Mobile Data Access Expansion, Price Information Diffusion, and Firm Performance: Ethiopia's Transition to 3G in 2008

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Discussion Paper

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Abstract

This paper investigates whether enhanced access to mobile communications, primarily through expanded coverage of data plans, increases competition by making price information more widely available to households and firms. The operational mechanism is that better household and firm telecommunications access closes the price information gaps between buyers and sellers, leading to more market competition and enhanced firm productivity. These effects are expected stronger among domestic firms which have not been exposed to international competition as well as younger and smaller firms that have yet to establish their reputation. To identify these effects, we use Ethiopia's transition from 2G to 3G broadband network standard in 2008 as an exogenous shock and exploit the geographic and time variation across districts of data plan availability and shares of expenditure on mobile telecommunications (mobile apparatus, mobile card expenditure, and data plan subscription). Our primary data sources are manufacturing establishment census data and household expenditure surveys. We use a quasi-experimental design to estimate the casual impact of the 3G network rollout on manufacturing markups and productivity. Results from the difference-in-differences and triple differences estimations provide evidence of intensified market competition due to mobile communication access expansion. Introducing broadband induced markups to decline, and productivity to rise, across manufacturers but especially for those establishments that became relatively more exposed to competition, younger and small establishments. In addition, manufacturing employment tends to grow faster in locations that gained access to 3G.

JEL Codes: F14, J23, J24, J63, L86, O15, O33

Keywords: Ethiopia, price information asymmetry, 3G mobile broadband, market competition, markups, productivity, employment, manufacturing

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1. Introduction

In this paper, we explore how manufacturing firm performance changed after the upgrading of broadband communications infrastructure – enhancing data flows and internet access – in Ethiopia in 2008 when the 3G network was introduced. We conjecture that the possibility of improved mobile communication–both voice and multimedia, including internet-based–potentially closed gaps in price-information asymmetries between buyers and sellers. Through this demand-side channel, improved data plan coverage and internet access increase competition as buyers are more knowledgeable about prices. The resulting reduction in the price dispersion of selected intermediate inputs and final products can boost firm performance. Intensified competition can lead to higher TFP and lower markups due to better incentives to preserve and grow market share, as well as reduced intermediate input prices improving firm performance. In particular, manufacturers facing intensified competition will have more incentives to lower production costs to preserve their profit margins. Indeed, increased information availability of competitor prices by both suppliers and buyers can make enterprise market selection more stringent.

In low-income countries, price information asymmetry and the induced higher price dispersion, are common because of market remoteness and missing or low-quality communications infrastructure. This poses significant challenges to accessing market information and overall market development of low-income and lower middle-income countries where the digital divide is pronounced. For example, the living standards of most households engaged in the primary sector (agriculture, fishery, natural resource extraction, and forestry) in these countries are heavily impacted by commodity spot prices (Jensen, 2007). As a result, market distortions, due to price information asymmetry, are amplified along value chains in a way that severely affects the well-being of the most vulnerable. In this respect, communications technology improvements, and specifically mobile phone access, can substantially facilitate information flows, enhance market efficiency and improve household welfare.

Aker and Mbiti (2010) show the extent and channels through which mobile phone coverage expansion has influenced the economic behavior and performance of producers, traders, and consumers in Africa. These channels also apply to mobile phone network upgrades that improve access to data flows. First and foremost, mobile phone communication – both voice and multimedia – reduces costly information search, and hence improves access and flow of price data that translates into enhanced market efficiency and coordination among economic agents. Buyers and sellers incur these costs in search of information on input and output prices and other market and non-market information relevant to product attributes offered by diverse suppliers. Second, it is associated with job creation potential due to higher labor productivity – not just for telecom-related services but much more widely. Third, improved information exchanges that come with mobile phone communication enable better assessment of shocks and mitigation of related risks across households and market makers. Fourth, enhanced access to mobile communications can expand financial services access through mobile banking and payment services. Lastly, beyond the demand-side channels emphasized here whereby less price information asymmetry boosts competition and firm performance, there are supply channels that also enhance productivity through better management of supply chains, relaxation of financial constraints, better functioning factor markets (including the labor market), as well as cheaper and better inputs.

A growing body of literature examines the effect on economic behavior and outcomes of improvements in information and communications technology (ICT) using micro-level data. For example, Jensen (2007), based on micro-level survey data from the fishing industry in India, reports substantial price reductions as well as welfare gains because of the adoption of mobile phones by producers and wholesalers. Based on survey data from Southeast Asian countries (Thailand, Vietnam, Laos, and Cambodia), Hubler and Hartje (2016) document an economically large and significant positive effect of smartphone ownership on household income.

Evidence from Sub-Saharan African studies points in the same direction. Muto and Yamano (2009), using data from households in Uganda, find that mobile phone network expansion has led to increased market participation of farmers as well as sales of perishable crops in remote areas. Indeed, sales of a perishable crop (banana) increased relative to a storable one (maize). These positive, significant results are attributed to a decline in marketing costs of agricultural products because of the increased flow of information that comes with the mobile phone network coverage. Furthermore, the results indicate that simple expansion of mobile phone coverage itself (not necessarily ownership and usage of a mobile phone) gave rise to better market participation and revenue outcomes for producers of perishable products.

Moreover, Aker (2010) attributes 10-16 percent of the reduction in grain price reduction in Niger to the introduction of mobile phones between 2001 and 2006. This effect is more pronounced in markets that are remote and less well-connected. The results also suggest network externalities but find no evidence of spillover effects (to untreated units, markets with no mobile phone coverage) and collusive behavior. In another study on Niger, Aker and Fafchamps (2014) examine the effect on producer price dispersion and uncover that mobile phone coverage led to a decline in cross-market and intra-annual price variation for a semi-perishable products whereas there is no significant effect for products that are less perishable and storable. In earlier work, Aker (2008) also finds that reduction in search costs and cross-market price variation is positively related to improved welfare—traders (roughly 29% rise in profits) and consumers (about 5% decrease in prices and substantial increase in quantity consumed due to lower relative grain prices).

