Why Did Air Conditioning Adoption Accelerate Faster Than Predicted? Evidence from Mexico

Lucas Davis (Berkeley) Paul Gertler (Berkeley)

September 2025

Climate Change literature often make forecasts far into the future

- **Studies Predicting Future Air Conditioning Adoption**

  (Isaac and Van Vuuren, 2009; Akpinar-Ferrand and Singh, 2010; Pavanello et al., 2021; Davis et al., 2021; De Cian et al., 2025; Abajian et al., 2025)

- **Studies Predicting Future Energy Consumption**

  (Rosenthal et al., 1995; Mansur et al., 2008; Franco and Sanstad, 2008; Auffhammer and Aroonruengsawat, 2011; Auffhammer et al., 2017; Wenz et al., 2017; Van Ruijven et al., 2019; Rode et al., 2021)

- **Studies Predicting Agricultural Yields, Mortality, Conflict, etc.**

  (Deschênes and Greenstone, 2007; Schlenker and Roberts, 2009; Burke et al., 2009; Deschênes and Greenstone, 2011; Burke et al., 2015; Carleton et al., 2022)

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There is a large and growing number of these types of studies, but researchers rarely return later to check the accuracy of their predictions.

Return to Davis and Gertler (2015) w/ 12+ more years of data

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Contribution of air conditioning adoption to future energy use under global warming

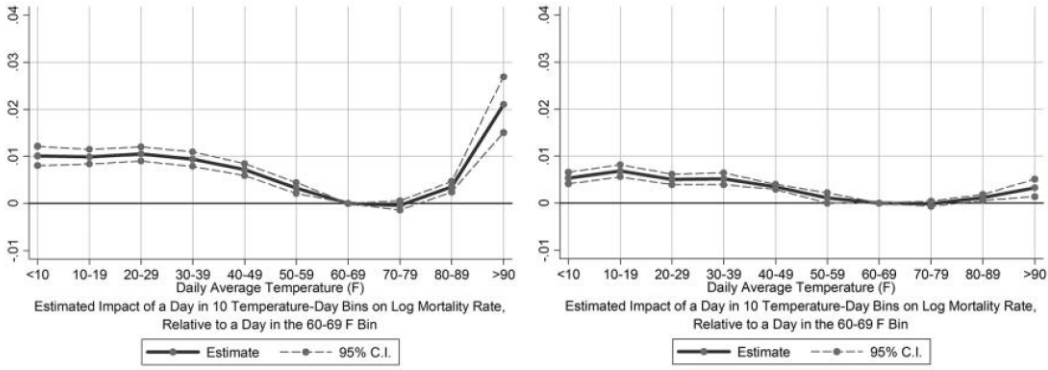
Lucas W. Davis and Paul J. Gertler Authors Info & Affiliations

At the time we wrote: *"The use of AC is poised to increase dramatically over the next several decades as global temperatures go up and incomes rise around the world."*

Estimate model of AC adoption as a function of income and temperature, and then used forecasts from the literature on income and temperature to predict future AC adoption.

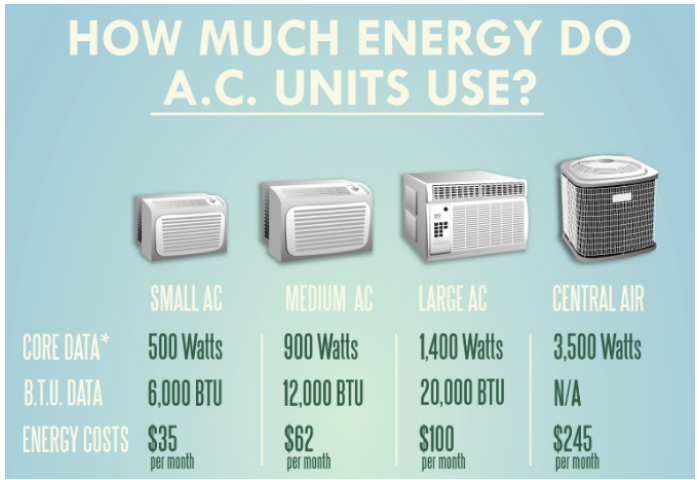
Now, with 12+ years of additional data, we revisit our predictions.

