	N	Mean	St. Dev.	Min	Max
Total Return (%)	6,782	0.476	0.501	−0.857	3.239
- Asset Return (%)	6,782	0.179	0.389	−0.714	1.881
- Net Income Return (%)	6,782	0.296	0.264	−0.445	1.384
- Income Return (%)	6,172	0.608	0.496	−0.019	8.496
- Operating Expenses (%)	6,178	0.266	0.319	−0.088	6.939
- Capital Expenditures (%)	6,782	0.116	0.150	−0.797	1.937
Holding period (years)	6,782	5.598	3.356	2	25
Temperature (°C)	6,782	15.629	4.503	5.197	25.650
Temperature over 30°C (%)	6,782	0.200	0.141	0.000	0.655
Temperature below 0°C (%)	6,782	0.150	0.138	0.000	0.541
Precipitation (mm)	6,782	2.594	1.155	0.046	5.620
Distance to centroid (m)	6,782	1,631	606	36	3,005
Property Types					
Apartment	1,917				
Hotel	172				
Industrial	2,127				
Office	1,744				
Retail	822				

Total Return Repeat Sales

- We use the following total return repeat sales model;

$$TotalReturn_{i,m,j,t,s} = \mu_{m,t,s} + \theta_{j,t,s} + \epsilon_{i,m,j,t,s},$$

- where

$$TotalReturn_{i,t,s} = \underbrace{\frac{V_{i,t} - V_{i,s}}{V_{i,s}}}_{\text{Asset return}} + \underbrace{\frac{\sum_s^t CF_{i,s,t}}{V_{i,s}}}_{\text{Net Income return}} .$$

  - μ percentage price level difference in MSA m between the buy (s) and sale (t),
  - θ percentage price level difference in property type j between the buy (s) and sale (t),
  - ϵ is residual, which we assume has mean zero and is normally distributed with standard error σ_ϵ.
- The "differenced" selection matrices (μ and θ) have value -1 at time of buy, 1 at time of sale, and zero otherwise.

Adding Temperature Variables

- Next, we add our temperature variables to the total return repeat sales model as such;

$$TotalReturn_{i,m,j,t,s} = \underbrace{\beta T_{q,i,t,s}}_{\text{Added temp. variables}} + \mu_{m,t,s} + \theta_{j,t,s} + \epsilon_{i,m,j,t,s},$$

- where:

$$T_{q,i,t,s} = \left\{ \frac{\#\text{ days} > 30^{\circ}\text{C}_{q,i,t,s}}{365\text{ days}}, \frac{\#\text{ days} < 0^{\circ}\text{C}_{q,i,t,s}}{365\text{ days}}, \text{Total precipitation}_{q,i,t,s} \right\}$$

- The interpretation is as follows: For every year that a property was held while the temperature was above (below) 30°C (0°C) the total return changes by β.
- We identify the effect within year, MSA and within property types. However, note that the repeat sales model is essentially the same model in level, but with a property fixed effect, meaning we also look within property.
- We cluster standard errors by: MSA $\times$ year sold.

Effect Total Returns

	Dependent variable:				
	Dependent variable: Total Return (%)				
	(1)	(2)	(3)	(4)	(5)
Temp over 30°C	0.056***	−0.036***	−0.054***	−0.057***	−0.071***
	(0.012)	(0.011)	(0.010)	(0.019)	(0.027)
Temp below 0°C	0.025*	−0.057***	−0.057***	−0.079***	−0.125***
	(0.014)	(0.012)	(0.010)	(0.022)	(0.039)
Precipitation (mm)	0.009***	−0.001	−0.003**	0.002	−0.003
	(0.002)	(0.001)	(0.001)	(0.002)	(0.004)
Constant	0.264***	0.086***	0.061***	0.058***	0.044***
	(0.021)	(0.014)	(0.013)	(0.012)	(0.013)
Year FE	no	yes	no	no	no
Year × PT FE	no	no	yes	yes	yes
Year × DIV FE	no	no	no	yes	no
Year × MSA FE	no	no	no	no	yes
Observations	6,782	6,782	6,782	6,782	6,782
R^2	0.090	0.355	0.440	0.502	0.619
Adjusted R^2	0.089	0.350	0.425	0.469	0.517
Residual Std. Error	0.478	0.404	0.380	0.365	0.348

