

# **Spatial Transformation and Energy Efficiency: Lessons from India**

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# An Outline

- Developing countries are undergoing rapid spatial transformation. Their transformation is taking intriguing twists and turns. Whether spatial transformation exacerbates or alleviates energy efficiency is important for issues ranging from improving growth to stemming rising pollution levels.
- Our work focuses on the intersection of economic geography and energy usage. How has energy efficiency evolved? Do they differ spatially across urban and rural areas? Is energy usage converging or diverging across different states?
- Building on macro-micro linkages, we provide an analytical foundation for understanding the heterogeneity that exists in energy usage patterns. This helps policy makers to consider the unintended consequences of well motivated policies (transport, urbanization, private sector development) and mitigate pollution levels.
- How developing countries (India in particular, which is the fourth largest energy consumer in the world) manages growth and its underlying industrialization, urbanization and infrastructure investments will have important environmental implications.

# Energy Efficiency trends are hard to add up.

- While we may instinctively rank some dimensions of energy efficiency in order, the trends in India are hard to add up. The aggregate trends and their future trajectories are comprised of spatial and industrial developments in energy usage.
- Urban settings reduce the cost of electricity use per output level due to denser customer bases and more efficient plant sizes for local energy producers, **but** the largest enterprises in India are moving towards rural locations, often provisioning some of their own energy, and new plants are often built in the process.
- Average electricity consumption is larger among organized/formal plants in **rural** regions than in urban regions. This deviation is growing over time.
- India is slowly improving energy efficiency. Its energy intensity of GDP has declined from 1.09 kilogram unit of oil equivalent (koe) in 1981 to 0.66 in 2011. **China's energy intensity** is roughly 1.5 times that of India.
- Electricity consumption per capita in India is low at 566 KWh, compared to the world average of 2,782 KWh per capita. Nearly 35 percent of enterprises in the manufacturing sector have insured themselves against outages by self-generating.

# Spatial Transformation is taking intriguing turns.

- The organized sector in India is migrating to rural locations with the share of urban plants falling from 72% to 62% from 1989 to 2010. In contrast, the unorganized sector is urbanizing, with the share of urban plants increasing from 21% to 42% during the same period.
- The organized sector has located in rural sites along major transport corridors, like the Golden Quadrangle transport highway network. This has activated medium-density intermediate cities to be an important part of India's manufacturing growth.
- Three energy usage trends stand out. First, plants in urban areas generally use less electricity. Second, greater distance from larger cities is generally associated with higher electricity usage per output level. Third, intermediate cities may not be behaving differently with respect to energy usage.