Why is this important? (1) AC saves lives

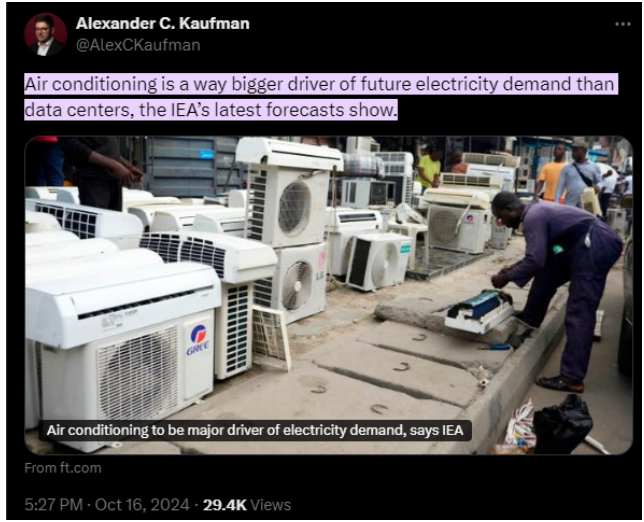


Source: Barreca, Alan, Karen Clay, Olivier Deschenes, Michael Greenstone, and Joseph S. Shapiro. "Adapting to climate change: The remarkable decline in the US temperature-mortality relationship over the twentieth century." Journal of Political Economy 124, no. 1 (2016): 105-159.

Why is this important? (2) AC is energy intensive



(3) AC is a big driver of future energy demand (IEA)



(4) Will stress the grid requiring large investments in generation and transmission

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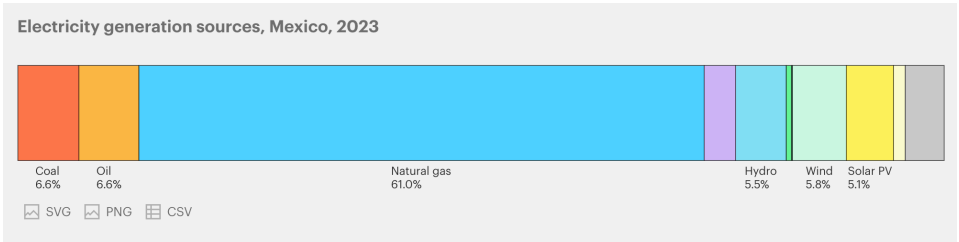
Mexico heat wave triggers 'exceptional' power outages, president says

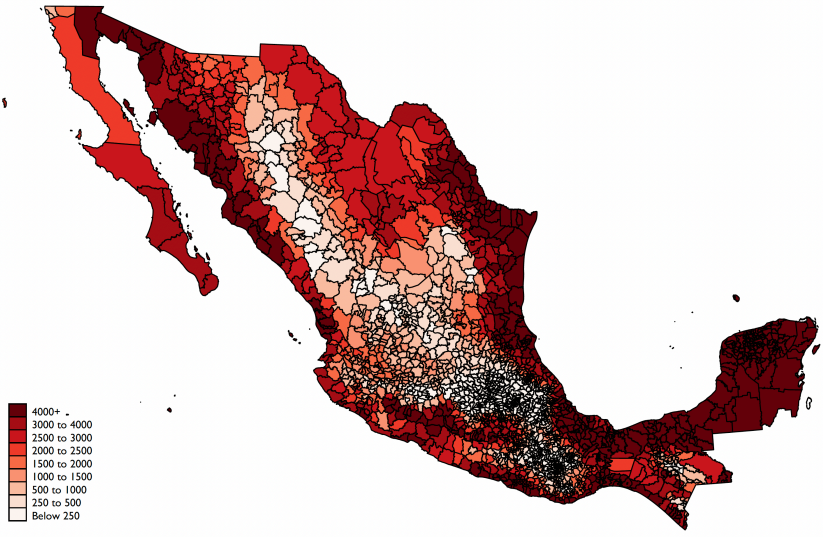
By **David Alire Garcia** and **Adriana Barrera**

