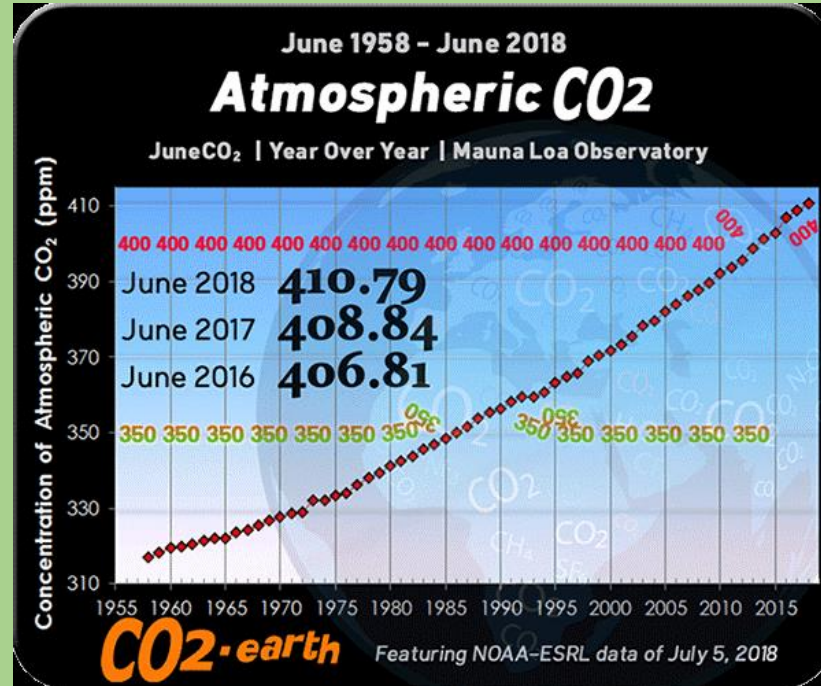# The Critical Role of Markets in Adapting to Climate Change

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The Climate Change Challenge as CO2 Levels Increase

The Climate Change Challenge Will Grow Worse

- Yes, we are decarbonizing the electric power grid
- Yes, electric vehicle progress is taking place
- But, the demand for energy in the developing world is huge and coal and natural gas offer reliable service.

  - Wolfram C, Shelef O, Gertler P. How will energy demand develop in the developing world?. Journal of Economic Perspectives. 2012 Feb;26(1):119-38.

  - Davis LW, Gertler PJ. Contribution of air conditioning adoption to future energy use under global warming. Proceedings of the National Academy of Sciences. 2015 May 12;112(19):5962-7.

  - Dargay J, Gately D, Sommer M. Vehicle ownership and income growth, worldwide: 1960-2030. ENERGY JOURNAL. 2007. 1;28(4):143.

My Climate Change Adaptation Research Question

- New reduced form empirical studies of the **Damage Function**
- Based on panel estimates for unit i at time t :
- $Damage_{it} = b_0 + b_{1t} * Climate\ Vector + U_{it}$
- Is b_{1t} shrinking toward 0 as a function of t?
- Are economies reorganizing to become better and better at adapting to "Mother Nature's Punches"?

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Some Prominent Examples of Damage Function Estimates

- Building on the Nordhaus 2018 Nobel Prize framwork
- Burke MB, Miguel E, Satyanath S, Dykema JA, Lobell DB. Warming increases the risk of civil war in Africa. Proceedings of the national Academy of sciences. 2009 Dec 8;106(49):20670-4.
- Burke M, Emerick K. Adaptation to climate change: Evidence from US agriculture. American Economic Journal: Economic Policy. 2016 Aug;8(3):106-40.
- Burke M, Hsiang SM, Miguel E. Global non-linear effect of temperature on economic production. Nature. 2015 Nov;527(7577):235.

$$Damage_{it} = b_0 + b_{1t} * Climate\ Vector + U_{it}$$

- Estimating these "cause and effect" regressions creates a problem
  - Researchers use these historical estimates
  - And use a climate change forecast to predict the future impact
  - ΔDamage $= bhat_{1t} * \Delta Climate\ Vector$
- Researchers ignore general equilibrium effects, the Lucas Critique and the role of markets in reallocation.