Furthermore, there are potentially two opposing effects when it comes to increased access to price information. First, better availability of price information reduces prices because consumers are better equipped to make alternate choices through the demand side channel we focus on.[1] Another effect could be that if the 3G network expands the variety of inputs to which manufacturers have access that can induce higher quality and productivity. On this, see for example Kugler and Verhoogen (2009), who document how Colombian manufacturers are better able to engage in quality upgrading and technology adoption when they access wider varieties of imported inputs. The evidence from most agriculture-based studies documents that the effect is usually reflected in higher commodity prices (see, for example, Goyal, 2010), and operates through the supply side.

In terms of the impact of mobile communication access on financial services and banking coverage in Africa, the most cited example is that of M-Pesa in Kenya. This mobile banking and payments operation has been the model for start-ups elsewhere.[2] The evidence by Jack and Suri (2014) shows that M-Pesa reduced transaction costs and boosted risk sharing in Kenya, facilitation intertemporal consumption smoothing. Thus, mobile communication access can reduce the volatility of demand. Relatedly, Suri and Jack (2016) find that M-Pesa coverage expansion has been associated with increased consumption and reduced poverty. The channels for these outcomes have been increased savings and financial resilience as well as better labor market outcomes. M-Pesa has facilitated the transition from agriculture into business, especially for women. Also, M-Shwari in Kenya, one of the most popular digital loan services in the world, was found by Suri et al. (2021) to increase household resilience to shocks. Overall, expanded mobile

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[1] Strictly speaking the demand-side effect we emphasize implies lower mark-ups due to intensified competition rather than lower prices. It could be that if higher quality and more expensive inputs are used, prices go up and mark ups go down.

[2] M-Pesa (M for mobile and Pesa for money in Swahili) was started by Safaricom, a subsidiary of Vodafone, in 2007.

communication access could increase sales, through higher consumption, and stabilize revenue streams, by reducing consumption uncertainty.[3]

Research on the impact of digital technologies tends to focus on the supply side, and especially how technology upgrades improve the efficiency of suppliers in their operations as better information emerges to improve sales (e.g., about the weather, input market conditions, local market prices, labor market trends), better credit options materialize through fin-tech (e.g. wider banking service access, easier credit ratings), and knowledge spillovers disseminate faster – within firms, industry-wide and along the value chain through both backward and forward linkages. The predominant literature focuses on digital technologies as factors of production.

Notably, Hjort and Poulsen (2019) find that the availability of fast internet connections through submarine cables in Africa has resulted in a large positive employment effect regardless of the skill profile of workers, and the positive employment effect is attributed to a higher rate of firm entry, productivity gains and more exports associated with the arrival of fast internet connection. In addition, Dutz et al. (2012) study how establishments' innovation activities affect their employment growth using enterprise-level data from a large sample of countries, including 11 Sub-Saharan African countries. Their results show that innovating establishments registered significantly faster employment growth compared with their non-innovating counterparts, and this relationship is more pronounced when establishments use the internet; it is shown that internet usage is positively correlated with both more innovation and higher productivity. Using Brazil's staggered internet rollout, Dutz et al. (2017) also shows that in the manufacturing sector, internet access induces positive employment and wage effects in both medium- and high-skill occupations.

In addition to our focus on manufacturing, a departure from the predominant focus of earlier studies on agriculture and rural households in the context of developing economies, another distinctive feature of the study is the exploration of the demand channel whereby expansion of broadband technology affects the behavior of producers by providing broader access to price and product information to customers and competitors, rather than through technological impact on the production function or access to lower-cost inputs. We investigate the relationship between improved access to price information through the transition from 2G to 3G network (measured at the district ("woreda") level as the share of households

[3] In April 2022, Ethiopia's central bank said drafted a bill to pave the way for foreign investors like Safaricom to offer mobile money services. Existing laws only allowed locally owned non-financial institutions to offer the services.

accessing data through smartphones) and firm performance measures (e.g., TFP, labor productivity, markups, employment, and wages) vary across woredas with different shares of mobile penetration use over time. Our exogenous shock to identify these impacts is Ethiopia's transition from 2G to the 3G broadband network standard, with coverage starting in 2008, and the induced changes in the geographic variation across woredas of data plan take-up, as the rollout was deployed gradually throughout the national territory. We exploit the differential timing of 3G access across woredas.

The 3G broadband connections allow multiple types of communication services including simple voice, video, data, and other multimedia services. It facilitates communications allowing the spread of information either for firms or consumers, reducing information asymmetries. For example, the market price for goods or services depends on whether there is information about the prices charged by other similar firms either in the region or in other regions, and whether consumers have access to that information.

By combining data from the census of large and medium manufacturing establishments with household expenditure surveys, results from the difference-in-differences and triple differences estimation show that in woredas with enhanced mobile technology access after 3G, possibly by closing the information asymmetry gap between buyers and sellers, we observe in the manufacturing sector lower markups, enhanced firm productivity, as well as higher employment. Furthermore, the estimated effects are stronger for firms operating exclusively in domestic markets (less exposed ex-ante to market competition, for example through global export market discipline) as well as younger and smaller establishments with less reputation.