Effect on Asset Returns

	Dependent variable:				
	Asset Return (%)				
	(1)	(2)	(3)	(4)	(5)
Temp over 30°C	−0.007	−0.036***	−0.048***	−0.063***	−0.079***
	(0.010)	(0.010)	(0.009)	(0.017)	(0.023)
Temp below 0°C	−0.041***	−0.067***	−0.066***	−0.091***	−0.149***
	(0.011)	(0.010)	(0.009)	(0.021)	(0.031)
Precipitation (mm)	0.002*	−0.001	−0.002**	0.001	−0.002
	(0.001)	(0.001)	(0.001)	(0.002)	(0.004)
Constant	0.190***	0.098***	0.082***	0.081***	0.071***
	(0.017)	(0.012)	(0.011)	(0.010)	(0.011)
Year FE	no	yes	no	no	no
Year × PT FE	no	no	yes	yes	yes
Year × DIV FE	no	no	no	yes	no
Year × MSA FE	no	no	no	no	yes
Observations	6,782	6,782	6,782	6,782	6,782
R^2	0.008	0.206	0.294	0.368	0.514
Adjusted R^2	0.007	0.201	0.275	0.325	0.384
Residual Std. Error	0.388	0.348	0.331	0.320	0.305

Effect on Income Return

	Dependent variable:				
	Net Income Return (%)				
	(1)	(2)	(3)	(4)	(5)
Temp over 30°C	0.064***	0.0002	−0.005	0.007	0.008
	(0.005)	(0.004)	(0.004)	(0.007)	(0.013)
Temp below 0°C	0.066***	0.010**	0.009**	0.011	0.024
	(0.006)	(0.004)	(0.004)	(0.008)	(0.016)
Precipitation (mm)	0.007***	−0.0002	−0.001	0.001	−0.0003
	(0.001)	(0.0005)	(0.0004)	(0.001)	(0.002)
Constant	0.074***	−0.012**	−0.021***	−0.023***	−0.027***
	(0.009)	(0.005)	(0.005)	(0.005)	(0.006)
Year FE	no	yes	no	no	no
Year × PT FE	no	no	yes	yes	yes
Year × DIV FE	no	no	no	yes	no
Year × MSA FE	no	no	no	no	yes
Observations	6,782	6,782	6,782	6,782	6,782
R^2	0.359	0.600	0.650	0.675	0.739
Adjusted R^2	0.359	0.598	0.640	0.653	0.670
Residual Std. Error	0.212	0.168	0.159	0.156	0.152

Breaking Down Net Income

	Dependent variable:		
	Income	OpEx	CapEx
	(1)	(2)	(3)
Temp over 30°C	−0.005	0.003	−0.006
	(0.018)	(0.016)	(0.009)
Temp below 0°C	−0.015	−0.019	−0.018*
	(0.019)	(0.015)	(0.010)
Precipitation (mm)	0.003	0.001	0.001
	(0.002)	(0.002)	(0.001)
Constant	−0.029***	−0.010	0.008*
	(0.009)	(0.007)	(0.004)
Year × PT FE	yes	yes	yes
Year × MSA FE	yes	yes	yes
Observations	6,172	6,178	6,782
R^2	0.845	0.815	0.541
Adjusted R^2	0.806	0.768	0.418
Residual Std. Error	0.218	0.154	0.114

What is Driving These Results?

- We find that sales prices drop in areas with temperature stress, but it is not caused by a drop in (free) cash flows.
- Next we will have a look at the following;
  - **Robustness.** Are the results robust when changing some of the specifications.
  - **Fundamentals... or not?** The results are clearly driven by discount rates. More specifically the risk premium. However, this does not explain why the risk premium goes up.
- Previous literature is inconclusive on whether temperature stress affects fundamentals or not.