The Climate Vector Embodies Ambiguous Risks

- Relative to the past, "fat tail" events for climate outcomes such as temperature, rainfall, and natural disasters
- The specifics vary by geography, spatial downscaling of climate models
- A key issue is "perception versus reality" concerning these emerging risks.
- climate scientists are making progress modeling these effects and it is growing cheaper to spread this information about risks
- Robustness research and "known unknowns"
- Danger if we over-trust any one model

Why Does Climate Risk ⇒ Economic Risk?

- Marginal increase in death risk

- Marginal Damage to the capital stock

- Marginal damage to farmer productivity

- Marginal damage to public infrastructure

The IMF's Ongoing Resilience Research in Belize

- How much will climate change contribute to the nation's poverty rate?

- How much will climate change lower the Belize GNP growth rate?

- How can the IMF provide social insurance to reduce the negative impacts of natural disaster shocks and economic instability?

- Natural disasters cause recession or make a recession worse or create a rebuilding boom?

Economic Development as a Climate Adaptation Strategy

- Kahn ME. The death toll from natural disasters: the role of income, geography, and institutions. Review of economics and statistics. 2005 May;87(2):271-84.

- Kellenberg DK, Mobarak AM. Does rising income increase or decrease damage risk from natural disasters?. Journal of urban economics. 2008 May 1;63(3):788-802.

Reading #1: Auffhammer and Kahn (2019)

- The LDC farmer challenge = declining profits due to weather
- Adapt by changing crops?
- Adapt by learning from other farmers how to cope?
- Adapt by moving to the city?
- Frictions that limit behavioral changes at the extensive margin
- Risk of rural violence if fail to adapt! (tragedy of the commons in a Malthusian setting with climate change reducing resources)

Climate Change as a Lottery

- Production is a function of rain. There is no storage. All farmers were initially growing crop #1

Probability Old climate	Probability new climate	Rainfall outcome	Crop #1 production	Crop #2 production
.05	.25	Low	10	25
.6	.5	Medium	50	60
.35	.25	High	100	70

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The Portfolio Problem and the Lucas Critique

- Crop #1 is the high risk/high return strategy
- Crop #2 is the "safer" choice
- If the farmer's utility function features a subsistence point then he will want to shift to crop #2 to raise his expected utility in the face of climate change
- Is the farmer aware that the climate has changed?
- What transition costs must be paid to substitute crops?
- Can the farmer finance these costs?
- Is there a well functioning land market to sell his land?

The Portfolio Problem and Information Updating

- Is the farmer aware that the climate has changed?
- Manski CF. Measuring expectations. Econometrica. 2004 Sep;72(5):1329-76.
- Benjamin DJ, Brown SA, Shapiro JM. Who is 'behavioral'? Cognitive ability and anomalous preferences. Journal of the European Economic Association. 2013 Dec 1;11(6):1231-55.
- **More LDC research is needed here --- cognition!!**

Shifting Comparative Advantage in Farming

- Misallocation and Climate change adaptation
- Opportunity cost for the land ; who manages it and how used?
- Costinot A, Donaldson D, Smith C. Evolving comparative advantage and the impact of climate change in agricultural markets: Evidence from 1.7 million fields around the world. Journal of Political Economy. 2016 Feb 1;124(1):205-48.
- Markets for allocating the land

Urbanization as Adaptation

- If the farmer has working age or teenage children, does he send some of them to the city?
- Does he invest more in their education because he intends to send them to the city?
- Jensen R, Miller NH. Keepin"em Down on the Farm: Migration and Strategic Investment in Children's Schooling. AER forthcoming
- Bryan G, Chowdhury S, Mobarak AM. Underinvestment in a profitable technology: The case of seasonal migration in Bangladesh. Econometrica. 2014 Sep;82(5):1671-748.

