Structural Transformation, Agriculture, Climate, and the Environment

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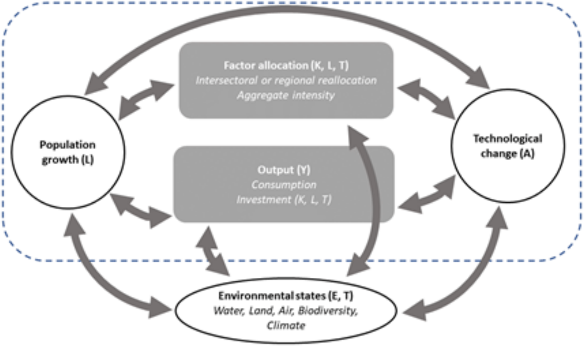
Motivation

- Standard growth models: $Y = Af(K, L, T)$
  - A: Hicks-neutral technology parameter (TFP)
  - $f(.)$: production function
  - K: capital stock, L: work force, T: available land, Y: total output (and income)
- These models make strong assumptions, among them:
  - Economic processes are independent of changes in the natural environment
  - Yields a striking prediction: In equilibrium, K,L,T endowments, are non-decreasing over time, thus $f(.)$ is as well
  - Only the *relative* returns to a factor of production, like land, may diminish, not the *absolute* returns

Motivation



- This paper makes the case for relaxing that untenable assumption
- Climate and environmental conditions *affect and are affected* by
  - absolute and relative factor productivity
  - the rate of technological change
  - the structural transformation process

The climate and environmental impacts of structural transformation

Agricultural production and GHG emissions

- Agriculture, Forestry and Other Land Uses (AFOLU) are responsible for $\approx$ 24% of global GHG emissions
    - Agricultural production alone is responsible for more than half
    - AFOLU emissions have increased substantially in Asia, poised to do so in Africa
- Carbon intensity per unit of output has declined by about 40% in both crop and livestock production since the 1970s (Bennetzen, Smith, and Porter, 2016b)
- But LMICs expanded both emissions and production over 1970-2007 (Bennetzen, Smith, and Porter, 2016a)

Agricultral production and land use

- The same agricultural technological change that reduced carbon intensity has dramatically affected land use
- Agricultural extensification appears the main driver of deforestation globally, responsible for
  - 83% of forest cover loss across the tropics between 1980 and 2000 (Gibbs et al., 2010)
  - 51% from 2001 to 2015, over which time 92% of Africa's forest cover loss was attributable to smallholder agricultural extensification (Curtis et al., 2018)
- Agricultural land conversion is also the primary driver of biodiversity loss, especially in LMICs (IPBES, 2019)

Agricultural production and water use

- Agriculture accounts for roughly 70% of aggregate water withdrawals, often exceeding 80% in Africa and Asia
- Agriculture also pollutes, generating chemical residues and livestock waste (Paudel and Crago, 2021)
    - which especially affects fisheries productivity and human health (e.g., HABs, infectious diseases)

Feedback from climate and environmental change to structural transformation

Impacts on returns to land & agricultural technologies

- Rising temperatures have substantial ecological and hydrological impacts, which disproportionately affect agriculture
  - Shift ranges of pest and pathogens (Bebber 2015) w/ substantial crop losses related to pests in a warming climate (Deutsch et al. 2018)
  - Increase in evapotranspiration, exacerbating salinization in coastal regions especially (Colombani et al. 2016)
- Climate change has slowed TFP and yield growth in major crops
  - Mostly due to recent warming trends, with a few regional exceptions (Lobell and Field 2007, Lobell et al. 2011).
  - Anthropogenic climate change may have reduced global agricultural TFP by about 20% over 1961-2020, with even larger impacts in warmer regions such as sub-Saharan Africa (Ortiz-Bobea et al. 2021).

Impacts on returns to land & agricultural technologies

- Climate and environmental change can indirectly affect the relative returns to land-based livelihoods through changes in agriculture's risk profile
  - Incomplete insurance markets: climate variability induces risk averse households to reallocate labor and capital towards non-farm livelihoods less subject to climate risk (Barrett et al. 2001; Macours 2013)
  - Increased climate variability can induce collapse of fragile (e.g,. pastoralist) systems (Barrett and Santos 2014)
  - Exogenous productivity shocks can
    - generate windfall gains directly, or via a temporary stimulus to local demand for non-farm nontradables (Foster and Rosenzweig 2007; Emerick 2018)
    - cause shortfalls that households cover through increased non-farm labor effort (Kochar 1999; Jayachandran 2006)