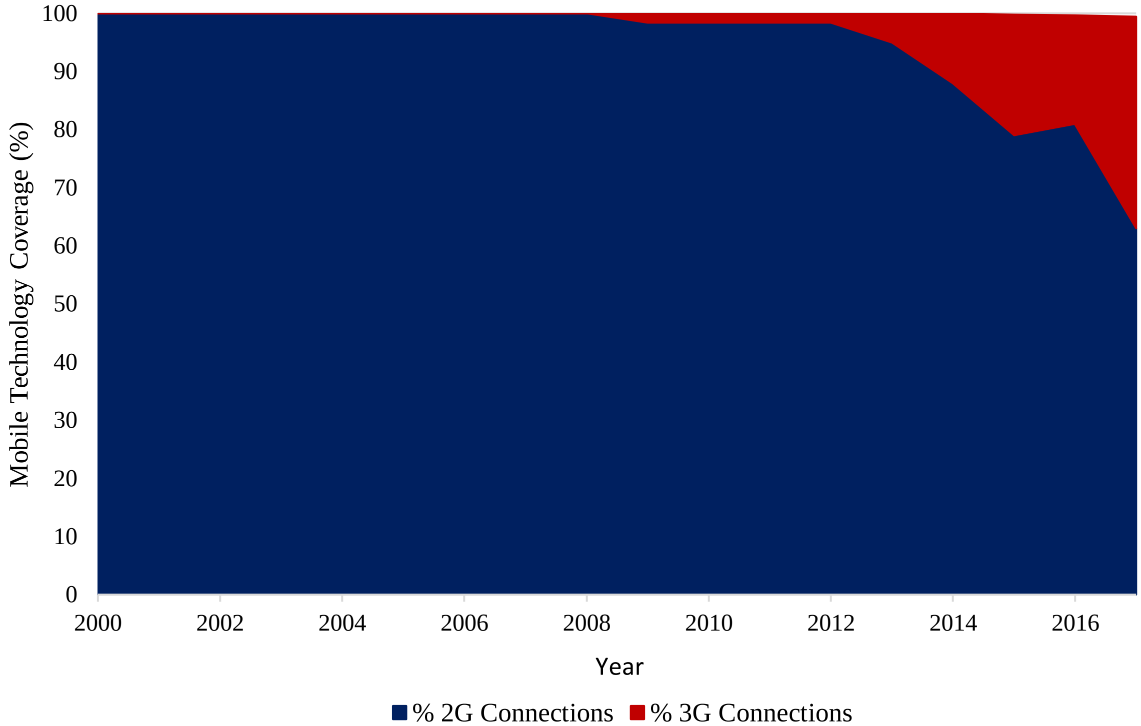
In Ethiopian markets, like most of sub-Saharan Africa, information asymmetries are widespread. Both consumers and firms must incur search costs, and sometimes other transaction costs, to access reliable information about prices, buyers, sellers, quality of products, and quantities supplied or demanded. This introduces inefficiency through costs of bargaining, time, and monetary costs of supervision and enforcement in dealing with prices. More widespread access to price information changes customer behavior and induces manufacturing suppliers to face intensified competition. As such, their incentives are affected in a way can reduce not only markups and likely price dispersion but also boosting productivity as well as wages and employment. More competition can enhance the incentives investments into cost-cutting technologies. In addition, as shown by Suri (2011), as benefits and costs of technologies are heterogeneous, producers with low net returns do not adopt a technology even if it can substantially boost efficiency. Variation in heterogeneous net benefits to the technology can be an explanation to limited take up. To the extent that competition intensification induced by mobile communication coverage expansion homogenizes the benefits from new technologies, it can be a factor in inducing higher rate of technology adoption. The resulting higher total factor productivity can be a source of faster formal job creation. In countries such as Ethiopia with limited fixed broadband communication and poor infrastructure, the role of mobile broadband connection is far-reaching. It would play a significant role in reducing information asymmetry, particularly for prices and other product characteristics through faster dissemination of market information.

The remainder of the paper is organized as follows. Section 2 provides historical context to Ethiopia's telecommunication services including coverage of 2G and 3G mobile technology. Section 3 describes the data sources and constructs the variables to measure mobile network connection and firm performance. Section 4 presents the estimation strategy and discusses the results. Section 5 concludes.

2. Context: Transition from 2G to 3G in Ethiopia

Ethiopia was an early adopter of telecommunication services with the introduction of long-distance telephone lines between Addis Ababa and Harar in 1894, along the newly launched railway line, followed by an expansion between 1902 and 1913 across various sub-regions of the country. Internet service was introduced in 1997 and cellular mobile service was launched in 1999. The growth of the sector has long been stalled, however, until the late 2000s with the re-organization of the national monopoly, formerly the Ethiopian Telecommunications Corporation (ETC) into Ethio Telecom. Subsequently, the Ethiopian mobile market has experienced rapid growth, though from a very low base. The introduction of the third generation (3G) mobile technology was one of the important developments that launched rapid growth in the sector, with possible positive implications for the performance of the manufacturing sector and hence economic growth. The national ICT policy first drafted in 2006 notes the centrality of investing in ICT infrastructure to serve as a key driver of a competitive industry and engine of economic growth.

Figure 1: Coverage of 2G and 3G Mobile Technology in Ethiopia (2000-2017)



Source: GSMA, 2020

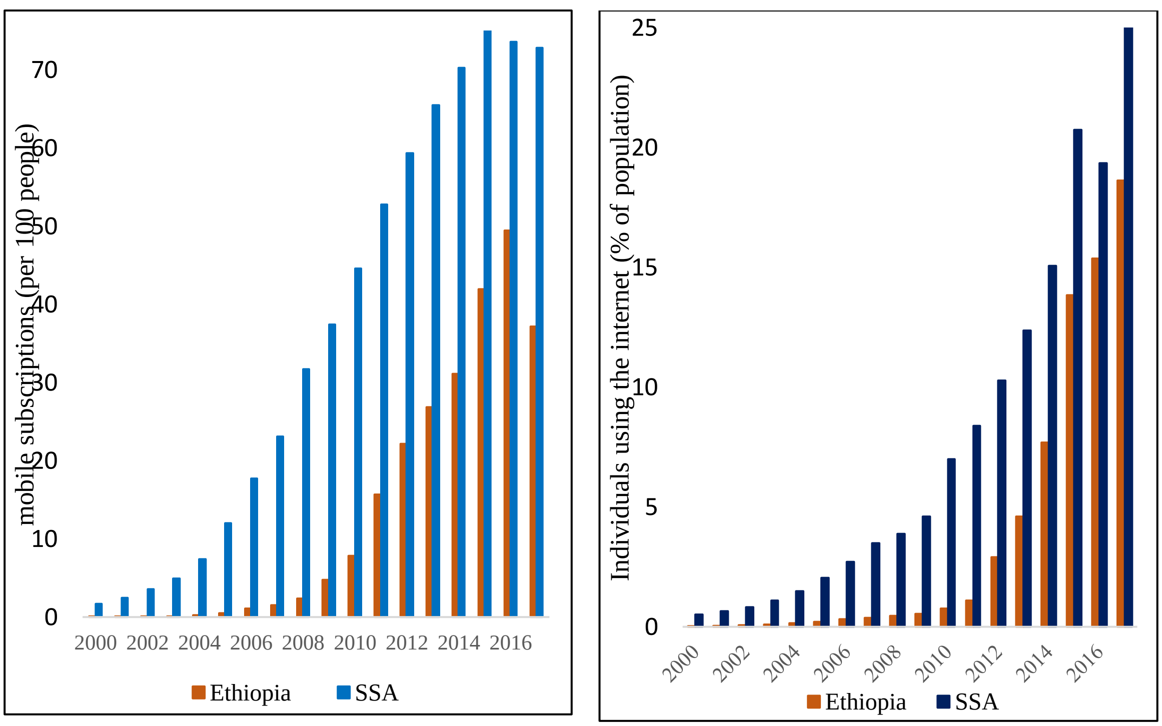
The level of development of the ICT sector in Ethiopia is one of the lowest in the world. Though a significant share of the mobile networks still employs 2G technologies, following the adoption of 3G technologies in 2008/2009, the country has shown significant growth in mobile broadband technology. In 2007, before the launch of 3G in the country, the proportion of individuals using the internet as a percentage of the population was extremely low at less than half of one percent. After a decade, in 2017, this has risen to more than 18 percent. Comparable figures for SSA were 3.5 percent in 2007 and 25.4 percent in 2017 (figure 2).

