

Climate Change Concerns and Mortgage Lending

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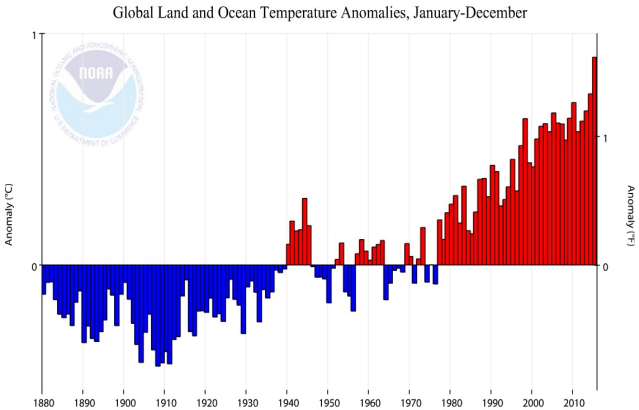
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Outline

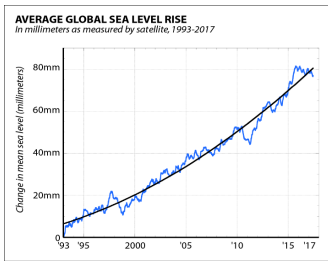
- 1 Motivation
- 2 Data
- 3 Empirical Results
- 4 Mechanism
- 5 Conclusion

Motivation



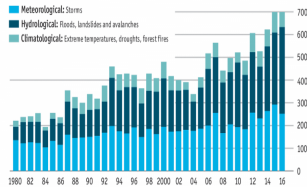
- Global temperature has been rising since 1970s

Motivation (cont'd)



A rising tide

Natural disasters by cause



- Along with the rising temperature is sea level rise, more frequent natural disasters and extreme weather events

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 - and the likelihood of extreme price movements in future

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 - and the likelihood of extreme price movements in future
- Policymakers increasingly concerned about the systematic risks imposed by climate change on financial stability (Carney, 2015)
- One approach is to increase the amount of reliable information on FI's exposure to climate-related risks ("Disclosure")
 - Task Force on Climate-related Financial Disclosures

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- Policymakers increasingly concerned about the systematic risks imposed by climate change on financial stability (Carney, 2015)
- One approach is to increase the amount of reliable information on FI's exposure to climate-related risks ("Disclosure")
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- But FIs also need to be aware of (or believe in) climate change in order to take actions ("Belief")

Research Question

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- Mortgages are collateralized by real estates, which are vulnerable to climate-related risks including sea-level rises, wildfires, and storms etc. (Bernstein et al., 2019; Baldauf et al., 2020)



U.S. Air National Guard photo by Staff Sgt. Daniel J. Martinez, (Aerial view of flooding from Hurricane Harvey in Port Arthur, TX)



Homes destroyed by the Camp Fire in California in November

Why Mortgage Lending?

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- While firms can adapt to climate change through geographic relocation and product diversification, adaptation for real estate is difficult
 - The number of flood insurance policies and their total dollar amount have declined substantially since 2006 (Kousky, 2018)
 - Policyholders may not maintain their flood insurance over time as the median tenure was only 2 to 4 years (Michel-Kerjan et al. 2012)

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 - The number of flood insurance policies and their total dollar amount have declined substantially since 2006 (Kousky, 2018)
 - Policyholders may not maintain their flood insurance over time as the median tenure was only 2 to 4 years (Michel-Kerjan et al. 2012)
- Mortgage applications are subject to discretionary approval by local loan officers, whose beliefs about climate change may affect their lending decision (Cortes, Duchin, and Sosyura, 2016)
- Mortgage is the largest component of household debt (\$9.3 trillion at 2018) and has historically related to systematic risks

Motivation (cont'd)

- *"It is less likely that borrowers will continue to make mortgage payments if their homes are literally underwater. As a result, lenders, servicers and mortgage insurers are likely to suffer large losses." – Freddie Mac (2016)*
- *What will happen to the 30-year mortgage – a key building block of finance – if lenders can't estimate the impact of climate risk over such a long timeline, and if there is no viable market for flood or fire insurance in impacted areas? – Larry Fink (2020)*

