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Adapting the US Residential Sector to Global Warming

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Motivation

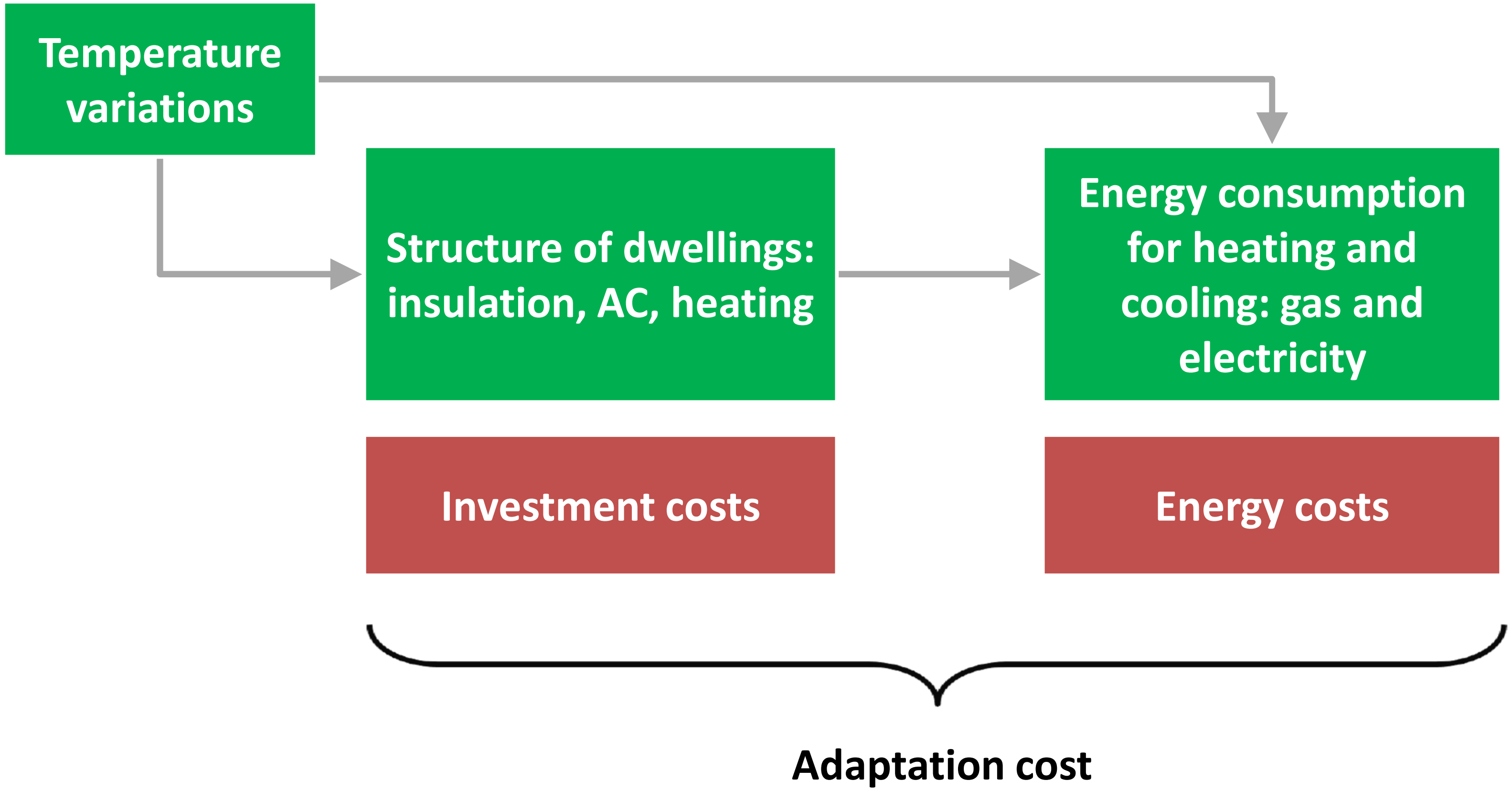
- Over the next decades, climate will change with certainty
  - At best, limited to a 2°C increase relative to pre-industrial levels
- But the cost is uncertain because the adaptation potential is difficult to predict
- In particular, this applies to climate econometrics
  - Panel data approaches which exploit weather shocks within a given spatial area to identify impact of climate change on various economic outcomes
- Why?
  - Because assess the short term impact of weather shocks leaving no time to economic agents to adapt

Adaptation in the residential sector

- Adaptation involve multiple decision makers and different time horizons.
- From the short term to the long term:

1. Adjusting energy use (less heating, more cooling)
2. Modifying the structure of the dwelling (investing in AC, insulation…)
3. Building new dwellings
4. Innovating in cooling technologies
5. Redesigning urban space