The introduction of 3G in 2008/2009 has contributed to rapid growth in internet access compared to most countries in SSA, though still at very low levels. In 2007, the country's mobile connection coverage was entirely 2G, as 3G had yet to be introduced. After a decade, 2G coverage fell to 63% while 3G coverage rose to 37%, narrowing the gap between 2G and 3G coverage. Despite significant progress, the country still lags in connectivity and adoption of digital technologies relative to countries with similar levels of economic development. This had significant negative implications for industrial development and economic growth. As shown in figure 2, only about 18.6 percent of Ethiopia's population in 2017 was connected to the internet, which was below the sub-Saharan African average and much lower than countries such as Kenya, Nigeria, Tanzania, and Senegal. However, both internet subscription and the number of mobile subscriptions has shown significant growth from 2007 to 2017.

Mobile coverage has seen rapid growth during the period, with an annual growth rate of over 50% since 2007. During the study period, the number of mobile SIM card subscribers jumped from a mere 1.2 million in 2007 to 22 million in 2012. Mobile cellular subscriptions (per 100 people) have risen from 1.5 to 37 between 2007 and 2017 while the comparable figure for SSA was 23 and 72 for 2007 and 2017, respectively. The rapid growth both in mobile subscriptions and internet access follows the introduction of 3G technologies. Though Ethiopia has adopted 4th generation (4G) technology in 2015, 3G is expected to remain the dominant mobile broadband technology for some time.

Figure 2: Mobile and internet access in Ethiopia and SSA (2000-2017) – GSMA, 2020

(a) Mobile Subscription (per 100 people) (b) Individuals using internet (% of population)

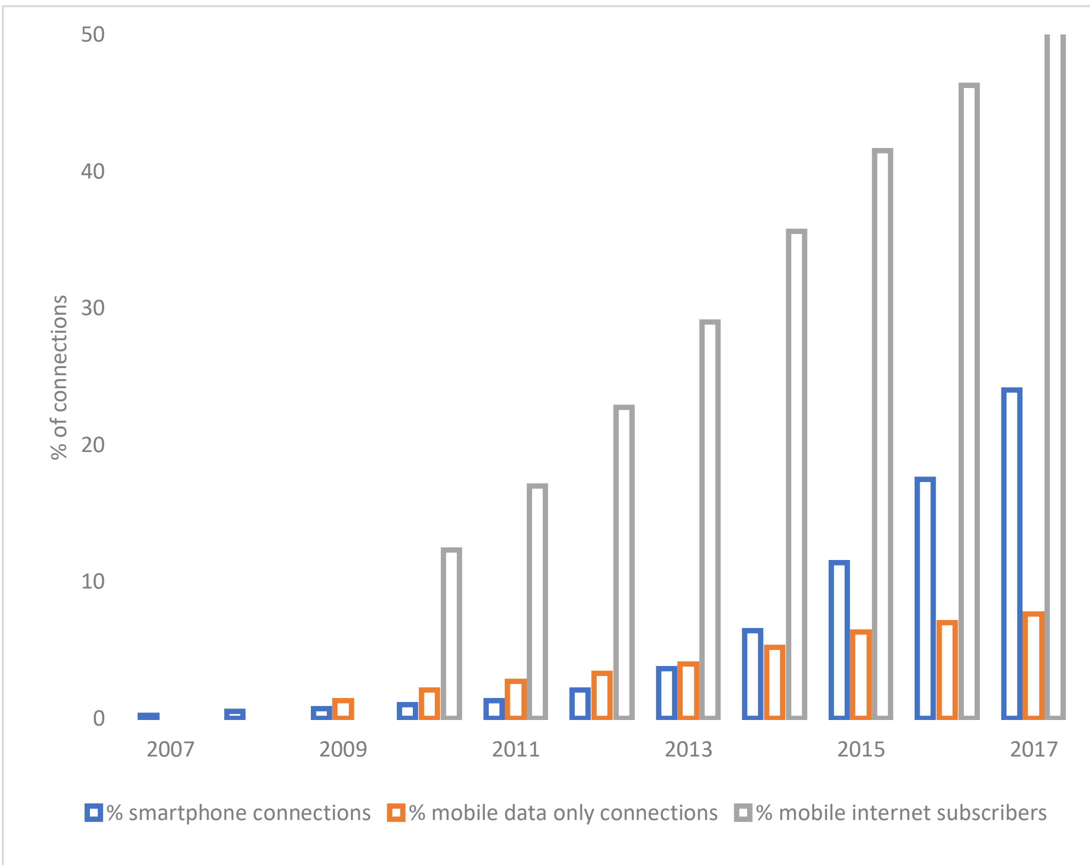


Source: GSMA, 2020

The transition to 3G was expected to boost the competitiveness of the economy. Indeed, the transition from 2G to 3G was considered a technical leap in terms of the possibilities it created for firms and consumers by enabling faster mobile broadband connection, expansion of data-enabled phones, and increased flexibility and mobility.

Following the launch of 3G technologies, the percentage of mobile internet subscribers has increased from 0% in 2007 to close to 52% in 2017, and the percentage of smartphone connections has jumped from 0.2% to 24% during the same period (Figure 3~~a~~).

Figure 3. Growth in Mobile Broadband, Mobile Connections, Subscriptions in Ethiopia (2000-2017)



Source: GSMA, 2020

The period following the rollout of 3G broadband networks coincides with more robust growth in Ethiopia, often putting the country among the fastest growing economies in the world. Though the adoption of broadband technologies itself could be an outcome of this fast growth, it has also played a significant role in facilitating the growth of industries and reinforcing market competition, and hence productivity growth through better resource allocation and faster technology adoption, particularly in the manufacturing sector. This paper examines the impact of access to 3G broadband networks on firm productivity in Ethiopia through its impact on closing gaps in information asymmetries about market prices.