May 8, 2024 1:13 PM PDT · Updated 5 months ago

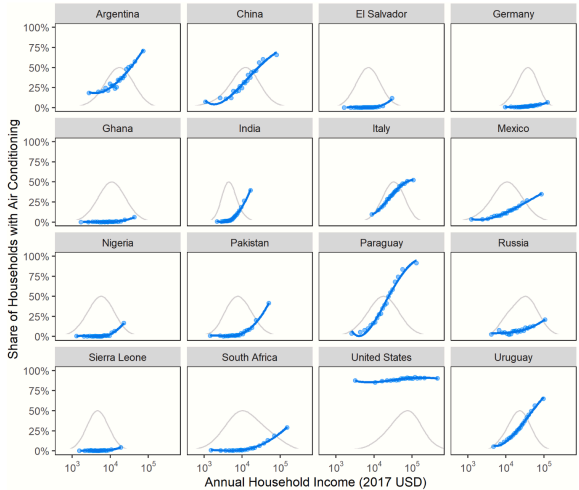
(5) Most electricity comes from fossil fuels, so more AC means more carbon emissions.



Mexico ideal setting for studying AC, large variation in CDDs



Adoption in Mexico consistent with other countries



Our Previous Paper

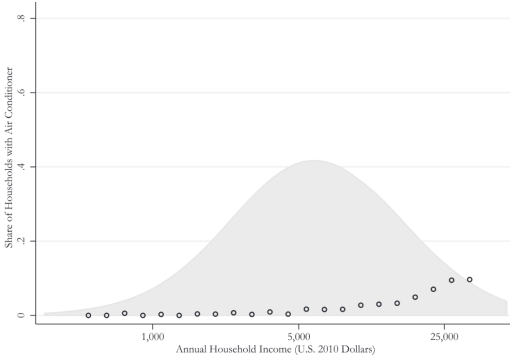
Used household-level data from 2010 to estimate ***Engel curve*** by probit:

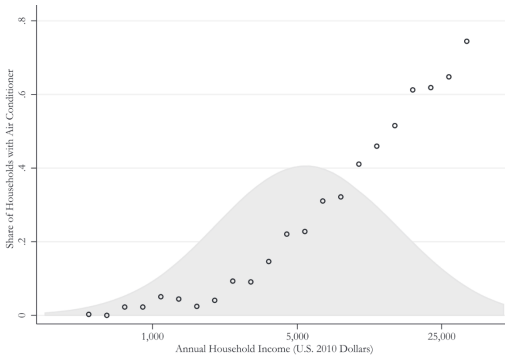
$$1(\textit{Air Conditioner})_i = \alpha_1 \textit{Expenditures}_i + \alpha_2 \textit{CDD}_m + \alpha_3 1(\textit{Warm Municipality})_m + \alpha_4 \textit{Expenditures}_i * 1(\textit{Warm Municipality})_m + \theta_s + \epsilon_i$$

where:

$1(\textit{Air Conditioner})_i$	dummy for if household i has AC.
$\textit{Expenditures}_i$	household expenditures
$\textit{CDD}_m$	cooling degree days for municipality
$1(\textit{Warm Municipality})_m$	municipalities with above average CDDs
θ_s	state fixed effects

Interaction allowed us to capture the pattern in cool (left) vs warm (right) municipalities





Predictions

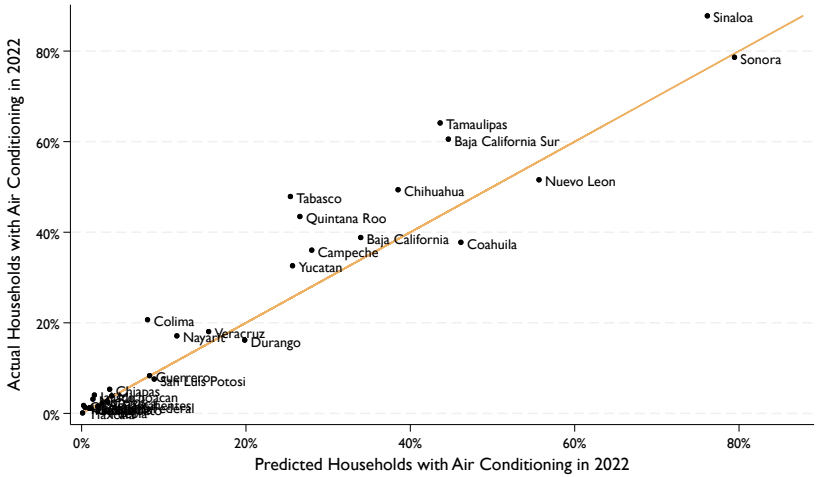
Combined estimated model with assumptions about growth in expenditures and CDDs to predict future air conditioning adoption.