Robustness Checks

- We run the following extra models to check if our results are robust;
  - We run a **Weighted Least Square model**. The weights are based in an initial stage on (1) the distance to the centroid of the 4x4 km grid, and (2) the holding period.
  - We run a **random effect model**, where every 4x4 km gets its own (random effects) trend. This to control for any left out unobserved heterogeneity.
  - **Net Asset Returns**. In this specification we subtract (sum of) the capital expenditures from the asset price appreciation during the holding. This gives the "actual" price appreciation net of the CapEx.
  - **Type of Buyer**. We take into account the buyer type of the real estate, local versus national, and private versus institutional.
- None of these specifications changed the results in a meaningful way.
  - We also run a model with **temperature as explanatory variable**, instead of the extremes. We find no significant results when regressing temperature itself on total returns.
  - We also find that the effect is more profound after 2000.

Capital Depletion?

	Dependent variable:				
	Insurance Return (%)				
	(1)	(2)	(3)	(4)	(5)
Temperature over 30°C	0.002***	−0.0002	0.001	0.002***	0.001
	(0.0004)	(0.0005)	(0.001)	(0.0005)	(0.001)
Temperature below 0°C	−0.002***	−0.004***	−0.002***	−0.002***	−0.003***
	(0.0004)	(0.0004)	(0.001)	(0.0004)	(0.001)
Precipitation (mm)	0.0003***	0.00002	−0.00004	−0.0001**	0.0001
	(0.00004)	(0.0001)	(0.0001)	(0.00005)	(0.0001)
Constant	0.006***	0.002***	0.001**	0.001***	0.0005
	(0.001)	(0.0004)	(0.0003)	(0.0003)	(0.0003)
Year FE	no	yes	no	no	no
Year × PT FE	no	no	yes	yes	yes
Year × DIV FE	no	no	no	yes	no
Year × MSA FE	no	no	no	no	yes
Observations	6,991	6,991	6,991	6,991	6,991
R^2	0.191	0.377	0.552	0.542	0.691
Adjusted R^2	0.191	0.373	0.545	0.516	0.624
RMSE	0.010	0.009	0.008	0.008	0.007

Effect on Appraisal Values

	Dependent variable:				
	Appraisal Return (%)				
	(1)	(2)	(3)	(4)	(5)
Temperature over 30°C	−0.007	−0.030***	−0.059***	−0.051***	−0.066***
	(0.008)	(0.008)	(0.016)	(0.007)	(0.015)
Temperature below 0°C	−0.028***	−0.047***	−0.074***	−0.059***	−0.103***
	(0.009)	(0.008)	(0.024)	(0.007)	(0.017)
Precipitation	0.003***	0.0004	−0.001	0.002*	−0.001
	(0.001)	(0.001)	(0.003)	(0.001)	(0.002)
Constant	0.100***	0.037***	0.021**	0.015	0.014
	(0.013)	(0.011)	(0.010)	(0.010)	(0.009)
Year FE	no	yes	no	no	no
Year × PT FE	no	no	yes	yes	yes
Year × DIV FE	no	no	no	yes	no
Year × MSA FE	no	no	no	no	yes
Observations	7,643	7,643	7,643	7,643	7,643
R^2	0.007	0.206	0.283	0.364	0.503
Adjusted R^2	0.007	0.202	0.274	0.326	0.388
RMSE	0.330	0.296	0.282	0.272	0.259

Effect on Standard Deviation of the Cash Flows

	Dependent variable:			
	SD(Income)	SD(OpEx)	SD(CapEx)	SD(Net Income)
	(1)	(2)	(3)	(4)
Temp over 30°C	0.012**	0.014	0.005	0.022**
	(0.005)	(0.010)	(0.003)	(0.010)
Temp below 0°C	0.017***	0.043***	0.008**	0.045***
	(0.006)	(0.012)	(0.003)	(0.012)
Precipitation (mm)	−0.001	0.0002	−0.001*	−0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Constant	0.024***	0.025***	0.013***	0.035***
	(0.002)	(0.003)	(0.001)	(0.004)
Year × PT FE	yes	yes	yes	yes
Year × MSA FE	yes	yes	yes	yes
Observations	6,172	6,552	6,178	6,782
R^2	0.639	0.297	0.536	0.304
Adjusted R^2	0.548	0.103	0.420	0.117
Residual Std. Error	0.020	0.054	0.015	0.055

