# ICT investments on productivity: The example of mobile towers in Ethiopia

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- After experiencing sustained and high economic growth, Ethiopia entered a reform period to realign economic incentives and encourage private sector-driven growth.

- Investments in the information, communication, and technology (ICT) sector have emerged as one potential engine of future growth and productivity. This includes the construction of mobile towers and giving access to mobile networks.

- Our findings show how ICT investments relate to substantial positive growth effects. These includes beneficial contributions of mobile coverage towards structural transformation, especially towards jobs associated with a modern, less agrarian economy. There are also positive interaction effects with locations that have all-weather road access.

- Finally, our evidence suggests there are potential beneficial effects of mobile coverage on market integration, by limiting price gaps and price variability over time.

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## Overview

The Ethiopian economy has experienced sustained, high growth over the past two decades, and access to infrastructure improved significantly. However, productivity growth has not kept pace with public investments. Eventually, economic growth slowed and macroeconomic imbalances emerged. These economic challenges prompted the new administration led by Prime Minister Abiy Ahmed in 2018 to adjust the country's policy response to identify and focus on new growth drivers: building on the achievements of the past two decades, Ethiopia entered a reform period to realign economic incentives and to encourage private sector-driven growth.

### ICT investments as a potential growth driver

Investments in the information, communication and technology (ICT) sector have emerged as one potential engine of future growth and productivity. Of the manifold dimensions along which ICT investments could possibly affect productivity, this policy brief focuses on one particular example: the large-scale expansion of mobile towers throughout Ethiopia over the last two decades.

Mobile tower construction and the resulting access to mobile networks can dramatically improve information provision, communication and coordination in the economy. Farmers learn about up-to-date market prices, workers hear about job openings, firms find suppliers and buyers, and economic activity can reallocate to increase growth and welfare: some farmers produce more for market, while others leave farms for factories, workshops or service sector jobs; traders compete between market places; workers migrate or commute to jobs; firms access modern technology and innovate; new enterprises are being founded; households gain access to a (mobile) bank account; and school children learn how to use modern technology.

## Policy motivation for research

### The effects of mobile tower expansion on growth and productivity

In this policy brief, we present early-stage findings on some of the above effects of mobile towers on growth and productivity: we highlight that growth proxies improve in villages and towns with better mobile tower coverage. We can show that structural transformation out of agriculture into manufacturing and services is stronger in better connected places. We can show that these occupational changes are particularly focused in jobs associated with 'modern' production. Finally, we can tentatively confirm that when the areas around agricultural markets receive mobile tower coverage, price gaps and seasonal variation in prices decrease – a strong indicator for improved market integration and efficiency.

All evidence presented here broadly confirms that improved mobile tower coverage is associated with improved growth, productivity and welfare outcomes for locations that received coverage.

## Methodology

### Data used for analysis and descriptive insights into mobile tower expansion

To arrive at these findings, we make use of four distinct sources of data. First, a new database of 14,657 geo-identified mobile phone towers in Ethiopia. Obtained from freely available sources, the dataset originates covers the period from 2009 to 2020. Tower construction time is identified by the moment a tower first interacts with an end-user device. This information is then supplemented with official information provided by the Ethiopian government to the Global System for Mobile Communications Association (GSMA) on mobile towers that existed before 2009.

Second, geospatial information from Ethiopia is combined to arrive at estimates of the approximate population under cover and their location. For this exercise, we use population rasters available from the Gridded Population of the World (GPW), which provide Census-derived population density information at a spatial resolution of approximately 1km by 1km, available for the years 2005, 2010, 2015 and 2020. We complement this information with raster data on annual nighttime luminosity and area covered with built structures, as objective proxies for economic growth. These geospatial datasets are then aggregated to a set of 689 districts ('*woredas*', based on the 2007 Census) to map and aggregate individual- and household-level data to a larger geographic unit that remains stable over time, irrespective of district splits or merges.

Third, we combine all available waves of individual- and household-level microdata from the National Labour Force Surveys (NLFS; 1999, 2005 and 2013) and the Demographic and Health Surveys (DHS; 2000, 2005, 2011 and 2016), which provide information on respondent's economic activity, their occupation, as well as information on household ownership of assets. This information is available for tens of thousands of randomly sampled individuals throughout Ethiopia.