Markets and Urbanization

- Is the LDC nation open to world food imports?

    Glaeser EL. A world of cities: The causes and consequences of urbanization in poorer countries. Journal of the European Economic Association. 2014 Oct 1;12(5):1154-99.

- Cities in Africa as agriculture "middlemen" (75%)?
- Henderson JV, Storeygard A, Deichmann U. Has climate change driven urbanization in Africa?. Journal of development economics. 2017 Jan 1;124:60-82.

The Extent of Market Based Consumption Smoothing

- If rural families are adapting by sending children to the city and the children remit income to the parents, consumption will be much smoother than household income

- Townsend Redux

- If markets for weather insurance, consumption is further smoothed.

- Mobarak AM, Rosenzweig MR. Informal risk sharing, index insurance, and risk taking in developing countries. American Economic Review. 2013 May;103(3):375-80.

- How does the IMF and World Bank work together to measure this?

Migration to the LDC City and the Poor's Risk Exposure

- Incentives of urban mayors to welcome the new urban poor?
- **Example:** Are Slum dwellers connected to the water grid?
- Feler L, Henderson JV. Exclusionary policies in urban development: Under-servicing migrant households in Brazilian cities. Journal of urban economics. 2011 May 1;69(3):253-72.
- Feler and Henderson's approach should be expanded to every LDC.
- Within such nations, which cities welcome the rural poor to move there?
- Urban comparative advantage: Which cities want more low skill workers to become centers of textile production? Gains to trade!

Slum Housing Quality and Withstanding Natural Disasters

- Brueckner JK. Slums in developing countries: New evidence for Indonesia. Journal of Housing Economics. 2013 Dec 1;22(4):278-90. and Harris Selod at the World Bank and slum research

Hurricane Keith's Category IV forces affected buildings large and small. Typically, damages recorded were:

Roofing sheets ripped off

Roofing tiles ripped off

Roofing sections dislodged

Entire roof loss

Wall collapse following roof loss

Complete destruction of poorly built structures

Hurricane Keith in Belize in 2000

https://www.oas.org/pgdm/document/BITC/papers/belize.doc

Close observation revealed that most damages could have been avoided if the following were adhered to:

Appropriate lath/ Purlin spacing

Appropriate roof sheet fixings (every corrugation)

Appropriate roof shingle/Tile fixings

Use of full length rafters and purlins (ie. Without short splices)

Use of joist/rafter cleats or hangers

Bolted hurricane straps for rafters/ trusses at belt beam

Nuts & bolts at corbel for lean-to roofs

Notched bracings for elevated wooden houses

Deep embedment of wooden posts without pad footing

The Critical Role of LDC Municipal Finance in Climate Risk Mitigation

- Cutler D, Miller G. Water, water, everywhere: municipal finance and water supply in American cities. National Bureau of Economic Research; 2005 Jan 31.
- Which LDC cities can issue municipal bonds? Who rates these bonds?
- If a city can upgrade its infrastructure for water quality, insulates the city from many risks.
- If the city collects property taxes, Ricardian model predicts capitalization and a tax base for paying back the debt.   --- The Big Data Revolution
- The IMF role here in rating such bonds and evaluating emerging risks

Recap! b1 is a reduced form parameter that we choose!

- New reduced form empirical studies of the **Damage Function**
- Based on panel estimates for unit i at time t :
- $Damage_{it} = b_0 + b_{1t} * Climate\ Vector + U_{it}$
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Reading #2:   Climate Change Adaptation: Lessons from Urban Economics

- In an open system of cities, Tiebout and Sherwin Rosen offer several key insights
- Menu of cities and neighborhoods in cities allows for sorting based on hedonic type
- Dynamic compensating differentials equilibrium -- local land owners as residual claimants with incentives to play defense!
- Applicable for LDCs with many cities