3. Data description

This study uses two different datasets collected by the Ethiopian Central Statistical Agency (CSA), namely the Ethiopian large and medium scale manufacturing and electricity industries survey (LMMI), and the household consumption and expenditure surveys (HCES). LMMI is an establishment-level census panel data covering the years from 2000 to 2014. The census covers all public and private manufacturing establishments that have more than 10 employees and use power-driven machinery for production. The dataset provides detailed information on sales, production, wages and benefits, number of employees, cost and quantity of raw materials, types of ownership, and location. The firms are categorized based on the International Standard Industrial Classification (ISIC) at the 4-digit level. The total number of establishments in the dataset across the years is 19,235 and the yearly average number of observations is 1,282 establishments.

HCES, which is key to measuring internet access at the district (or "woreda") level, is a nationally representative survey collected by the CSA for the years 2004-5, 2010-11, and 2015-16. The surveys contain extensive socio-economic information about Ethiopian households at both the individual and household levels. The information includes socio-demographic characteristics of household members such as age, sex, education, health, labor force participation, household expenditures by main food items, telecommunication services expenditures, housing amenities, assets, and access to infrastructure and services. The dataset has a total of 1,496 households across the years and approximately 499 households each year. As the LMMI dataset only extends until 2014, we use only the first two waves from the HCES data, namely 2004-5 and 2010-11.

3.1 Mobile internet access measures

The HCES communication questionnaire modules provide household expenditure information on various communication-related items. These include mobile apparatus, mobile cards, telegram, internet, sim cards, fixed line, fax, and email. Of those, we chose mobile cards in estimating a woreda's mobile communication utilization intensity and internet access. As mobile cards are purchased to use data plans on smartphones, this variable is used to gauge what fraction of a woreda's population has mobiles, thereby measuring the level of data plan access.

As Ethiopia introduced the 3G networks in 2008, thus permitting the use of smartphones, the running assumption here is that the household expenditure on mobile cards considerably increased after 2008, indicating wider and better internet access on the palm. On average, a household's real expenditure on mobile cards in 2004-5 was 907.4 Birr whereas it surged to 1,436.2 Birr in 2010-11.

By using the expenditure levels, we postulate that households in a woreda would have access to the mobile internet once the average household expenditures on mobile cards exceed a certain threshold. As the 3G rollout in Ethiopia started in 2008, we compare changes in the expenditure levels between 2004-5 and 2010-11 and assign each woreda into treatment and control groups. Specifically, a woreda is defined to be in the treatment group (with the treatment dummy variable taking a value of 1) if changes in real average expenditure from 2004 to 2010 in a woreda exceeds the median of the distribution, and in the control group otherwise. Given the limited publicly available data on internet access in Ethiopia at the woreda level and internet usage at the firm level, this binary measure of internet access is the best indicators for our study.

3.2 Establishment Performance Measures

Using the richness of the LMMI dataset, we construct alternative establishment performance measures. The main variables of interest are markup and productivity estimates. We follow the De Loecker et al. (2012 and 2018) framework and estimate establishment markups without making any assumptions beyond cost-minimization behavior. As for firm productivity, it is measured by output per worker and total factor productivity (TFP), which is estimated using the Ackerberg et al. (2015) approach.

4. Estimation Strategy and Regression Results

4.1 Difference-in-Differences and Triple Differences

As explained earlier, Ethiopia adopted the 3G broadband network in 2008, thereby substantially improving mobile communication access. Taking advantage of the geographic variation of such shock, this study employs the difference-in-differences (DID) methodology in estimating the impact of enhanced local mobile access on firm performance. Specifically, the DID models compare firm performance across woredas in the treated and control groups before and after the adoption of 3G networks in 2008.

As explained in the previous section, the woredas that experienced above the median increase in mobile expenses, adjusted for inflation, between 2004 and 2010 are coded as treated woredas. The control group woredas are the opposite cases. Table 1 below describes the number and percentages of woredas in each treated and control group. The number of control and treated woredas is not the same due to missing woreda identifying codes.

Table 1 – Control and Treated Woredas

	No.	Percent
Control	1,473	56.48
Treated	1,135	43.52
Total	2,608	100

Source: HCES, 2004 and 2010

The DID regression specification is here:

$$Y_{ijt} = \alpha + \beta_1 MobileAccess_{ij} + \beta_2 Post_{ij} + \beta_3 Mobile\ Access_{ij} * Post_{ij} + \eta_t + \mu_i + \varepsilon_{ijt} \qquad (1)$$

where, Y_{ijt} is a set of firm performance measures described in the previous section for firm i in woreda j in year t. Depending on the measures, Y_{ijt} can take the form of a log or change in log. $MobileAccess_{ij}$is 1 if the woreda, where the firm i operates, had above the median increase in the real term mobile expenses between 2004 and 2011 and clustered at woreda j; 0 otherwise. $Post_{ij}$ refers to 1 for the years 2008 through 2014, which are the years after the introduction of the 2008 3G broadband; 0 otherwise. $MobileAccess_{ij} * Post_{ij}$is an interaction term of $MobileAccess_{ij}\ and\ Post_{ij}$ which is 1 if firm i in a treated woreda j for the years 2008 through 2014; and 0 otherwise. η_t and μ_i are year dummies and firm fixed effects respectively. Also, ε_{ijt} is an idiosyncratic error term. In specification (1), the coefficient of interest is β_3, which estimates the difference-in-differences effect on firm performance due to enhanced mobile access after 2008 in the subset of woredas that experienced average household expenditures on mobile apparatus and mobile data plans above the median relative to all other locations.

4.1.1 Differences-in-Differences Parallel Trends and Regression Results

This section reports graphical evidence of selected outcome variables that the treated and control woredas show similar pre-trends before the adoption of 3G networks in 2008, but display a different pattern after 2008.

Also, statistical evidence of the parallel trends is presented. We use the method of Angrist and Pischke (2009, pp.238-239) to test whether the woreda-specific time trends before the treatment (i.e., the introduction of 3G in 2008) do not differ in the treated and control woredas. We report joint F-statistics where the null hypothesis is that the coefficients of the woreda-specific time trends are not jointly different from zero.

