Urban Informality, Floods and Spatial Equilibrium: Evidence from Mumbai

Kathryn Nicholson
George Washington University

Abstract

Flooding has become among the most prevalent and costly natural disasters globally, with 20 percent of the world's population in flood-prone areas, 90 percent of which are in low- and middle-income countries (LMICs). With economic activity concentrated in cities, urban markets represent the primary center requiring climate adaptation as well as a primary source for change. Evaluating climate impacts in rapidly growing LMIC cities requires incorporating vacant land expansion alongside a potentially large informal sector. I focus on Mumbai, a major urban center facing severe inland and coastal flooding that is projected to worsen. I build a quantitative spatial general equilibrium model with vacant land, formal and informal firms and housing, and flood risk in the development decision to quantify how flooding reshapes economic activity and housing development. I document a formal-informal divide in urban housing market responses to flood risk. Productivity costs of flooding are high for the formal and informal sector, but especially for informal areas. The results show incorporating informal market dynamics and land availability is critical for analyzing climate impacts and policy in developing cities.

Context

- There is a dynamic extensive and intensive margin to slums and climate risk.
  - **Extensive**: Slums are more likely to be in flooded areas, and more likely to be in places of worsening flooding.
  - **Intensive**: Slums are larger in areas of worse flooding and growing into areas of worsening risk.
- Slums in India between 2008-2012 grew 150% in size, number of slum HHs 50%.
- About 30% of slums are in waterlogged areas of frequent stagnant water.
  - **Reduced form results:** Waterlogged slums in high rainfall areas are growing differentially fast, growing 45% larger annually.
- Rainfall and flooding has been increasing in all of India, and in Mumbai.
  - Rainfall in India has increased since 1970 where there is a structural break.
  - Floods in India have increased in frequency since 2000.
  - Extreme monsoonal rainfall in Mumbai has increased since 1970 and 2015.

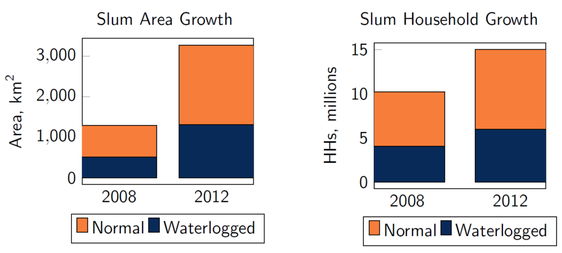


Figure 1. India slum growth 2008 to 2012.

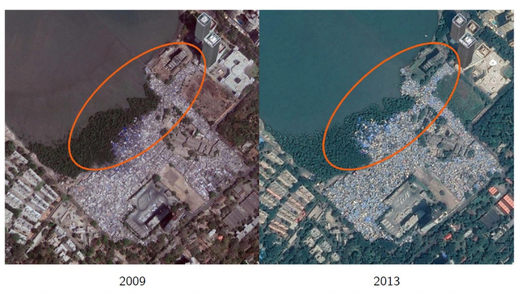
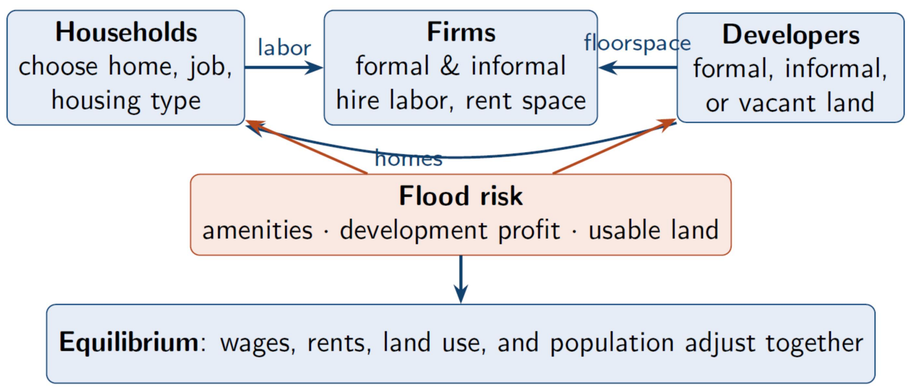


Figure 2. Colaba Slum, Mumbai, 2009 and 2013.

QSM Model Architecture

Quantitative Spatial model (QSM) over 88 locations within Mumbai.
Model features: Formal and informal housing and firms, individuals, vacant land



- Workers pick residence, workplace, housing type
- Firms choose number of workers to hire and how much floorspace to operate on
- Developers choose between vacant, formal or informal floorspace development

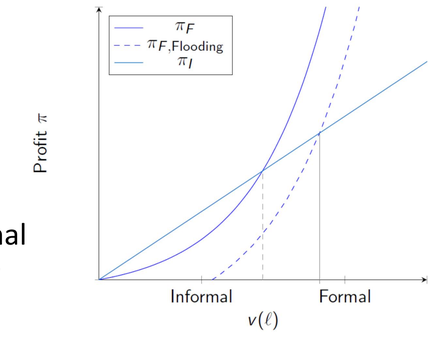
Model Mechanisms

Flooding changes the development tradeoff between vacant, formal, informal.

Housing Production: Multistory buildings use a Cobb-Douglas aggregate of land and capital $H_i = T_i^{1-\eta} K_i^{\eta}$ where T_i supply of developable land, plots $\ell \in [0, T_i]$; each plot is developed formally, informally, or left vacant.

Developers maximize profits according to each technology (formal or informal) and the highest profit determines use.

With flooding: Formal technology chosen if higher profits and/or lower flood risk. Informal technology chosen if low profitability and/or high flood risk.