Assumed 2% annual real growth for household expenditures based on a US government forecast of 3.7% annual real growth for Mexican GDP 2010-2040.

Predicted future CDDs using temperature predictions by municipality for a moderate emission scenario (RCP 4.5) from a suite of climate models (Climate Wizard)

Aggregated to the state and national levels using the 2010 ENIGH sampling weights

How Accurate Were the Predictions?



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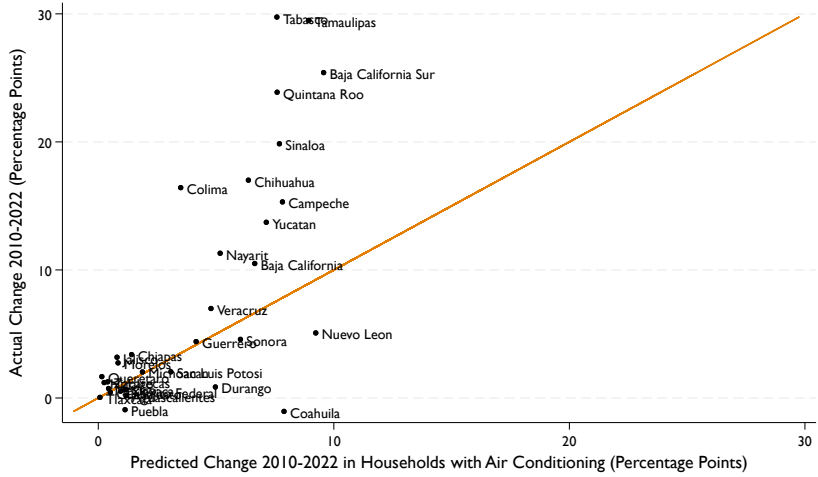

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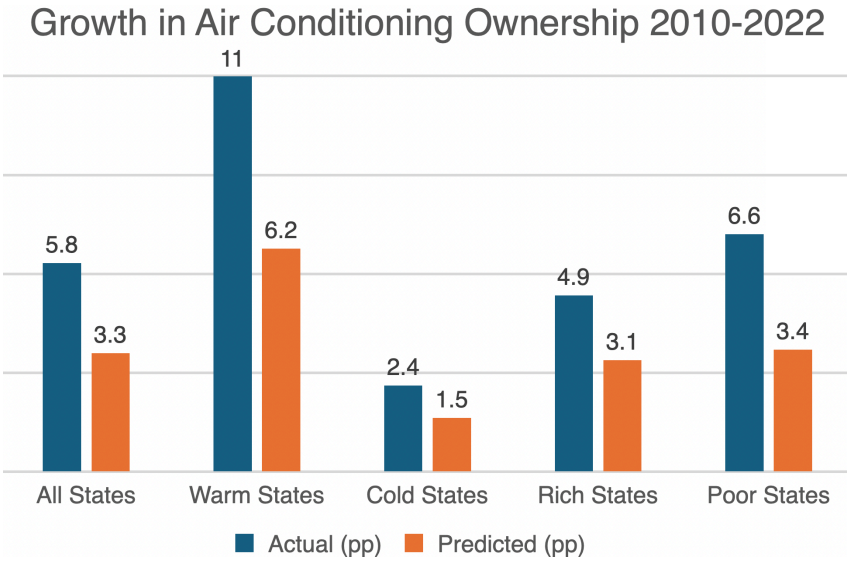
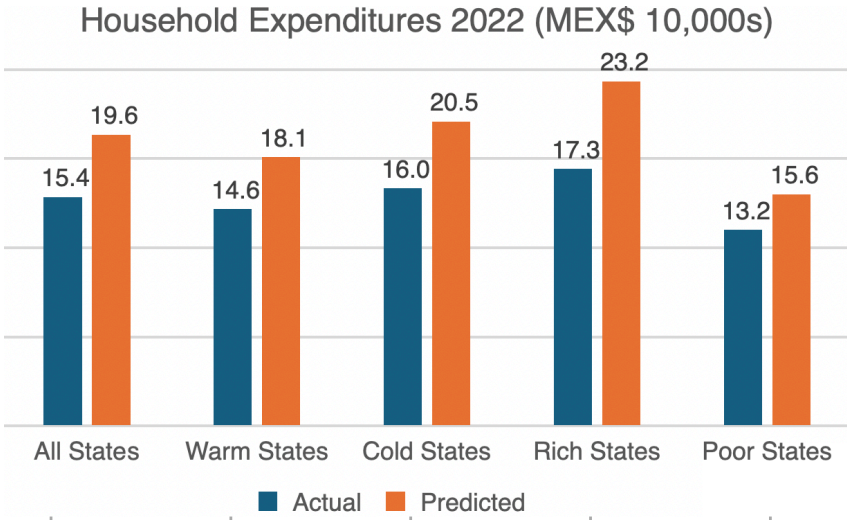