Impacts on returns to land & agricultural technologies

- Sea-level rise (SLR) and increased flooding due to climate change interact dangerously with natural subsidence
    - Under business-as-usual and moderate emission-mitigation-policy scenarios, by 2050 most of the tropics are projected to experience annual exposure to the present-day 100-year extreme SLR (Vousdoukas et al. 2018)
- SLR effects are spatially concentrated
    - 8 Asian countries – Bangladesh, China, India, Indonesia, Japan, Thailand, the Philippines, and Vietnam – are home to more than 70% of the world population now occupying land vulnerable to SLR (Kulp and Strauss 2019; Vousdoukas et al. 2020).

Impacts on returns to land & agricultural technologies

- Summary: economic feedback effects of anthropogenic climate/env't change on land disproportionately impact agriculture, esp. in rainfed tropical agroecosystems more vulnerable to rising temp, SLR and shifting animal and plant pest and pathogen ranges.
- May retard structural transformation in lower-income, agrarian countries by slowing rate at which agricultural productivity growth
  - releases labor to non-farm sectors (esp. formal non-farm)
  - generates surpluses to invest off farm
  - and stimulates domestic demand for non-farm non-tradables

Impacts on human capital formation

- High temperatures generally worsen human capital outcomes
  - increased risk of infant mortality, low birth weight and preterm delivery (Deschênes, Greenstone, and Guryan, 2009; Banerjee and Maharaj, 2020)
  - increased adult mortality rates (Deschênes and Greenstone, 2011)
  - worse cognition and educational outcomes (Graff Zivin, Hsiang, and Neidell, 2018; Park et al., 2020; Garg, Jagnani, and Taraz, 2020)
- Limited evidence on the impacts of long-run variation in temperature on human performance
  - few results available (e.g., (Graff Zivin, Hsiang, and Neidell, 2018)) suggest caution in projecting long-run climate impacts based on estimates from short-run weather shocks

Impacts on human capital formation

- Precipitation's impacts on human capital outcomes differ by contexts and time scale
  - In India, early-life positive rainfall shocks improve school enrollment, grade progression and test scores of children
  - But positive rainfall shocks have contemporaneous negative effects on school attendance, enrollment and education performance (Shah and Steinberg, 2017)
- The apparent mechanisms mostly concern
  - Income effects in the face of liquidity constraints that reduce inputs important to child development
  - Substitution effects in the face of increasing opportunity cost of schooling associated w/ higher wages and MRPL in ag

Impacts on human capital formation

- Air pollution has large, negative effects on fetal, infant and child mortality (Jayachandran, 2009; Arceo, Hanna, and Oliva, 2016; Heft-Neal et al., 2018; Bombardini and Li, 2020)
- In utero and early-childhood exposure to pollution can have lasting effects on various later-life outcomes: school exams, adult labor force participation, adult earnings, and IQ test scores (Bharadwaj et al., 2017; Black et al., 2019; Isen, Rossin-Slater, and Walker, 2017; Sanders, 2012)
- Effects concentrate mainly in urban areas, although the burning of crop residues/forests can reduce geographic differences

Impacts on human capital formation

- The impacts of water quality on human capital in LMICs has been less well studied.
  - Upstream use of rivers for bathing and other sanitary practices explains as much as 7.5% of diarrhea-related deaths annually in Indonesia (Garg, Hamilton, et al., 2018)
  - The effects fall disproportionately on rural and poorer households with less access to piped, potable water and indoor plumbing

Impacts on human capital formation

- Deforestation affects human capital accumulation through
  - increased air pollution due to smoke and suspended particulates from burning forest to clear land for cultivation
  - induced local climate change and disease ecology
    - Tropical deforestation due to agricultural expansion has been repeatedly linked to increased vector-borne and zoonotic disease (Tucker Lima et al., 2017; Brock et al., 2019)
    - Agricultural drivers – primarily land conversion – are associated with more than 25% of all new infectious diseases in humans since 1940, including more than 50% of zoonoses (Rohr et al., 2019)
- Deforestation has spatial spillover effects
  - The effects on neighboring and remote regions that are not deforested dominate the local effects (Winckler et al., 2019)

Impacts on human capital formation

- The estimated net impact of climate and environmental change on human health capital is perhaps best captured by the estimated disability adjusted life years (DALYs)
  - Poor air and water quality contributed 22% of the DALYs lost globally in 2010 (Lim et al., 2012)
  - Human, domestic animal, and zoonotic infectious pathogens are climate sensitive, and will likely worsen with climate change to account for perhaps 40% of total DALYs (McIntyre et al., 2017)