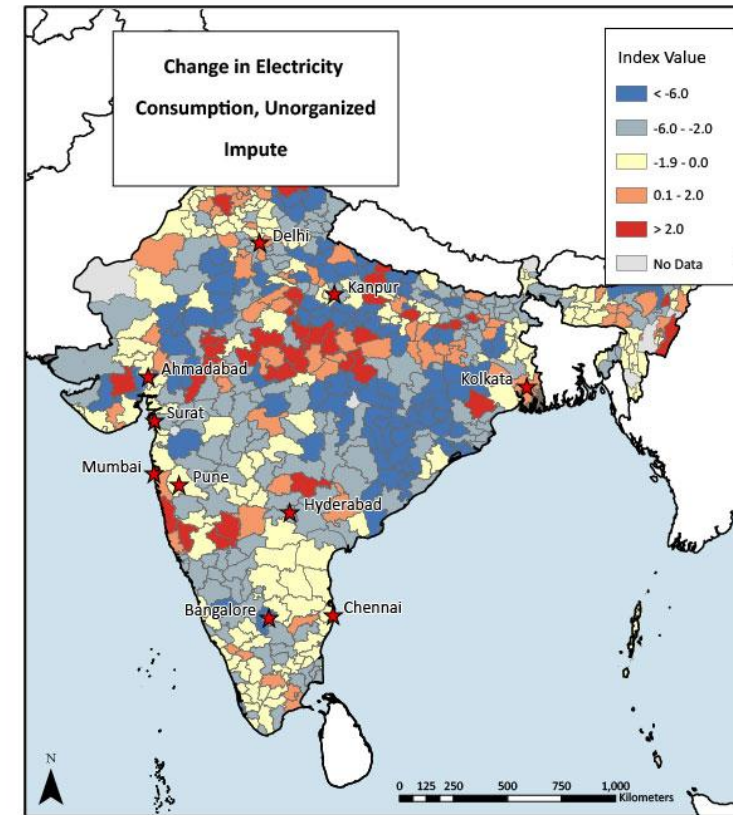
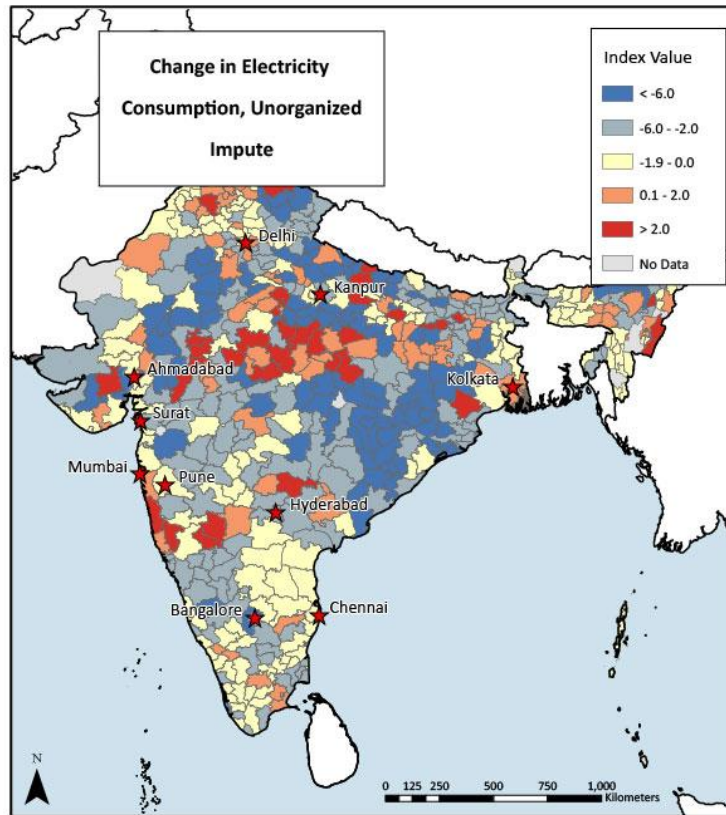
# Heterogeneity in energy usage across urban and rural areas.

- Electricity consumption per unit of output declined in urban areas for the formal enterprises.
- Electricity consumption per unit output peaked in the rural areas in 2000 and thereafter it declined for the formal enterprises.
- Informal enterprises in urban areas show a declining trend as well, while their rural counterparts show a declining trend only if we consider the data with imputations.

# Heterogeneity in energy usage across states but also substantial convergence.

- Usage of electricity per unit output is remarkably high in some states (e.g., Madhya Pradesh, Orissa), and their consumption per unit output is in double digits and often twice the national average ratio.
- By contrast, in states like Delhi and Haryana, electricity consumption per unit of output remains consistently below the national average ratio.
- The regional differences are also reflected at the district level, with regional patterns being especially prominent in the unorganized sector. In the organized sector, the local heterogeneity within states is as large as the heterogeneity across states.
- There has been a substantial convergence across states in terms of electricity usage per unit of output.
- Observation of higher electricity consumption per output unit for a given state may indicate inefficient usage. However, it could also indicate greater available supply of energy in the local area or the sorting of plants that need electricity to places where the electricity can be readily provided.

# District-level changes in average electricity usage rates



# Heterogeneity in energy usage across industry but also some convergence.

- Textiles, paper and paper products, basic metals, and non-metallic mineral products display the largest consumption of energy per unit output. Industries that display lowest usage include tobacco products and office, accounting and computing machinery.
- Differences in usage levels partly reflect the nature of industrial production processes and chosen scale that makes some industries generally more electricity intensive than others.
- Convergence over time in usage levels across industries. In fact, the convergence correlations at the industry level are as high as they are at the state level.
- This convergence is as much through growth in consumption levels for some industries (e.g., office, accounting and computing machinery) than declines in other industries (e.g., textiles).
- Enterprises in rural areas consume more electricity per unit of output. This pattern aligns with anecdotes of larger plants moving to rural areas, building their own generation facilities, and potentially taking advantage of weaker regulations regarding production and pollution.