In other words, we test whether λ is jointly different from zero in the following specification,

$$Y_{ijt} = \mu_0 + \lambda_0 t + D_{it}\mu + D_{it}\lambda t + \theta_i + \varepsilon_{ijt} \quad (2)$$

where Y_{ijt} is a set of firm performance measures for firm i in woreda j in year t. μ_0 is a woreda-specific intercept and λ is a woreda-specific trend coefficient of the interaction term between the treatment D_{it} and time trend t.

Figure 4 illustrates pre-and post-trends of log of markup in treated and control woredas. The pre-trends show that markups for establishments in the treated and untreated woredas followed similar ups and downs before the adoption of the 3G broadband networks. However, after 2008 the establishments in the two groups of woredas appear to present a different pattern, with markups declining more in treatment woredas.

This is consistent with the notion that markups tend to be higher where competition is less intense, e.g., due to lower access to price information through mobile telecommunications. The joint F-statistics of the parallel trends is 0.52 with a p-value of 0.7922, implying that the parallel trends assumption cannot be rejected.

Figure 4 – Parallel Trends for Log of Markup (ACF-DLW)

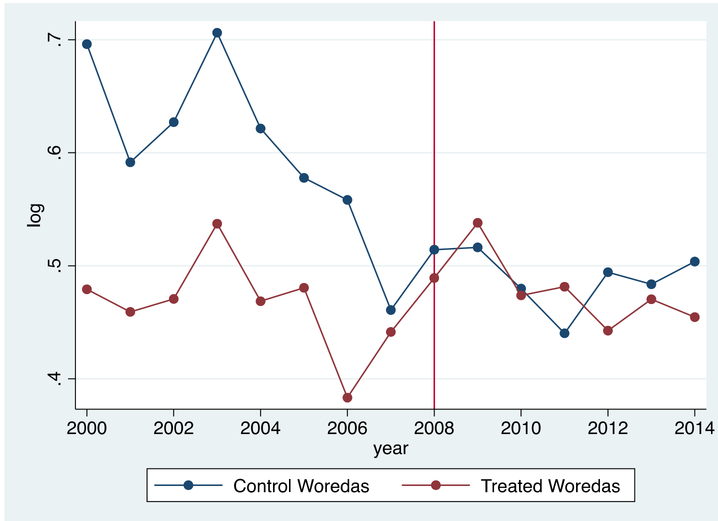


Figure 5 presents parallel trends before 2008 in terms of the log of employment in the treated and control woredas. The pre-trends display that firms in the treated and control woredas move in a fairly parallel fashion in terms of employment.

However, the trends change after 2008 in which the employment paths diverge and the treated woredas have faster employment growth. The joint F-statics of the woreda-specific time trends is 1.50 with a p-value of 0.1838, suggesting that the parallel trends assumption is satisfied pre-2008.

Figure 5 – Parallel Trends for Log of Total Employment

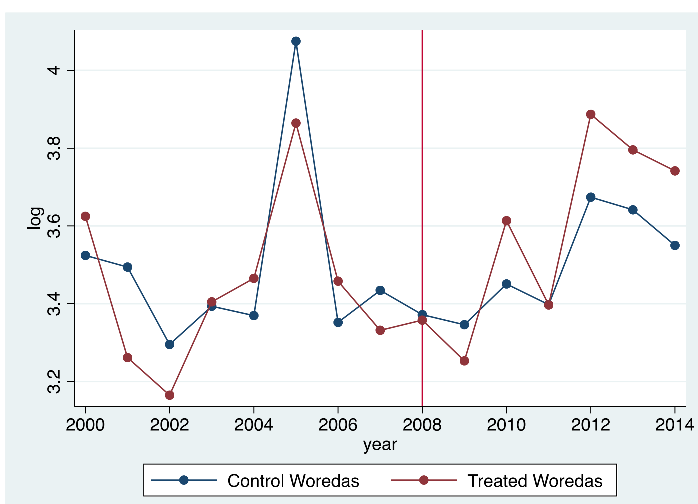
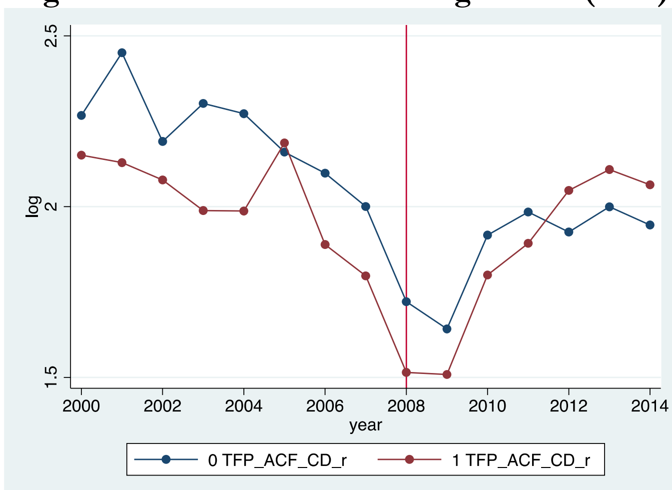


Figure 6 below portrays pre- and post-trends of log of TFP in the treated and control woredas using mobile cards. Similar to other trends so far, the pre-trends here tend also move together in both groups of woredas and we cannot reject the null hypothesis of parallel trends. Then, after 2008 the post-trends deviate from each other with TFP growing faster in treated woredas and overtaking the average TFP in control woredas between 2011 and 2012. The joint F-statistics of the parallel trends is 1.01 with a p-value of 0.4206, so that the null hypothesis of pre-2008 parallel trends cannot be rejected.

Figure 6 – Parallel Trends for Log of TFP (ACF)



4.1.2 Differences-in-Differences Regression Results

Using specification (1), this section reports the results of the DID regression on firm performance outcome variables – log of labor productivity, log of total factor productivity, log of the markup, and log of total employment. In the regressions, average mobile apparatus expenses in woredas are used for classifying treatment.

We test whether the channel for 3G rollout to improve firm performance is increased competition by estimating the impact on markups. As shown in Table 2, across the specifications, we identify that establishments operating in woredas with improved mobile access due to the 3G network experienced a 29% decline in markups.

This evidence is consistent with our conjecture that a key channel whereby expanded mobile communication access boosts productivity is increased competition. Since lower markups are a sign that profit margins are being squeezed by the fact that customers are aware of more alternatives, this exerts downward pressure on prices.