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 - Temperature shocks are plausibly exogenous to economy and helps making causal inference (Dell, Jones, and Olken, 2014)

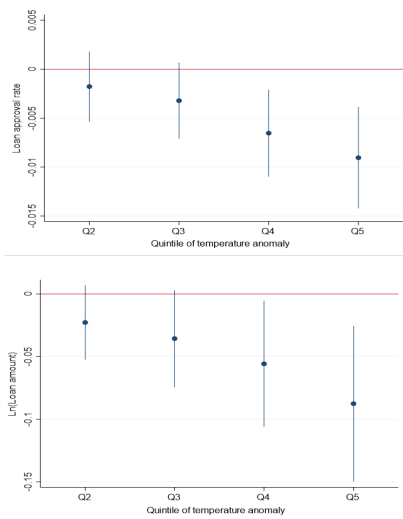
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- High local temperatures also lead to significant reduction in mortgage origination (Loan approval rate and Loan amount)

Preview of Empirical Results (cont'd)



- a county in its warmest years has a 0.90 percentage point (8.76%) lower mortgage approval rate (loan amount) compared to its coldest years

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- Our result is not fully driven by changing local economic conditions and demand for credit:
 - We control for state*year FE and county FE
 - We control county-level macroeconomic variables and borrower characteristics
 - Results hold in counties with strong demand for mortgage credit
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- The "belief" channel: lenders' rising concerns about climate change affect their lending decisions
 - Effect stronger in counties with strong prior belief about climate change
 - Effect stronger after public become more aware of climate change
 - Effect stronger in counties more exposed to sea-level rise risk

Contribution and Related Literature

- **The economic impacts of climate change:**

- Rising temperature reduces GDP growth at country and state level (Dell, Jones, and Olken, 2012; Colacito, Hoffmann, and Phan, 2019)
- At the micro-level, higher temperature negatively affect agricultural yields (Schlenker and Roberts, 2009), labor supply (Zivin and Neidell 2014), labor productivity (Seppanen, Fisk, and Lei, 2006), and firm profitability (Hugon and Law, 2018; Addoum et al., 2019)

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- **Climate-finance literature that concerns whether financial market efficiently price climate risks:**
 - Hong, Li, and Xu (2019): global stock markets underreact to drought risks
 - Giglio et al. (2018), Bernstein et al. (2019), Baldauf et al. (2018), and Murfin and Spiegel (2019) in real estate markets
 - Painter (2018): municipal bond market prices in climate change risks

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- **Local weather fluctuations influence public beliefs about climate change:**
 - Myers et al. (2012), Zaval et al. (2014), and Akerlof et al. (2013) survey evidence in U.S and globally
 - Choi, Gao and Jiang (2018) using Google search activities
 - We show that agents' heightened concerns for climate change affect their real decision-making

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 - All mortgage applications reviewed by qualified financial institutions
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- Loan interest rate and characteristics from Fannie Mae and Freddie Mac loan-level dataset
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- County-level macroeconomic variables from Census Bureau and Bureau of Labor Statistics
- House price index from Federal Housing Finance Agency

Summary Statistics

	Mean	STDEV	25th percentile	Median	75th percentile
<i>Climate change measures</i>					
Temperature anomaly	1.0746	0.2482	0.8931	1.0736	1.2503
Precipitation anomaly	0.0756	0.1267	-0.0119	0.0834	0.1672
<i>Borrower and loan characteristics</i>					
Loan approval rate	0.7046	0.0824	0.6400	0.7046	0.7564
Loan amount (in million)	190.7746	100.9206	5.2841	18.8995	74.5747
Ln(Loan amount)	9.5558	2.1434	8.0421	9.3355	10.9509
Debt-to-income	1.6709	0.3376	1.4270	1.6181	1.8707
Income (in thousand)	63.2623	16.9842	52.4876	58.8058	68.3129
Ln (Income)	4.0741	0.2323	3.9180	4.0285	4.1800
Fraction of minority applicants	0.2241	0.1148	0.1467	0.1826	0.2698
Ln (# of applicants)	6.4518	1.8371	5.2020	6.3132	7.6062
<i>Macroeconomics characteristics</i>					
Employment growth	0.0095	0.0113	0.0024	0.0083	0.0153
Wages growth	0.0402	0.0137	0.0316	0.0391	0.0471
Population growth	0.0055	0.0101	-0.0012	0.0041	0.0103
<i>Other variables</i>					
Worry	0.4876	0.0505	0.4500	0.4800	0.5200
Timing	0.3966	0.0350	0.3700	0.3900	0.4200
Sea-level rise	0.0122	0.1100	0.0000	0.0000	0.0000