# Decompositions of Electricity Usage

- Electricity usage per output unit decreased between 2000 and 2010, for India as a whole and within each sector.
- In the decompositions of these changes, we find that most reductions in usage came from lower usage in existing state-industry-urban/rural cells.
- The second biggest factor for promoting lower usage was the lower usage levels among fast-growing sectors. By contrast, spatial movements of manufacturing activity across India did not significantly reduce electricity consumption per unit of output and may have even increased it.
- The split nature of manufacturing mobility—with the organized and unorganized sectors moving in opposite directions with respect to urbanization—diminished the energy usage reductions from what might have otherwise occurred. When separated, the **within** component of both sectors is a stronger force for reductions in electricity consumption while the **between** effect acts to increase usage levels. Combining sectors washes out some of these within effects.
- Patterns of migration for sectors across states and industries also play a role.

# Decompositions of changes in energy usage per output unit

	Total Activity		Organized Sector		Unorganized Sector		
	Without winsorization and imputation	With winsorization and imputation	Without winsorization and imputation	With winsorization and imputation	Without winsorization and imputation	With winsorization and imputation	
	(1)	(2)	(3)	(4)	(5)	(6)	
A. Sector change in electricity usage per output unit using balanced panel of state-industry-urban/rural areas							
Share start	0.054	0.044	0.063	0.047	0.025	0.036	
Share ending	0.035	0.030	0.038	0.031	0.023	0.023	
Share change	-0.018	-0.015	-0.024	-0.016	-0.002	-0.012	
B. Decomposition: Bailey et al. (1992)							
Within component	-0.018	-0.014	-0.022	-0.014	-0.002	-0.010	
Between component	0.001	0.001	0.001	0.021	0.009	0.013	
Covariance term	-0.001	-0.002	-0.003	-0.023	-0.009	-0.016	
Total	-0.018	-0.015	-0.024	-0.016	-0.002	-0.012	
C. Decomposition: Griliches and Regev (1995)							
Within component	-0.018	-0.015	-0.023	-0.025	-0.007	-0.018	
Between component	0.000	0.000	-0.001	0.010	0.005	0.005	
Total	-0.018	-0.015	-0.024	-0.016	-0.002	-0.012	

# Is land, labor or energy holding back India?

- Given the importance of different factors of production and their relative scarcities, it is useful to compare energy usage to land and building usage. This comparison principally highlights how land and building access appears to be the larger constraint for India than energy access.
- This is not to say that India cannot make substantial improvements upon its current energy position—these steps are necessary and important.
- Land and building costs per unit of output are rising for all sectors of Indian manufacturing. This trend is in sharp contrast to the broad-based declines in energy usage per unit of output.
- Land and building usage per output unit for the organized sector is 2-3 times larger than electricity usage per output level, and for the informal sector, land and building usage tends to be 5-10 times larger than electricity usage.

# Policy implications

- India faces multiple challenges.
- Effective policy may need to extend beyond urban areas and also include rural areas.
- Usage is an important component of efficiency, and, all else being equal, using less electricity to achieve a given level of output is more efficient. But one should not label every increase in electricity cost per unit of output a bad thing. In a context where electricity supply is often incomplete and uncertain, efficiency can involve increased usage levels as it unlocks better production techniques.
- India is home to about 350 million people who lack access to electricity. Lack of access to energy and unreliable energy supply forces firms to invest in self-generation capacity at the expense of more productive capital, outsource part of the production process, or expand firm size.
- India's policy makers are frequently framing their thoughts in terms of which input to industrialization—e.g., land, energy, labor—is the biggest bottleneck for India's advancement. Need more work here.

# Conclusions

- Spatial transformation has not improved energy efficiency.
- There has been substantial convergence in usage levels across states and industries. Reallocation of activity across sites has not sped up these declines and may have slowed them.
- Medium-sized plants have the most difficult time given that their modest plant scale does not justify extensive investments in self-provision capacity but their higher levels of operation make them more vulnerable to uncertainty than smaller plants. In this sense, access to power may even be a barrier to scaling businesses in India, limiting allocative efficiency.

# Conclusions

- To the extent that electricity production standards and pollution emissions are homogeneous across India, then our results (positive and negative) can be mostly translated into associated pollution outcomes.
- However, there are many reasons to believe the creation of energy has different pollution emissions across India, especially the self generation of electric power. Better insights are needed into whether a trade-off exists between productivity gains for individual firms from self-production of power and greater pollution as a result. This would be informative for improving the design of possible carbon pricing schemes.
- More insights are needed in the energy usage impact of infrastructure projects. Is there a relationship between infrastructure development and the movement of heavy-use industries towards areas with electricity subsidies, which are quite common across India?

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