Since the margin in the short run to lower costs is limited, the intensified competition will result in lower markups. The increased availability of price information in nearby markets will induce more widespread sales and underpricing. That is indeed what we find in the specification including firm-level controls.

Table 2 – DID for Log of Markup (ACF-DLW)

VARIABLES	(1) Base	(2) Establishment-level
MobileAccess*Post	-0.290**	-0.290**
	(0.136)	(0.131)
Observations	2,597	2,545
R-squared	0.064	0.172
Year FE	NO	YES

Note: Column (1) is the baseline specification. Column (2) adds firm-level controls, including firm size, firm age, and capital intensity. Robust standard errors are clustered on Woreda. Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1)

Table 3 reports that firms operating in woredas with improved mobile access due to the 3G network experienced a 23.3% rise in labor productivity. This evidence is consistent with our conjecture that a key channel whereby expanded mobile communication access is through more stringent market competition.

This works through the demand side due to the closing of the gap in price information between buyers and sellers. When information is less asymmetric, customers have more choices, and this induces competition. As a result, profit margins are compressed, and firms have more incentives to reduce costs through improved productivity.

Table 3 – DID for Log of Labor Productivity

VARIABLES	(1) Base	(2) Establishment-level
MobileAccess*Post	0.0501	0.233*
	(0.152)	(0.137)
Observations	2,334	2,289
R-squared	0.063	0.265
Year FE	NO	YES

Note: Column (1) is the baseline specification. Column (2) adds firm-level controls, including firm size, firm age, and capital intensity. Robust standard errors are clustered on Woreda. Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1)

With more competition and lower profit margins, the incentives to lower production costs are magnified. This induces firms to lower production costs to increase profitability. If productivity-enhancing investments are expanded, this can induce both higher labor productivity as well as TFP. In Table 4, we find a 17-18% increase in TFP although moderately significant.

Table 4 – DID for Log of TFP (ACF)

VARIABLES	(1) Base	(2) Establishment-level
MobileAccess*Post	0.185**	0.178**
	(0.0864)	(0.0836)
Observations	2,597	2,545
R-squared	0.085	0.168
Year FE	NO	YES

Note: Column (1) is the baseline specification. Column (2) adds firm-level controls, including firm size, firm age, and capital intensity. Robust standard errors are clustered on Woreda. Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1)

To the extent that 3G catalyzed competitive dynamics, we expect that the induced acceleration in productivity growth would increase labor demand. This expansion in job creation in manufacturing would be reflected in higher employment.[4] In Table 5, we find a moderately significant employment effect across the specifications, suggesting that firms in the woredas with enhanced internet access tend to hire 23-26% more than firms in the untreated woredas. The results suggest firms exposed to more intense competition responded by hiring more employees. This pattern is consistent with higher labor productivity due to the intensification of competition in woredas with more improvement in telecommunications access.

Table 5 – DID Results on Log of Employment

VARIABLES	(1) Base	(2) Establishment-level
MobileAccess*Post	0.230** (0.115)	0.267** (0.106)
Observations	2,597	2,545
R-squared	0.129	0.276
Year FE	NO	YES

Note: Column (1) is the baseline specification. Column (2) adds firm-level controls, including firm size, firm age, and capital intensity. Robust standard errors are clustered on Woreda. Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1)

4.1.3 Triple Differences: Non-Exporting, Young, Small and Homogeneous Product Establishments

In case there is some time-varying confounder that changes across woredas violating the parallel trend assumption (Wing et al. 2018), this section identifies within-woreda comparison groups that are not exposed to treatment but are potentially exposed to the time-varying confounder — namely, export-orientation, establishment age, and size.

[4] As the manufacturing firms operate largely in the formal sector, it is likely that formal employment is boosted through the expansion of mobile communication.

In particular, if our results were driven by supply-side effects of the 3G network rather than the demand-side effect we emphasize, whereby 3G network services raise competition as price information becomes more widely available, both export-oriented and domestic-market oriented firms would experience similar boosts in firm performance, other things equal. However, if as we posit the pro-competitive effect of 3G is also operating through the demand-side, we expect that the export establishments exposed to international competition beforehand will be less impacted in their performance by the expansion in mobile communication as they were already exposed to competitive forces before the 3G rollout. At the same time, we expect price information asymmetry to be most salient for young and small establishments which have yet to consolidate their reputation and position in the domestic market. Therefore, we expect older and large establishments to experience a smaller reduction in mark-ups and a smaller boost in productivity than younger and small establishments.

Exporters, establishments that have foreign sales, account for 974 observations in the panel; this constitutes, on average, 65 exporting establishments per year. Domestic establishments, which are exclusively dedicated to the domestic market – account for 6,726 firms in the panel dataset and, on average, 449 establishments per year.

We compare whether exporting establishments that are subject to the same local mobile communication access expansion also experience competition intensification. In particular, since exporting firms have been already exposed to the discipline of global markets, they are not impacted to the same degree as 3G closes the gap in asymmetric information about prices between sellers and buyers. While local firms are more likely to experience intensified competition brought about by enhanced mobile communication access. This section employs the triple differences regression method in estimating different effects on local vs. exporting firms receive from the 3G network rollout. The specification for the triple differences model is:

$$Y_{ijt} = \alpha + \beta_1 MobileAccess_{ij} + \beta_2 Local_{ijt} + \beta_3 Post_{ij} + \beta_4 MobileAccess_{ij} * Local_{ijk} + \beta_5 Post_{ij} * MobileAccess_{ij} + \beta_6 Post_{ij} * Local_{ijt} + \beta_7 Post_{ij} * MobileAccess_{j} * Local_{ijt} + \eta_t + \mu_i + \varepsilon_{ijt} \quad (3)$$

where, Y_{ijt} is a set of firm performance measurements of firm i in woreda j in year t. $MobileAccess_{ij}$ refers to a dummy variable for firm i in woreda j that have an above-median increase in the share of households with mobile expenses (i.e., mobile cards and mobile apparatus) that are likely associated with smartphones, between 2004 and 2011. $Post_{ij}$ is 1 after 2008 (i.e., the treatment group). $Local_{ijt}$is a 1 if establishment i in woreda j only sells domestically and is 0 if there is any engagement in export markets, and 1 otherwise.η_t and μ_i are year and establishment fixed effects $\varepsilon_{ijk}$is an idiosyncratic error. In the triple difference regression, our coefficient of interest is β_7, which estimates the firm type-specific impact from the mobile internet access changes in local markets in woredas. We use similar specifications to assess the differential impact of 3G access on young and small establishments.