- Loan Approval Rate is the number of loan applications approved divided by the number of loan applications reviewed in a county-year (mean is 70%)
- Loan Amount is the total dollar amount of originated loans that are not sold to other institutions in the end of the year in a county-year

Persistence of Local Temperature Anomalies

Variable	Temperature anomaly (subsequent three years)	
	(1)	(2)
Temperature anomaly	-0.1132 (0.1535)	0.0596 (0.0596)
Constant	1.3644*** (0.2508)	1.1785*** (0.0640)
County fixed effects	YES	YES
State*Year fixed effects	NO	YES
Adj. R2	0.0648	0.9471
N	83408	83408

- local temperature anomalies are not persistent and unlikely to be informative about global warming trend

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Attention to and Belief in Climate Change

- We first verify that local temperature shocks are valid proxy of public beliefs about climate change
- Monthly Google Search Volume Index (SVI) (seasonally adjusted) of the topic “Global Warming” in each Designated Market Area to proxy for attention towards global warming
- Sample period from April 2004 to December 2016

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Variables	Abnormal_SVI	
	(1)	(2)
Temperature anomaly	0.0234** (0.0113)	
Temperature anomaly_Q5		0.0477** (0.0229)
Temperature anomaly_Q4		0.0038 (0.0230)
Temperature anomaly_Q3		0.0078 (0.0265)
Temperature anomaly_Q2		0.0019 (0.0229)
Constant	-0.2605*** (0.0179)	-0.2411*** (0.0182)
Year*Month fixed effects	YES	YES
Adj. R2	0.1545	0.1545
N	30,447	30,447

Temperature Anomaly and Climate Change Beliefs

- Climate change beliefs at county-year level from Yale Climate Opinion Maps (Howe et al., 2015)
 - *Worry* is the fraction of population in a county who are somewhat/very worried about global warming (mean 49%)
 - *Timing* is the fraction of population in a county who think global warming is already harming people in the United States now/within 10 years (mean 40%)
 - Sample period from 2014 to 2018

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Variables	Worry		Timing	
	(1)	(2)	(3)	(4)
Temperature anomaly	1.1748*** (0.0532)		0.7916*** (0.0691)	
Temperature anomaly.Q5		2.0558** (0.3522)		1.4317** (0.3044)
Temperature anomaly.Q4		0.7637*** (0.1081)		0.4793** (0.0989)
Temperature anomaly.Q3		0.0542 (0.1019)		-0.0407 (0.0997)
Temperature anomaly.Q2		0.0846 (0.1542)		0.0220 (0.1344)
Constant	49.2899*** (0.0716)	50.2778*** (0.0986)	41.6158*** (0.0930)	42.3016*** (0.0947)
State*Year fixed effects	YES	YES	YES	YES
Adj. R2	0.4869	0.4891	0.5411	0.5429
N	12421	12421	12421	12421

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- **Null hypothesis:** local temperature fluctuations will not affect mortgage origination
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 - or they do not connect higher local temperature to a larger narrative of climate change

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- **Null hypothesis:** local temperature fluctuations will not affect mortgage origination
 - if lenders think climate risks are irrelevant for mortgage loans
 - or they do not connect higher local temperature to a larger narrative of climate change
- **Alternative hypothesis:** Lenders become more concerned about climate change and its potential impact on local housing market after experiencing abnormally high temperature
 - lenders will reduce credit exposure to regions vulnerable to climate change risks, through approving fewer mortgage applications, originating lower amount of loans, or charging higher interest rates