Finally, we assemble a rich dataset of 12 years of grain-specific, monthly agricultural prices from 20 of the largest Ethiopian agricultural markets. This hand-collected data was digitised from records of the Ethiopian Trading Business Corporation (ETBC), formerly the Ethiopian Grain Trading Entreprise and we use this data to test if market prices at the same market over time (or across markets) converge in response to better information on the parts of farmers and traders.

## Key findings

The following descriptive insights may provide some background into the nature of Ethiopia's mobile tower expansion: until 2012, mobile towers were mostly confined to Ethiopia's main cities, and tower constructions expanded into secondary cities from 2013 onwards. Especially 2015 and 2016 saw rapid expansion, and according to our data for the year 2020, 332 out of 689 *woredas* remain at zero coverage, 257 *woredas* had less than 22% of population under coverage, 101 *woredas* had between 22% and 100% coverage, and 19 *woredas* had full mobile tower coverage.

Our quantitative analysis of the above data provides a number of interesting findings. As we discuss below, these findings are merely evidence of correlations between mobile tower expansion and outcome variables of interest, but nonetheless highlight patterns that are of policy interest.

### Economic growth

With respect to evidence on economic growth, we can confirm that *woredas* with a greater expansion of tower coverage experience better growth outcomes: we find results for two outcomes that economists consider as reliable proxies for economic growth, that is *woredas*' degree of nighttime luminosity (strongly positively correlated with income per capita and economic activity) and *woredas*' area that is covered by buildings (again capturing economic activity).

### Structural transformation

Next, we consider structural transformation, that is the process of moving workers out of agriculture into modern sectors of the economy. Generations of scholars in development economics have confirmed quantitatively and qualitatively that sustained economic growth only appears possible where subsistence agriculture gets successfully replaced by manufacturing or services occupations, which tend to be more productive and, therefore, superior for raising incomes. We can confirm that mobile tower expansion across *woredas* over time is significantly associated with structural transformation out of agriculture. Both for individuals surveyed by the DHS and for those surveyed by the NLFS with respect to their occupation and main economic activity, a woreda that hypothetically moved from no tower coverage to full tower coverage (0 to 100%) would see a drop of 13.5% employment share in agriculture, heading instead into services (+7.8%) and manufacturing (+5.7%).

Given the predominant engineering choice to expand mobile towers along roads, we wonder if road access or mobile coverage is the deciding feature that correlates with structural transformation. Therefore, we make use of previous research on road access to investigate this potential interaction. We highlight three insights: first, that mobile coverage in *woredas* that do have access to an all-weather road are significantly associated with the overall patterns pf structural transformation out of agriculture discussed before.

Interestingly, for the few places that receive mobile coverage but lack road access the structural transformation pattern appears to see an intensification of agriculture. Overall, as the p-values indicate, even accounting for a possible interaction with road access, the combined effect of mobile coverage still remains statistically significantly negative for agriculture and positive for services and manufacturing. Similarly, we can confirm the same qualitative pattern for the more remote sample of NLFS *woredas*, albeit not statistically significantly different from zero.[1]



## Jobs

Which occupations and jobs are particularly affected by mobile tower expansion? Elementary agricultural jobs see a lot less employment, whereas plant operations, professional services and, retail/wholesale service occupations account for the lion's share of structural transformation in locations that see mobile coverage expansions over time. In sum, this finding tentatively points towards a modernisation of the economy aided by mobile coverage.

## Market integration and efficiency

Finally, another potential impact of mobile coverage with great relevance for economic welfare in Ethiopia would be mobile coverage-induced improvements to market integration and efficiency, as seen elsewhere in the world. Preliminary results confirm a positive effect of mobile coverage on market integration and efficiency: across three distinct definitions of price variability at the market place (and within classes of major grains traded), increases in mobile coverage are negatively correlated with price variability. In other words, better price information and coordination via improved access to mobile networks decreases wasteful price extremes within seasons, less intraseasonal price variability and lower intraseasonal peak prices.[2]

Given data constraints, potential other outcomes of interest not yet considered in this policy brief are firm productivity, especially for the many small and medium-sized firms for whom informational frictions may be most pressing; household welfare; and the potential role of mobile coverage in decreasing migration and job search frictions. Furthermore, possible complementarities with other infrastructure expansions, especially electrification should be investigated.