Mechanisms

Why did AC adoption exceed our predictions?

- Have **expenditures** increased more than expected?
- Have **cdds** increased more than expected?
- Has the **population** migrated to warmer areas?
- Was our original model too **inflexible**?

Have Expenditures Increased More than Expected?



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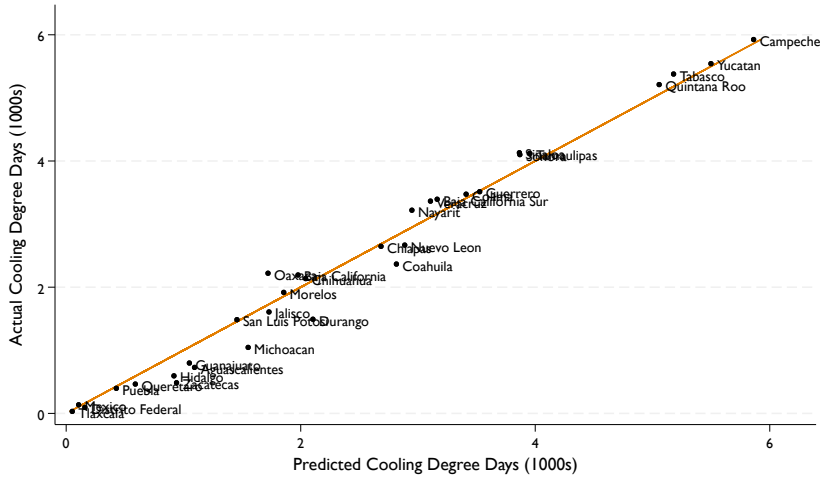

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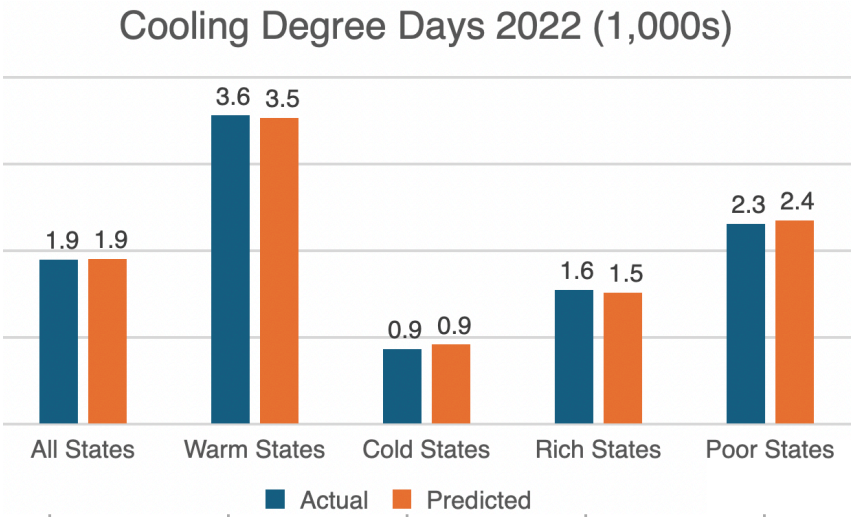