Empirical Methodology

- Our empirical methodology closely follow the climate-economy literature (Dell, Jones, and Olken, 2014) and rely on exogenous weather variation over time within a given spatial unit as identification

$$Y_{i,s,t} = \beta_0 + \beta_1 \text{TemperatureAnomaly}_{i,s,t-1} + \beta_2 \text{Controls}_{i,s,t} + \alpha_i + \phi_{s,t} + \epsilon_{i,s,t} \quad (1)$$

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- $Y_{i,s,t}$ is loan approval rate or Ln(loan amount) in county i of state s at year t
- $\text{TemperatureAnomaly}_{i,s,t-1}$ is the 36-month moving average temperature anomaly in county i of state s at year $t - 1$
- α_i is county fixed effects that absorb any time-invariant county characteristics
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- $\phi_{s,t}$ is state*year fixed effects that control for time-varying economic conditions at the state level
- Controls include borrower characteristics (averaged to county-year level) and county-level macroeconomic variables
 - Debt-to-income, Income, and Fraction of minority applicants
 - Employment growth, Wages growth, and Population growth
- When $Y_{i,s,t}$ is loan interest rate, i indicates (first 3-digit) zip code
- Standard errors are double clustered at the county and year level

Temperature Anomaly and Loan Approval Rate

Variables	Loan approval rate		
	(1)	(2)	(3)
Temperature anomaly	-0.0088*** (0.0020)		
Temperature anomaly_Quintile		-0.0023*** (0.0006)	
Temperature anomaly_Q5			-0.0090*** (0.0025)
Temperature anomaly_Q4			-0.0065*** (0.0022)
Temperature anomaly_Q3			-0.0032 (0.0019)
Temperature anomaly_Q2			-0.0018 (0.0017)
Constant	0.7042*** (0.0198)	0.7017*** (0.0197)	0.6989*** (0.0201)
Controls	YES	YES	YES
County fixed effects	YES	YES	YES
State*Year fixed effects	YES	YES	YES
Adj. R2	0.5871	0.5870	0.5870
N	83,408	83,408	83,408

Temperature Anomaly and Loan Amount

Variables	Ln(Loan amount)		
	(1)	(2)	(3)
Temperature anomaly	-0.0665** (0.0297)		
Temperature anomaly_Quintile		-0.0205*** (0.0074)	
Temperature anomaly_Q5			-0.0876*** (0.0302)
Temperature anomaly_Q4			-0.0558** (0.0245)
Temperature anomaly_Q3			-0.0356* (0.0188)
Temperature anomaly_Q2			-0.0227 (0.0144)
Constant	9.0309*** (0.2215)	9.0207*** (0.2189)	8.9992*** (0.2195)
Controls	YES	YES	YES
County fixed effects	YES	YES	YES
State*Year fixed effects	YES	YES	YES
Adj. R2	0.9194	0.9194	0.9194
N	81,865	81,865	81,865

Temperature Anomaly and Loan Interest Rate

Variable	Loan interest rate		
	(1)	(2)	(3)
Temperature anomaly	0.0001 (0.0001)		
Temperature anomaly Quintile		0.0000 (0.0000)	
Temperature anomaly_Q5			0.0000 (0.0001)
Temperature anomaly_Q4			-0.0000 (0.0000)
Temperature anomaly_Q3			-0.0000 (0.0000)
Temperature anomaly_Q2			-0.0000 (0.0000)
Constant	0.0477*** (0.0060)	0.0477*** (0.0060)	0.0477*** (0.0060)
Controls	YES	YES	YES
Zip code fixed effects	YES	YES	YES
State*Year fixed effects	YES	YES	YES
Adj. R2	0.9990	0.9990	0.9990
N	12,025	12,025	12,025

- Insignificant effect on loan interest rate are consistent with literature that loan pricing is driven mainly by computerized algorithms that rely on hard information, with relatively little input from loan officer (Rajan, Seru, and Vig, 2015)
- Also consistent with the credit rationing model of Stiglitz and Weiss (1981) in a market with adverse selection