Impacts on labor productivity

- The evidence on labor productivity remains scant, especially in developing countries
  - High temperature adversely affects labor productivity, even for indoor manufacturing activity in India (Somanathan et al., 2021; Adhvaryu, Kala, and Nyshadham, 2020)
  - Air quality can also directly affect labor productivity independent of human capital formation (Hanna and Oliva, 2015)
    - for both outdoor activities (Graff Zivin and Neidell, 2012)
    - and indoor activities (Adhvaryu, Kala, and Nyshadham, forthcoming; Chang et al., 2016; Chang et al., 2019), including by seemingly affecting cognitive performance and decision making
- Little compelling evidence exists on differential intersectoral effects
- Climate change may magnify pre-existing intersectoral labor productivity differences that help drive structural transformation. Deadweight loss from frictions to labor mobility likely to rise.

Impacts on allocation of labor

- 143 mn internal climate migrants predicted by 2050 (Rigaud et al., 2018), ignoring induced international migration.
- Climate refugees appear most likely to move to cities w/ jobs, social services, accelerating the spatial/intersectoral flow of labor for those who can migrate (Cattaneo and Peri, 2016; Cai et al., 2016)
- The complex relationship between climate and environmental change and migration appears highly contextual. No unified theory has yet emerged that satisfactorily reconciles key empirical observations (Cattaneo, Beine, et al., 2019; Kaczan and Orgill-Meyer, 2020; Hauer et al., 2020)

Major policy research questions

Agricultural research and extension

- Agricultural R & D and extension still play important role in LMICs
  - Rising food demand must be met mainly through local agri-food TFP growth to avoid increased food prices, poverty and food insecurity
  - Advances in genomics and synthetic biology can accelerate and broaden the scope of genetic advances and fine-tuning varietal characteristics to local needs (Barrett 2021)
- Adaptive research is especially needed for climate change, increased risk of drought and flooding (especially with sea water), and to pathogens and pests whose ranges are shifting
- Privatization of agricultural R&D raises important issues surrounding intellectual property and market concentration and the legal and economic institutions needed to support tech diffusion
- post-harvest R & D growing more important (Barrett et al. in press)

Facilitating de-agrarianization

- Accelerating de-agrarianization from CEA, plant-based and cellular ASF substitutes, circular feeds, etc. (Barrett et al. 2020) will
  - release labor from agriculture
  - release land for PES
  - expand the supply of intermediate inputs (e.g., electricity) for manufacturing, processing & services in secondary towns
  - stimulate rural non-tradables demand and employment through local general equilibrium effects
- De-agrarianization requires alternative, non-agricultural income streams become viable for rural landowners (Barrett 2021)
  - Renewable energy production
  - C markets to monetize sequestration in trees, soils, cover crops
  - Payments for ecosystem services

Rural infrastructure

- Rural communications, electricity, and road infrastructure are key investments for rural areas
  - partly by stimulating agricultural productivity growth
  - but perhaps even more by facilitating non-farm labor markets and enterprises (Asher and Novosad, 2020; Fan and Chan-Kang, 2005)
- Rural roads: mixed evidence
  - Highway upgrades in India led to substantial forest loss due to increased timber demand (Asher, Garg, and Novosad, 2020)
  - Road expansion in regions w/substantial prior clearing attracts dev't away from extensively forested areas (Weinhold and Reis, 2008)
- Access to broad band internet service
  - facilitates orderly migration out of geographic poverty traps (Kraay and McKenzie 2014; Barrett et al. 2019)
  - enables rural lands' remunerative use in non-agricultural production of energy or environmental services.

Conclusions

- Must explicitly incorporate bidirectional feedback b/n nature and land, labor and physical capital stocks and factor productivity, as well as TFP growth in future research on structural transformation
- Several big challenges ahead in this research agenda
  - High-quality, linkable data for rigorous empirical work remain scarce in LMICs, especially longitudinal health, socioeconomic, weather data and data that cover agri-food value chains over time
  - Research that endogenizes structural transformation, climate and environmental factors necessarily poses methodological challenges, esp. for causal inference
  - Advances in economic theory are necessary to develop testable hypotheses around mechanisms through which anthropogenic climate or environmental changes affect the returns to and intersectoral allocation of factors of production

Thank you for your time, interest, and comments!