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Table 1: Prediction Gap

(Prediction Gap = Predicted / Actual Growth in AC Ownership 2010-2022)

Model	Growth in Expenditures/CDDs	Population Weights	Prediction Gap
		A. All States	
Probit	Predicted	2010	0.566
Probit	Actual	2010	0.251
Probit	Predicted	2022	0.571
LASSO	Predicted	2010	0.629
		B. Warm States	
Probit	Predicted	2010	0.566
Probit	Actual	2010	0.253
Probit	Predicted	2022	0.570
LASSO	Predicted	2010	0.604

Mechanisms

Why did AC adoption exceed our predictions?

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		C. Cold States	
Probit	Predicted	2010	0.613
Probit	Actual	2010	0.264
Probit	Predicted	2022	0.611
LASSO	Predicted	2010	0.753
		D. Rich States	
Probit	Predicted	2010	0.633
Probit	Actual	2010	0.123
Probit	Predicted	2022	0.657
LASSO	Predicted	2010	0.711
		E. Poor States	
Probit	Predicted	2010	0.517
Probit	Actual	2010	0.360
Probit	Predicted	2022	0.508
LASSO	Predicted	2010	0.569

Mechanisms

- Have **expenditures** increased more than expected? No.
- Have **cdds** increased more than expected? No.
- Has the **population** moved toward warmer areas? No.
- Was our original model too **inflexible**? No.

Omitted Factors: Energy Prices and AC Efficiency

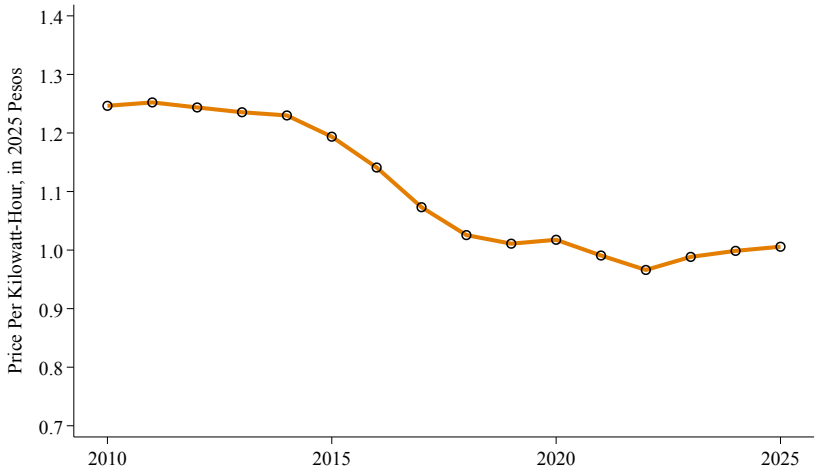
Striking out with our first several hypotheses, we went back to first principles.

Economists have long pointed out that demand for energy-using durables is derived from the demand for energy services (Hausman, 1979; Dubin and McFadden, 1984).

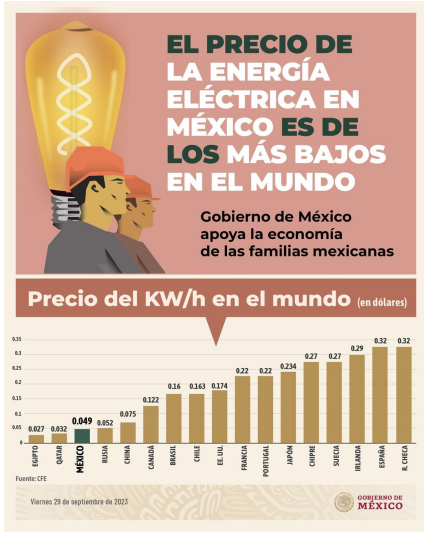
It makes sense to ask whether the price of cooling has changed?