This paper: the adaptation of existing dwellings



What we do

- Data: A panel of housing units located in 160 MSAs between 1985 and 2011 (around 58,000 observations)
  - Detailed information on investments made in home improvements, energy use
- A panel data analysis to identify the impact of location-specific temperature variations on:
  1. The volume of adaptation-related investments (purchase of major equipment and weatherization)
  2. Energy expenditure
- Combine the econometric estimates with the output of a climate model in order to predict the adaptation costs and energy use under the IPCC “business-as-usal” A2 scenario
  – A 6.1°F increase in 2090-2099 relative to 1980-1999

Data sources

- **American Housing Survey:**
  - Micro data that describe home improvements, in particular, the purchase of major equipment and weatherization, energy use, home occupiers, the location (the MSA)
  - 14 waves = biannual
- **Global Historical Climatology Network Daily:**
  - Construct temperature variables from 22,000 stations
  - Match all currently and formerly operating stations within a 50km radius of the centroid of each MSA
- **ECHAM model:**
  - An atmospheric general circulation model developed at the Max Planck Institute for Meteorology
  - Provide state-level monthly average temperature predictions for 2080 – 2099 under the A2 scenario

Preview of the findings

- The present discounted value of the cost for adapting homes to the "business-as-usual" scenario is **$7,200** per housing unit, but not statistically different from zero.
  - Around 3.4% of the average purchase price of the housing units
- Important disparities between hot regions and cold regions.
- A major shift from gas (-23%) to electricity (+34%)

Model 1: Investment

- Two investment equations:
  1. purchase of large equipment (e.g. air conditioners, heaters)
  2. insulation (e.g. roofing, siding, window replacements)
- Panel data model with time and household fixed effects:

$$I_{iht} = \alpha_h C_{it} + \beta_h X_{it} + \mu_{ih} + \tau_{ht} + \varepsilon_{iht}$$

with

- I_{iht}, the volume of investment made in year *t* by household *i* in investment category *h:*
- C_{it} = a vector of climate variables
- X_{it} = household size, access to energy
- μ_{ih} = by-home-by-category fixed effects
- τ_{ht} = time dummies
- ε_{iht} = a random noise

Climate variables

- Annual heating degree days = sum of degrees below 65°F based on average daily temperatures
  - Used by engineers to compute annual heating needs;
- Annual cooling degree days = sum of degrees above 65°F
- Not the contemporaneous value, but a weighted average of past values
  - Households are aware of inter-annual temperatures variations
  - Consistent with the adaptive expectation model
- Robustness checks with temperature bins
- # days with precipitation as a control

Main results: Investment

Type of investment	Equipment	Weatherization
Expected heating degree days	0.161**	0.322**
	(2.23)	(2.08)
Expected cooling degree days	0.354***	0.297
	(2.69)	(1.13)
Expected precipitations	-0.00399	0.0141
	(-0.39)	(0.58)
No. people in unit	-4.347	41.11*
	(-0.42)	(1.70)
Connection to pipe gas	89.83	138.1
	(1.55)	(1.43)
Observations	44,975	42,900

Model 2: Energy expenditure

- A dynamic panel data model with year and household fixed effects. dependent variable is :

$$\ln(E_{ift}) = \gamma_f \ln(E_{ift-1}) + \theta_f w_{it} + \sum_{h=1}^{3} \phi_{hf} K_{iht} + \omega_f Y_{it} + \mu_{if} + \tau_{ft} + \epsilon_{ift}$$

with

- $\ln(E_{ift})$: the logarithm of the annual consumption in home *I* in year t
- of fuel f (gas or electricity)
- w_{it} = CDD and HDD in year t in home i
- K_{iht} = the stock of past investments defined by $K_t = I_t + \rho K_{t-1}$ where ρ is a depreciation factor measuring the decay of past investments.
- Y_{it}= household size, access to energy
- μ_{if} = by-household-by-fuel fixed effects
- τ_{ft} = time dummies
- ϵ_{ift} = a random noise

Econometric issues

- Dynamic panel data model (Blundell-Bond estimator)
  - Energy use driven by persisting consumption patterns
- Lagged energy use instrumented with the time spent in the house
- Investment stocks instrumented with lagged values

Main results: energy expenditures

Type of fuel	Electricity	Gas
Lagged dependent variable (log)	0.402***	0.449***
	(3.86)	(3.25)
Heating degree days	0.00988***	0.0737***
	(2.94)	(3.94)
Cooling degree days	0.108***	0.0192**
	(5.16)	(2.03)
Capital in equipment	0.00411*	0.00941***
	(1.82)	(3.31)
Capital in weatherization	-0.000688	-0.00198***
	(-1.25)	(-3.06)
Capital in other amenities	0.000861***	0.000828**
	(2.67)	(2.27)
Precipitations	0.0108***	0.0112***
	(5.03)	(3.90)
Connection to pipe gas	-0.115***	0.186***