Robustness Tests

- The negative effect of temperature anomaly on mortgage lending is robust when we:
 - control for county-level house price index (Bernstein et al., 2019; Baldauf et al., 2020)
 - remove the Subprime Mortgage Crisis Period
 - control for the damages caused by natural hazards at county-year level
 - exclude from our sample five states including California, Florida, Louisiana, New Jersey and Texas that jointly account for nearly 70% of NFIP policies (Kunreuther and Michel-Kerjan, 2011)

Disentangling Credit Demand and Supply Channel

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 - reduce the local employment opportunities and income
 - shrink the tax base of local governments and its ability to maintain infrastructure and public service

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- Consistent with demand channel, counties experiencing high temperature have lower quality mortgage applicants [link](#)

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 - shrink the tax base of local governments and its ability to maintain infrastructure and public service
- Consistent with demand channel, counties experiencing high temperature have lower quality mortgage applicants [link](#)
- To account for the demand channel, we:
 - conduct subsample test for counties that have experienced strong demand growth for mortgage credit
 - placebo test using Fintech lenders

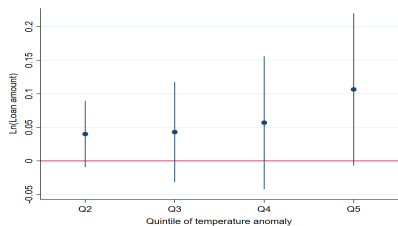
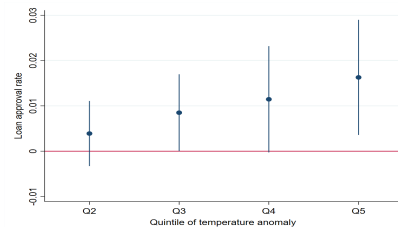
Tests Using Fintech Lenders

- For Fintech lenders, the application and review process for mortgages are almost entirely conducted online, and no human loan officers are involved in the decision-making process (Buchak, Matvos, Piskorski, and Seru, 2018)
- As a result, if temperature anomalies affect mortgage lending through its effect on local loan officers' climate change belief, we should find no effect for loans originated by Fintech lenders

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- On the other hand, if the effect we document is due to unobserved reduction in demand for mortgage in areas with abnormally high temperature, we should find a similar negative effect for Fintech lenders
- We follow Buchak et al. (2018) and identify seven Fintech lenders including QuickenLoans (from 2000), CashCall (from 2008), Guaranteed Rate (from 2008), Amerisave (from 2008), Homeward (from 2012), Movement (from 2013), and Summit Mortgage (from 2007)

Tests Using Fintech Lenders (cont'd)



- The positive effect of temperature anomaly on Fintech lending is inconsistent with demand channel, but consistent with Fuster et al. (2019) that Fintech lenders fill (partially) the credit gap left by traditional lenders as they can adjust supply more elastically

Outline

- 1 Motivation
- 2 Data
- 3 Empirical Results
- 4 Mechanism**
- 5 Conclusion

Evidence Supporting the Belief Channel

- The mechanism we propose is that lenders' perception of climate change increases significantly after they experience unusually warm weather, and they take actions to reduce lending to the local housing market

Evidence Supporting the Belief Channel

- The mechanism we propose is that lenders' perception of climate change increases significantly after they experience unusually warm weather, and they take actions to reduce lending to the local housing market
- Consistent with this belief updating mechanism, we find the effect of temperature anomaly on mortgage origination
 - is stronger in counties that hold strong prior beliefs about climate change [link](#)
 - is more pronounced among counties heavily exposed to the risk of sea-level rise [link](#)
 - is more pronounced in periods with more intense media coverage on climate change related topics [link](#)
 - placebo test using precipitation anomalies [link](#)

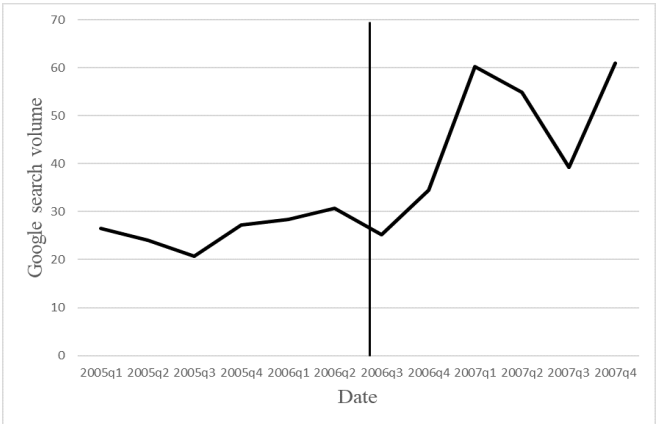
Public Awareness of Climate Change

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 - More likely when the public become more aware of climate change issues