We were aware of importance: *"The future pattern of AC adoption will also reflect what happens to prices. Equipment prices are likely to continue to decrease, further accelerating adoption. What will happen to electricity prices is less clear."*

Residential Electricity Prices (MX$ per kWh) Fell 19%



Residential Electricity in Mexico is Cheap!



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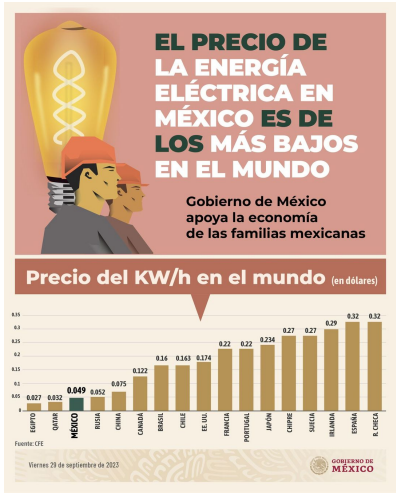
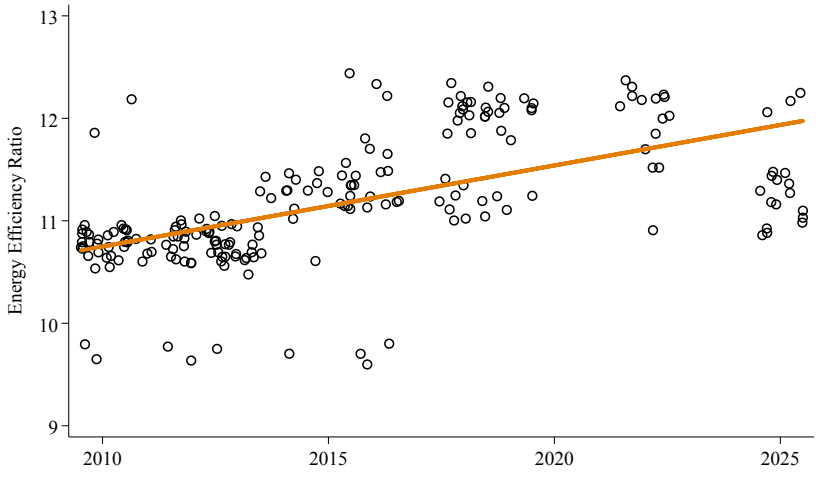
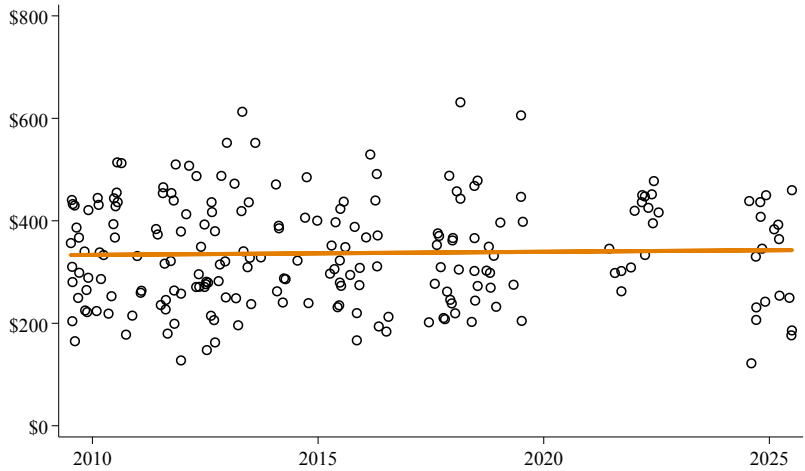


Political roots of energy subsidies (Burgess et al., 2020).