1 In contrast, for these more remote *woredas* in the NLFS, the road access effect alone is statistically significantly associated with structural transformation out of agriculture, and exclusively into services.

2 The analysis can be extended to study integration across markets, and effects on farmgate prices realised by farmers once they also have better mobile coverage. We leave these interesting avenues for follow-up work.

## Policy implications, limitations, and conclusion

This policy brief presents preliminary quantitative evidence of the potential growth, productivity and market integration effects of ICT investments, using the example of the mobile tower expansion in Ethiopia over the last two decades. Our findings are: (i) substantial positive growth effects, (ii) beneficial contributions of mobile coverage towards structural transformation, especially towards jobs associated with a modern, less agrarian economy, (iii) positive interaction effects with locations that also have all-weather road access, and (iv) potential beneficial effects of mobile coverage on market integration, by limiting price gaps and price variability over time.

All these findings are directly policy relevant, especially in light of the ongoing Ethiopian telecommunications privatisation, since an increase in the number of mobile phone providers would be expected to decrease prices, improve coverage, improve network quality and potentially also enlarge the product space of mobile services on offer (especially regarding future mobile banking, mobile internet, etc.). Therefore, the expected implications of telecommunications privatisation appear qualitatively comparable to the specific case of increased coverage from tower construction analysed here. However, with physical tower coverage reaching ever increasing parts of the population, it is exactly these other margins most likely affected by privatisation, such as prices/tariffs, network quality and new mobile products, that will become crucial for increasing access and usage of mobile networks and technology by households, farmers, traders, workers, firms and providers of public goods, such as schools, health centres and government that appear.

Several caveats and limitations are due with respect to the insights derived from this policy brief:

- The mobile tower data most likely suffers from two drawbacks and urgently requires verification using official administrative records. First, tower construction years may be inaccurate since towers were detected 'too late' despite an earlier construction. Second, the reported range of coverage is most likely an underestimate of real-world local coverage, whereas the engineering maximum of towers most likely provides an overestimate. Therefore, and in addition to official records, we are currently also conducting a detailed 'viewshed'-style analysis of real-world coverage that takes topological and geographic features of towers and their surrounds into account. We expect both administrative data for validation and higher accuracy of real coverage to greatly increase the precision of our estimates.

- The correlational evidence presented here cannot be interpreted causally: first, mobile tower expansion may have happened at the same time and place as other public investments, confounding results. Second, our imperfect measurement of tower construction introduces bias to the estimation that may attenuate economically large effects towards zero. Third, it remains unclear how tower

location and expansion paths were chosen by policymakers, such that reverse causality concerns loom large. What if not growth and structural transformation were results of increased mobile coverage, but instead that towers were deliberately placed in dynamic, fast-growing places? To cleanly estimate causal effects, we need to exactly understand engineer's objective function and constraints that guided tower build-out.

- The external validity of the past build-out of towers to any present and future build-out, densification and privatisation remain unclear. To gain more confidence in any such extrapolation, we require a more detailed analysis based on verified, high quality data, especially to analyse different sources of heterogeneity in effects – we need more analysis to understand when, where and why ICT investments generate growth and improve market integration.

The arguably limited evidence presented in this policy brief admits two conclusions.

1. Even the narrow example of mobile tower expansion provides ample evidence that ICT investments matter economically and may in fact constitute one of the new engines of growth Ethiopian policymakers are keen to identify.

2. With privatisation and greater competition being introduced shortly, this policy brief has highlighted how the findings from tower expansion are likely to carry over to other margins of improvements in access and usage of mobile networks, such that even this brief's imperfect findings can motivate a more thorough analysis of the coming reform in the ICT sector and to inform policy on how to improve efficiency, reduce informational barriers, generate wage employment, boost labour productivity, increase the labour force participation, facilitate access to credit, and finally unleash private-sector growth and investment.