Public Awareness of Climate Change

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 - More likely when the public become more aware of climate change issues
- Quasi-natural experiment surrounding the release of the Stern Review in October 2006
 - "Stern Review" is one of the earliest and most well-known analyses of the economics of climate change and likely significantly raise public awareness of climate change
 - Unlikely to change the physical risks of climate change
 - A documentary film, "An Inconvenient Truth", released around the same time, may also help raise public awareness of climate change

Google SVI for "climate change" around the Stern Review/Inconvenient Truth



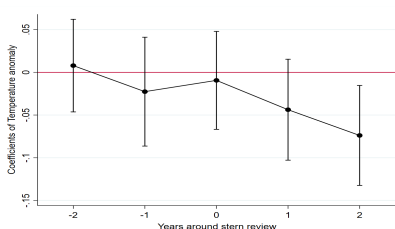
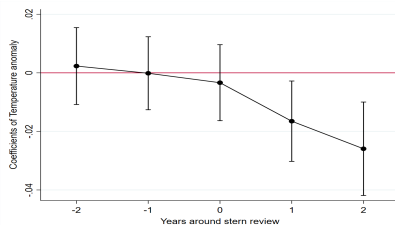
Topics lead to increased Google SVI for "climate change"

Related queries ? Rising ▼ ↓ <> 🔗

1	al gore climate change	Breakout
2	bali climate change	Breakout
3	an inconvenient truth	Breakout
4	economics of climate change	Breakout
5	new mexico climate change	Breakout

< Showing 1-5 of 25 queries >

Diff-in-Diff Analysis around the Stern Review



- This figure plots the estimated diff-in-diff coefficients of temperature anomaly on loan approval and loan amount in 2-year before and 2-year after the Stern Review was released in year 2006

Outline

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Conclusion

- Using mortgage origination as a laboratory, we test whether agents' beliefs about climate change affect their real decision-making
 - A strong negative effect of abnormally high local temperature on mortgage origination in US counties
 - This effect does not seem to be fully explained by changing local economic conditions and demand for mortgage credit
 - Effect stronger among counties with strong beliefs in climate change, most exposed to the risk of sea-level rise, and during periods of heightened media attention
- Important policy question: will the predicted rising temperatures and extreme weather events lead the society to reassess climate change risks and invest more resources in mitigation and adaptation?

Temperature Anomaly and Characteristics of Loan Applicants

Variable	Debt-to-income	Ln(Income)	Fraction of minority applicants	Ln(# of applicants)
Temperature anomaly	0.0144* (0.0075)	-0.0171*** (0.0045)	0.0110** (0.0051)	0.0139 (0.0199)
Constant	1.6669*** (0.0074)	4.0905*** (0.006)	0.2156*** (0.0055)	6.4619*** (0.0209)
Controls	YES	YES	YES	YES
County fixed effects	YES	YES	YES	YES
State*Year fixed effects	YES	YES	YES	YES
Adj. R2	0.7943	0.8717	0.7931	0.9544
N	83408	83408	83434	83434

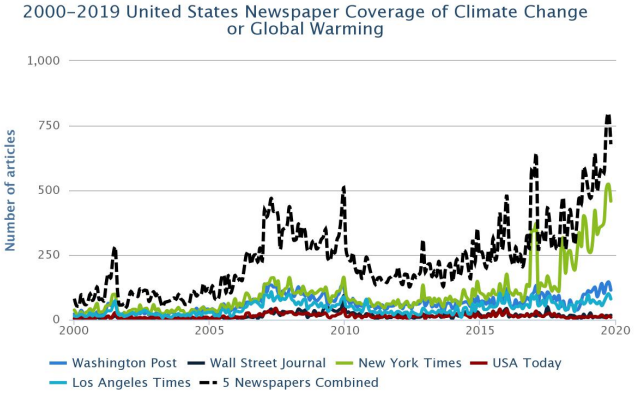
- Counties experiencing high temperature have lower quality mortgage applicants, as measured by higher debt to income ratio, lower income level and larger fraction of minority applicants
- However we control for these characteristics of mortgage applicants in the baseline regression (back to [main](#))