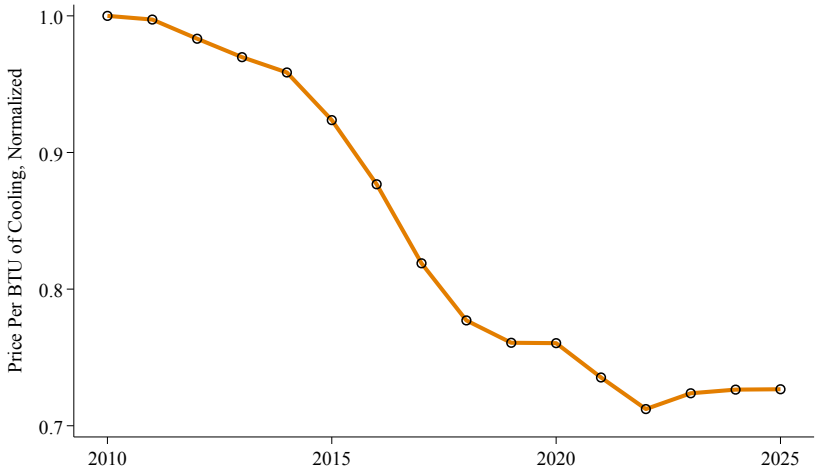
AC energy-efficiency increased 11%



AC prices flat



Price of cooling (MX$ per BTU) Fell 30%



Does the fall in price of cooling explain the prediction gap? YES!

Two approaches:

(1) Research from U.S. finds AC adoption highly sensitive to electricity prices. Applying a -0.59 elasticity from previous research to the 30% decline in the price of cooling yields an 18% increase in AC adoption, almost exactly the magnitude of the prediction gap.

(2) If preferences are Cobb-Douglas, then the coefficient on income in the Engel curve is inversely proportional to price. Estimating the Engel curve separately for 2010 and 2022, we show that the coefficient on income has increased 28% in warm municipalities, almost exactly the same as the 30% price decline.

Reduction in Prices Reduces Income Elasticities

Simplified version of the Engel curve: $x = \alpha + \beta Y$.

where β is the share of income spent on good x.

With Cobb-Douglas, $x^{\gamma} c^{\delta}$, demand is: $x = \frac{(\gamma Y)}{P_x}$

β in the Engel curve is:

$$\beta = \frac{\gamma}{P_x} \tag{1}$$

Hence, falling prices should increase income responsiveness over time

Compare Engel curves estimated with 2010 to 2022 household data

Table 2: Model Drift

	Estimated Using Data from 2010 (1)	Estimated Using Data from 2022 (2)
Annual Household Expenditure	0.024**	0.040**
	(.003)	(.003)
Cooling Degree Days	0.062**	0.078**
	(.010)	(.008)
1(Warm Municipality)	-0.074**	-0.068**
	(.024)	(.023)
Annual Household Expenditure * 1(Warm Municipality)	0.026**	0.023**
	(.004)	(.004)
Partial Derivative in Warm Municipalities $\frac{\partial 1(AirConditioning)}{\partial AnnualHouseholdExpenditure}$	0.050**	0.064**
	(.003)	(.003)
State Fixed Effects	Yes	Yes
Observations	27,655	90,102
Psuedo R^2	.50	.50
Mean of Dependent Variable	.127	.184

How Much of Change in Engel Curve Income Responsiveness Can be Explained by Reduction in Price of Cooling?

If preferences are Cobb-Douglas and do not change over time, then $\frac{P_t}{P_{t+1}} = \frac{\beta_{t+1}}{\beta_t}$.

Income responsiveness increased from

- 0.050 in 2010 to 0.064 in 2022 or a 28% increase in warm states and
- 0.024 to 0.040 or a 67% increase in cold states.

A 30% reduction price explains the entire increase in income responsiveness in warm states and half in cold states

Recall, however, most of the AC is in warm municipalities

Summary

Already nearly 1 million more ACs in Mexico than we predicted.

Accelerated adoption is widespread, but particularly pronounced in warm states.

Large implications for mortality, electricity demand, grid reliability, carbon emissions.

Evidence points to electricity prices and technological change as key mechanisms.

Lesson for Climate Change Literature

We provide a rare retrospective analysis in a literature mostly focused on prospective.

As with so many existing studies, we focused on income and temperature growth.

These factors are undoubtedly important, and still need much more study.

But we provide a reminder that prices and technological change matter too.

Thank You!

Comments Welcome! *lwdavis@berkeley.edy gertler@berkeley.edu*