Nations Featuring Urban Primacy and Few Cities

- Ades AF, Glaeser EL. Trade and circuses: explaining urban giants. The Quarterly Journal of Economics. 1995 Feb 1;110(1):195-227.
- rural to urban migration ⇒ general equilibrium effects
- incumbent wages down
- incumbent rents up
- political backlash against entrants and talk of "walls"
- Paul Romer and Charter Cities

Cities ⇒ human capital investment and use ⇒ higher incomes

- People with higher incomes have an ever growing set of adaptation strategies due to markets for everything
- Air conditioning is a prime example as is the cell phone

- Barreca A, Clay K, Deschenes O, Greenstone M, Shapiro JS. Adapting to climate change: The remarkable decline in the US temperature-mortality relationship over the twentieth century. Journal of Political Economy. 2016 Feb 1;124(1):105-59.

An IMF Data Suggestion

- Building on the MIT Billion Prices Project
- http://www.thebillionpricesproject.com/
- Create an adaptation Laspeyres index for each nation
- Study the diffusion of such durable goods; in year 2019 do more poor people own an air conditioner relative to in the year 2009 in the same LDC?
- Davis LW, Gertler PJ. Contribution of air conditioning adoption to future energy use under global warming. PNAS 2015
- The Boskin Report revisited (quality progress along the adaptation dimension)

Gary Becker's Household Production Framework (HPF)

- The HPF approach assumes that consumers use market inputs and their time to produce "goods"

- Stigler GJ, Becker GS. De gustibus non est disputandum. The american economic review. 1977 Mar 1;67(2):76-90.

- Michael RT, Becker GS. On the new theory of consumer behavior. The Swedish Journal of Economics. 1973 Dec 1:378-96.

- A consumer gains utility from consumption and from being comfortable. Comfort is produced as a function of outdoor temperature (T) and by buying and operating an air conditioner.

- Max U(c,Comfort) subject to: Comfort=f(T,e) and Income = c + F + p(e)*e, where is F is the fixed cost of buying an air conditioner, e is electricity and p(e) is the electricity price

The Expenditure Function Approach to Studying Climate Change Adaptation at time t and time t+j

- At time t, What is the minimum amount of $ you need to achieve a given utility level facing outdoor temperature T?
- How much are you willing to pay to not face the temperature increase induced by climate change?
- This is **not** a stationary problem, The FOC change as the comfort production function shifts
- Stationary preferences and a shifting household production technology
- Over time (think Boskin Report), the menu of adaptation products increases and become cheaper and more efficient. The air conditioner diffuses widely and more people (even the poor) adapt.

Reading #3   Bunten and Kahn (2017)

- The Optimal durability of capital is shorter when we face spatial uncertainty
- Option value is ever more valuable as volatility of spatial risk increases
- Modular capital that can be moved at a cost "Lego"
- A leading JMP in 2018 on sunk public infrastructure capital in Vietnam
- https://sites.google.com/prod/view/clarebalboni/home

Public and Private Capital Investments: Complements or Substitutes?

- Does government spending crowd out private self protection or re-enforce it?
- The interplay between building sea walls and building a nearby hotel
- moral hazard and "too big to fail" redux
- Kousky C, Luttmer EF, Zeckhauser RJ. Private investment and government protection. Journal of Risk and uncertainty. 2006 Sep 1;33(1-2):73-100.

Resilience through investing in People or Places?

"Likewise, social spending programs that redistribute from higher-income to lower-income groups can decrease poverty and inequality. They can also increase the resilience of lower-income households to economic shocks—including from demographics, technology and climate—which are expected to become more frequent and disruptive."

Forging a Stronger Social Contract—the IMF's Approach to Social Spending

By Christine Lagarde, Managing Director, IMF   June 2019

Person Based Interventions

- Early Education (Heckman)

- Move to Opportunity (in the U.S, Raj Chetty and co-author's work).
- A classic question in urban economics: Do you invest in urban places or urban people?

IMF's Role in LDC Climate Change Adaptation?