Results

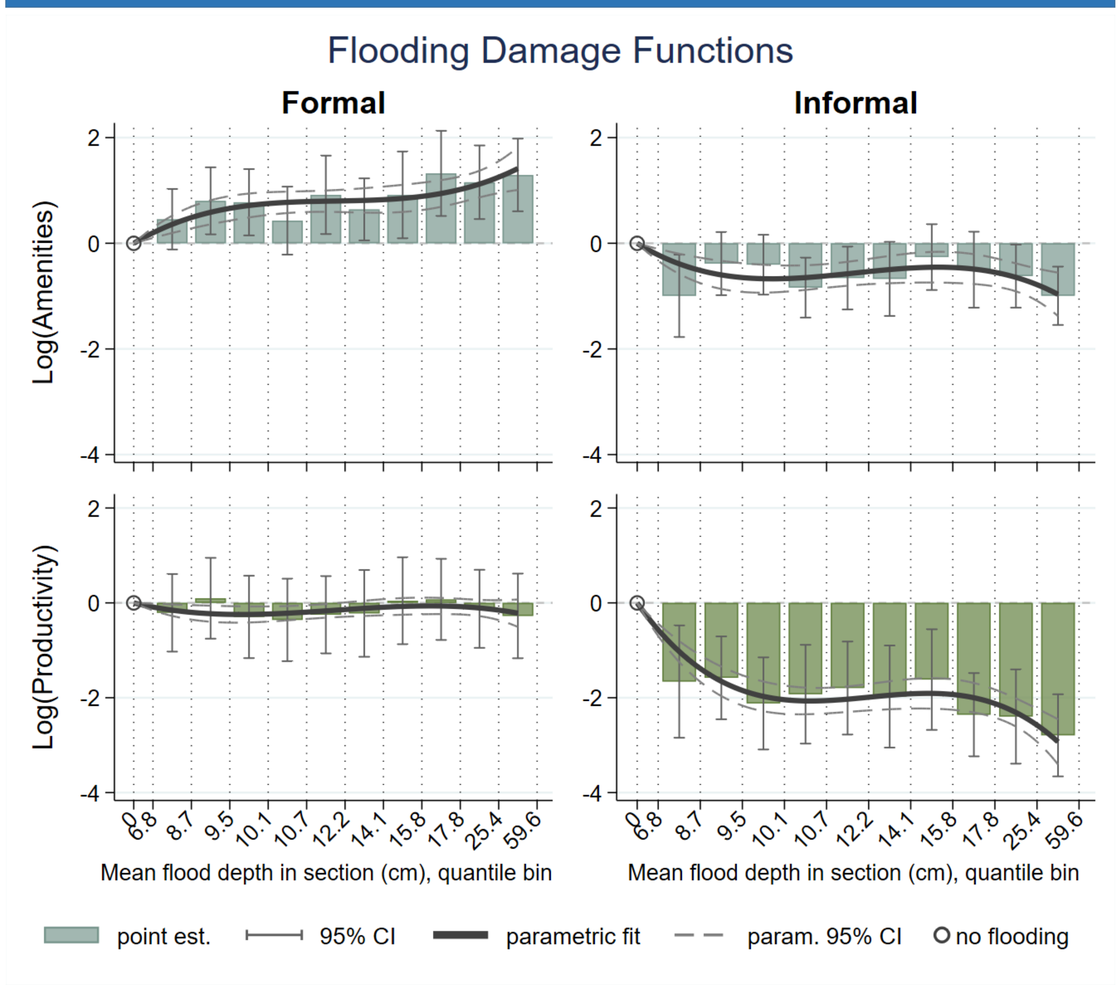


Figure 3. Formal and Informal sector damage functions for flooding

Model Counterfactuals

Quantitative exercises: given a shock, residents relocate.

1. Informal expansion: More informal housing in a ward, results in either denser or larger slum footprint.
2. Formalization: Remove informal development. Land shifts to formal or vacant, and households relocate across the city.
3. Land loss: Flooding or sea-level rise removes land. Informal floorspace shrinks more than formal, so the housing mix shifts formal.

Conclusions

Incorporating informal market dynamics and land availability is critical for analyzing climate impacts and policy in developing cities.

- Unlike damage functions for other types of hazards, costs from flooding are high and remain high across levels of flooding. Informal sector bears high costs.
- Formalization only increases welfare slightly.
- The spatial location of development is crucial.

Contact

Kathryn Nicholson
George Washington University
Email: kanicholson@gwu.edu
Website: https://kathrynnicholson.com
Phone: +19782540050

References

1. Balboni, C. (2025). In harm's way? infrastructure investments and the persistence of coastal cities. American Economic Review, 115:77–116.
2. Desmet, K., Kopp, R. E., Kulp, S. A., Nagy, D. K., Oppenheimer, M., Rossi-Hansberg, E., and Strauss, B. H. (2021). Evaluating the economic cost of coastal flooding. American Economic Journal: Macroeconomics, 13.
3. Gandhi, S., Kahn, M. E., Kochhar, R., Lall, S., and Tandel, V. (2022). Adapting to flood risk: Evidence from a panel of global cities. SSRN Electronic Journal.
4. Gechter, M. and Tsivanidis, N. (2023). Spatial spillovers from high-rise developments: Evidence from the mumbai mills. Working Paper.
5. Guedes, R., Iachan, F. S., and Sant'Anna, M. (2023). Housing supply in the presence of informality. Regional Science and Urban Economics, 99.
6. Harari, M. and Wong, M. (2024). Slum upgrading and long-run urban development: Evidence from indonesia. Forthcoming Review of Economic Studies.
7. Hsiao, A. (2024). Sea level rise and urban inequality. AEA Papers and Proceedings, 114:47–51.
8. Kocornik-Mina, A., McDermott, T. K., Michaels, G., and Rauch, F. (2020). Flooded cities. American Economic Journal: Applied Economics, 12.