Interaction with Sea-level Rise Risk

- One of the most relevant climate risks that real estates are exposed to is sea-level rise (SLR) (Rao, 2017)
- We group all counties into those exposed and not exposed to SLR risk using the measure from Hallegatte et al. (2013) and interact it with temperature anomaly
- Consistent with recent studies (Bernstein et al. 2020; Painter, 2020) that SLR risk is priced in the real estates and municipal bonds (back to [link](#))

Variable	Loan approval rate (1)	Ln(Loan amount) (2)
Temperature anomaly	-0.0087*** (0.0020)	-0.0657** (0.0296)
Temperature anomaly * Sea-level rise	-0.0113** (0.0046)	-0.1462* (0.0737)
Constant	0.7040*** (0.0198)	9.0285*** (0.2213)
Controls	YES	YES
County fixed effects	YES	YES
State*Year fixed effects	YES	YES
Adj. R2	0.5871	0.9194
N	83,408	81,865

Newspaper Coverage of Climate Change



CIRES Center for Science and Technology Policy Research, University of Colorado Boulder, http://sciencepolicy.colorado.edu/media_coverage

- This figure plots the monthly newspaper coverage of climate change or global warming in five US national newspapers (Washington Post, Wall Street Journal, New York Times, USA Today, and Los Angeles Times).
- The data is from Media and Climate Change Observatory Data Sets compiled by Boykoff et al. (2019).

Interaction with Newspaper Coverage of Climate Change

Variable	Loan approval rate (1)	Ln(Loan amount) (2)
Temperature anomaly	0.0048 (0.0062)	0.0175 (0.0487)
Temperature anomaly*Newspaper coverage	-0.0001** (0.0000)	-0.0002 (0.0002)
Constant	0.7706*** (0.0138)	9.3068*** (0.0898)
Controls	YES	YES
County fixed effects	YES	YES
State*Year fixed effects	YES	YES
Adj. R2	0.7677	0.9700
N	52,768	52,653

(back to [link](#))

Placebo Test Using Precipitation Anomaly

- The mechanism predicts the effect should be weaker when we use alternative weather events that are less likely associated with climate change in people's perception (e.g., $Pr(E|G) = Pr(E|NG)$)
- A placebo test using precipitation
- We verified precipitation anomaly has no effect on people's attention to and belief about climate change (back to [link](#))

Variable	Loan approval rate			Ln(Loan amount)		
	(1)	(2)	(3)	(4)	(5)	(6)
Precipitation anomaly	-0.0041 (0.0028)			-0.0051 (0.0317)		
Precipitation anomaly_Quintile		-0.0005 (0.0006)			0.0051 (0.0067)	
Precipitation anomaly_Q5			-0.0029 (0.0024)			0.0085 (0.0273)
Precipitation anomaly_Q4			-0.0008 (0.0019)			0.0185 (0.0208)
Precipitation anomaly_Q3			-0.0028* (0.0016)			-0.0035 (0.0140)
Precipitation anomaly_Q2			-0.0013 (0.0008)			-0.0133 (0.0109)
Constant	0.6954*** (0.0198)	0.6965*** (0.0203)	0.6966*** (0.0200)	8.0731*** (0.2187)	8.9611*** (0.2210)	8.9444*** (0.2211)
Controls	YES	YES	YES	YES	YES	YES
County fixed effects	YES	YES	YES	YES	YES	YES
State*Year fixed effects	YES	YES	YES	YES	YES	YES
Adj. R2	0.5869	0.5869	0.5869	0.9194	0.9194	0.9194
N	83,408	83,408	83,408	81,865	81,865	81,865