Property type, Temperature over 30°C

	Dependent variable:					
	Total	Asset	Net Income =	Income -	OpEx -	CapEx
	(1)	(2)	(3)	(4)	(5)	(6)
Temp ≥ 30°C	−0.080***	−0.101***	0.021	0.007	0.004	−0.014
	(0.031)	(0.012)	(0.027)	(0.018)	(0.013)	(0.010)
Hotel	−0.021	0.046	−0.067	0.224*	0.256**	0.041**
	(0.062)	(0.028)	(0.048)	(0.127)	(0.107)	(0.020)
Industrial	0.039	0.045***	−0.007	−0.034**	−0.026***	0.002
	(0.024)	(0.009)	(0.021)	(0.014)	(0.010)	(0.008)
Office	−0.007	0.028***	−0.034	−0.020	0.004	0.015**
	(0.025)	(0.009)	(0.022)	(0.014)	(0.010)	(0.007)
Retail	0.012	0.012	−0.0005	−0.036**	−0.025**	−0.0004
	(0.038)	(0.019)	(0.030)	(0.016)	(0.012)	(0.012)
Observations	6,782	6,782	6,782	6,172	6,178	6,782
R^2	0.623	0.519	0.743	0.857	0.835	0.546
Adjusted R^2	0.521	0.388	0.673	0.820	0.793	0.423
RMSE	0.347	0.304	0.151	0.210	0.145	0.114

Property type, Temperature below 0°C

	Dependent variable:					
	Total	Asset	Net Income =	Income -	OpEx -	CapEx
	(1)	(2)	(3)	(4)	(5)	(6)
Temp ≤ 0°C	−0.096**	−0.129***	0.034	−0.031	−0.038**	−0.029***
	(0.043)	(0.016)	(0.036)	(0.021)	(0.016)	(0.010)
Hotel	−0.192	−0.123***	−0.069	−0.292*	−0.181	−0.031
	(0.080)	(0.038)	(0.059)	(0.159)	(0.140)	(0.022)
Industrial	−0.010	0.002	−0.012	0.021	0.018*	0.014
	(0.025)	(0.010)	(0.023)	(0.016)	(0.010)	(0.012)
Office	−0.056	−0.036***	−0.020	0.050***	0.052***	0.024***
	(0.026)	(0.010)	(0.023)	(0.017)	(0.012)	(0.008)
Retail	−0.051	−0.040**	−0.011	0.014	0.015	0.014
	(0.036)	(0.016)	(0.030)	(0.017)	(0.012)	(0.012)
Observations	6,782	6,782	6,782	6,172	6,178	6,782
R^2	0.623	0.519	0.743	0.857	0.835	0.546
Adjusted R^2	0.521	0.388	0.673	0.820	0.793	0.423
RMSE	0.347	0.304	0.151	0.210	0.145	0.114

Adaption Levels

	Dependent variable:	
	Asset returns (%)	
c	T $\geq$ 30°C $\times(\bar{T}_m \geq c)$	T $\leq$ 0°C $\times(\bar{T}_m < c)$
14°C	-0.063***	-0.195***
15°C	-0.047***	-0.183***
16°C	-0.051**	-0.167***
17°C	-0.043*	-0.166***
18°C	-0.030	-0.164***
Year × PT FE	yes	yes
Year × MSA FE	yes	yes

- Where:
  - $\bar{T}_m$: The average temperature over the entire sample of the properties' MSA.
  - c : A threshold temperature.
- On the full sample the effect for column (1) was -0.079*** and for column (2) it was -0.149***.

Conclusions and Discussion

- We find an economically meaningful impact of a changing climate on CRE investment returns.
- This is mostly driven by asset value declines. Given that:
    - (1) we control for temporal variation, this cannot be contributed to the risk-free rate.
    - (2) we observe no impact on income over the last 40 years, and assuming that investor expectations were correct, we conclude that;
    - climate mostly impacts the uncertainty of the cash flows. Indeed, the volatility of the cash flows increase.
- It should be noted that some cities over the last 40 years benefited from a warming up of the climate. Because we also see a general decline of cold days.
- Cities that are net beneficiaries include; Boston, Seattle and Chicago.