- A microeconomist's perspective!
- During "normal times"
- "Honest Broker" --- stress tests of infrastructure similar to bank stress tests
- Facilitate the development of capital flows for enhancing resilience
- Alerting LDC leaders about "fat tail" risks --- imagination and option value and contingencies related to critical infrastructure

Misallocation Inhibits Climate Change Adaptation

- When price signals are "muffled", misallocation will occur and this will slow down adaptation.
- Water pricing for farmers in the U.S West
- The Political economy of open trade in agriculture to protect the poor from food price spikes
- Why do "wedges" persist and how costly are they?
- Becker GS. Public policies, pressure groups, and dead weight costs. Journal of public economics. 1985 Dec 1;28(3):329-47.

The IMF's Challenge When a Macro Crisis and a Natural Disaster Occur Simultaneously

- When a poor nation faces both a macro crisis and a natural disaster, how does the IMF respond?
- The poor face great risk
- Does the natural disaster exacerbate the macro crisis?

- Public versus private injections of cash
- Inject $ directly to people via "give directly"
- Registry, don't want people to move to the disaster area to receive a check (moral hazard).
- https://www.givedirectly.org/research-at-give-directly

The Big Data Revolution and New Real Time Data for Tracking Well Being

- https://www.citylab.com/environment/2018/05/watch-puerto-ricos-hurricane-migration-via-mobile-phone-data/559889/

Hurricane Maria and cell phone tracking to establish migration patterns

- Zheng S, Wang J, Sun C, Zhang X, Kahn ME. Air pollution lowers Chinese urbanites' expressed happiness on social media. Nature Human Behaviour. 2019 Jan 21:1.

- https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=duncan+thomas+indonesia+tsunami&btnG=

Empirical Tests of LDC Adaptation Progress

- Death counts from similar natural disasters
- Food prices when nation has bad climate induced harvest
- Price of electric power and blackouts when extreme heat
- Birthweight of new children born in that year and infant mortality
- Real time indicators of suffering
- Benchmarking nations --- should be part of the Sen and Stiglitz Standard of Living Index!

My New Climate Change Adaptation Book

- New reduced form empirical studies of the **Damage Function**
- Based on panel estimates for unit i at time t :
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- Is b_{1t} shrinking toward 0 as a function of t?
- Are economies reorganizing to become better and better at adapting to "Mother Nature's Punches"?

The Central Role of Human Capital in Adaptation

- Who has the capacity to "change their game" and cope with new risks?

- Who is "Leontief" such that they cannot adjust?

- How do markets protect the "infra-marginal"?

Conclusion

- Market prices signal scarcity. Climate Change➔ greater scarcity
- How do we cope with such scarcity? How do we substitute? Who can?
- The importance of country "specificity"
- My points today have been "high level" at "30,000 feet"
- I am eager to delve into the specific details of the adaptation challenges that different LDC nations face
- I have had very little to say today about carbon mitigation

- Glaeser EL, Kahn ME. The greenness of cities: carbon dioxide emissions and urban development. Journal of urban economics. 2010 May 1;67(3):404-18.

Conclusion #2   Political Economy and Climate Change Mitigation

- The political economy fight over introducing carbon pricing in the U.S and around the world revolves around income effects and incidence. (think of the French Yellow Vest protests)
- Who has the property rights to emit GHG?
- Economists are usually silent on this issue.
- Harstad B. Buy coal! A case for supply-side environmental policy. Journal of Political Economy. 2012 Feb 1;120(1):77-115.
- It will be easier to adapt to the challenge if we sharply mitigate now
- mitigation and adaptation as complements!

Conclusion #3 The Critical Role of Markets in Adaptation

- At a point in time, who has a comparative advantage in adapting to new risks?
- Markets send signals to encourage such individuals to use this skill
- Over time, how is this skill built up?
- The implications of Paul Romer's 2018 Nobel Prize research for climate change adaptation
- Acemoglu D, Linn J. Market size in innovation: theory and evidence from the pharmaceutical industry. The Quarterly journal of economics. 2004 Aug 1;119(3):1049-90.