Simulations of the A2 scenario for the end of the century (2080-2099)

A2 is a business-as-usual scenario leading to a global average surface warming of 6.1°F in 2090-2099 relative to 1980-1999

More specifically, an increase in # very hot days:

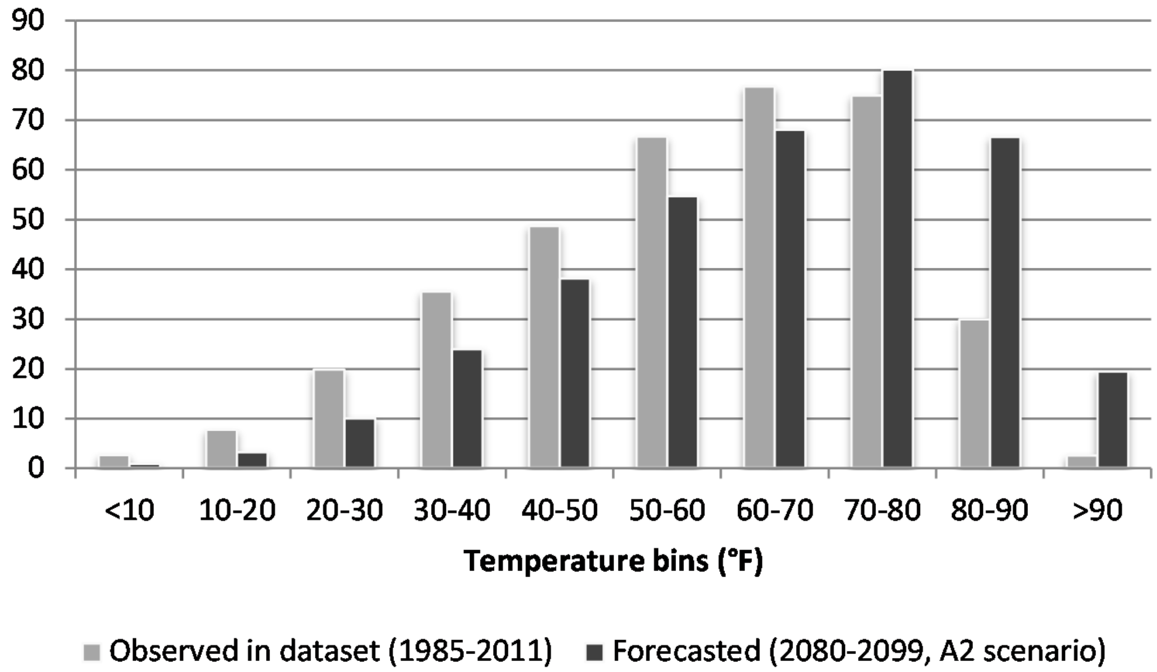


Figure 2: Observed and forecasted number of days falling within each temperature bin

Results, nationwide

Estimated impact of the A2 scenario (2080-2099) on annual investments and energy expenditure for a representative US housing unit

	Variation under the A2 scenario		
	In level		In percent
	Mean	95% confidence interval	
Present discounted adaptation cost †	+ $7,213	[- $1,332; + $16,918]	-
Annual investment in equipment	+ $121	[- $50, + $293]	+82%
Annual investment in weatherization	- $30	[- $380, + $320]	-7%
Annual electricity bill	+ $558***	[+ $272; + $953]	+34%
Annual gas bill	- $209***	[- $366; - $73]	-23%
Total annual energy expenditures	+ $349*	[-$38; +$822]	+14%

Results, by region

Estimated impact of the A2 scenario (2080-2099) on for a representative US housing unit in different US regions

US Climate Regions	Present discounted cost of adaptation
Central	-2,794
East North Central	-5,350
Northeast	-2,213
Northwest	-7,322***
West North Central†	-1,301
South	+25,029***
West	+11,406***
Southeast	+23,536***
Southwest	+16,633***

Without capital adjustments

Type of expenditure	Variation under the A2 scenario	
	Mean	In percent
Annual electricity bill	+ $365***	+20%
Annual gas bill†	- $160***	-17%
Total discounted cost of adaptation†	+ $3,409**	-

Under-estimation of the impacts

Conclusion

- A novel approach where we look inside the « black box » of adaptation
- In average, the US residential sector seems resilient to predicted temperature increases
  - But huge disparities across States
- Climate change would have a very strong impact on residential energy consumption
  - Less gas (in colder States)
  - Much more electricity (in hotter States)
- Failure to account for capital adjustments leads to underestimate the impacts

Thanks!