In comparison to the results from the DID regressions in the previous section, the triple differences regression results are expected to tease out whether different types of establishments show different performances when facing intensified local market competition. Furthermore, the triple differences method that compares changes over time of domestic-oriented, young, and small establishment performance in woredas with and without enhanced telecommunications access, compared to exporting, older and large establishments, would produce unbiased results (Wing et al. 2018).

4.1.4 Triple Differences: Regression Results

In Table 6, we report significant evidence of more markup reduction among non-exporting establishments. Across the specifications, the additional markup decline for domestic-oriented establishments is 38-41%. This complements the earlier DID evidence reported in Table 3 of an overall markup fall of 29%. The evidence is consistent with the demand-side channel from 3G network introduction being operational as competition increases.

Table 6 – Local Establishment Triple Differences for Markups (ACF-DLW)

VARIABLES	(1) Base	(2) Establishment-level
MobileAccess*Post*Local	-0.414**	-0.383**
	(0.183)	(0.183)
Observations	2,597	2,545
R-squared	0.075	0.095
Year FE	NO	YES

Note: Column (1) is the baseline specification. Column (2) adds firm-level controls, including firm size, firm age, and capital intensity. Robust standard errors are clustered on Woreda. Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1)

One consequence of stiffer price competition would be increased investments and efforts for productivity enhancement. As profit margins become razor thin, cost cutting is the main way to remain competitive. One key way to achieve lower manufacturing costs is through investments in technology upgrades as well as better organization of production. Thus, one implication of our conjectured effect of the 3G network is that productivity will go up. We check this hypothesis by assessing if there is a differential positive impact on TFP for non-exporters, other things equal, located in woredas most exposed to 3G network penetration.

In Table 7, we show the evidence from our exploration of the productivity channel through the impact on TFP post-2008 for non-exporting establishments in treated woredas. There is some evidence that TFP, like labor productivity, was boosted by the introduction of 3G networks for non-exporting firms in woredas with expanded access to mobile telecommunications. The estimated effect of 73.4% is significant at the 10% significance level in the specification with firm controls.

Table 7 – Local Establishment Triple Differences for Total Factor Productivity (ACF)

VARIABLES	(1) Base	(2) Establishment-level
MobileAccess*Post*Local	0.461	0.734*
	(0.437)	(0.421)
Observations	2,597	2,545
R-squared	0.097	0.170
Year FE	NO	YES

Note: Column (1) is the baseline specification. Column (2) adds firm-level controls, including firm size, firm age, and capital intensity. Robust standard errors are clustered on Woreda. Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1)

An important question is whether the pro-competitive effect of 3G beyond impacting markups and productivity also leads to the creation of more and better jobs. In particular, we posit that as a consequence of higher productivity there is a larger labor demand for firms exposed to intensified price competition. This would result in higher employment and wages. The evidence reported in the appendix (Tables A.1 and A.2) suggests insignificant but positive effects. Confirming if this channel may be operational, whereby increased marginal productivity of labor yields improvements in formal job creation and wages, would require more accuracy and precision than we have in measuring mobile access.

In Table 8, we report significant evidence of more markup reduction among younger establishments. Those are defined as establishments with ages below the median, which in our sample is 15 years. Across the specifications, the additional markup decline for younger establishments is 33%. The evidence is consistent with the demand-side channel from the 3G network introduction being operational as competition intensification impacts establishments with less reputation more intensively.

Table 8 – Younger Establishment Triple Differences for Markups (ACF-DLW)

VARIABLES	(1) Base	(2) Establishment-level
MobileAccess*Post*Young	-0.333***	-0.333***
	(0.0701)	(0.0702)
Observations	2,545	2,545
R-squared	0.078	0.088
Year FE	NO	YES

Note: Column (1) is the baseline specification. Column (2) adds firm-level controls, including firm size, firm age, and capital intensity. Robust standard errors are clustered on Woreda. Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1)

In Table 9, we show the evidence from our exploration of the productivity channel through the impact on TFP post-2008 for younger establishments in treated woredas. There is some evidence that TFP, like labor productivity, was boosted by the introduction of 3G networks for non-exporting firms in woredas with expanded access to mobile telecommunications. The estimated effect of 26.6% is significant at the 10% significance level in the specification with firm controls.

Table 9 – Younger Establishment Triple Differences for Total Factor Productivity (ACF)

VARIABLES	(1) Base	(2) Establishment-level
MobileAccess*Post*Young	0.225	0.266*
	(0.166)	(0.161)
Observations	2,545	2,545
R-squared	0.101	0.167
Year FE	NO	YES

Note: Column (1) is the baseline specification. Column (2) adds firm-level controls, including firm size, firm age, and capital intensity. Robust standard errors are clustered on Woreda. Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1)

In Table 10, we report significant evidence of more markup reduction among small establishments (those with 50 workers or less). Across the specifications, the additional markup decline for small establishments is 25-27%. The evidence is consistent with the demand-side channel from the 3G network introduction being operational as competition intensification impacts establishments that have lower market share and are less well established more considerably.

Table 10 – Small Establishment Triple Differences for Markups (ACF-DLW)

VARIABLES	(1) Base	(2) Establishment-level
MobileAccess*Post*Small	-0.269***	-0.251***
	(0.0741)	(0.0744)
Observations	2,583	2,531
R-squared	0.068	0.086
Year FE	NO	YES

Note: Column (1) is the baseline specification. Column (2) adds establishment-level controls, including size, firm age, and capital intensity. Robust standard errors are clustered on Woreda. Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1)

In Table 11, we show the evidence from our exploration of the productivity channel through the impact on TFP post-2008 for small establishments in treated woredas. The estimated coefficients have a positive sign but are not significant to gauge if TFP was boosted further by the introduction of 3G networks for small firms in woredas with expanded access to mobile telecommunications.

The estimated coefficients on higher labor productivity (output per worker) effects for younger and small establishments are significant at the 5% level. These results are presented in the Appendix (Tables A.3 and A.4).

Table 11 – Small Establishment Triple Differences for Total Factor Productivity (ACF)

VARIABLES	(1) Base	(2) Establishment-level
MobileAccess*Post*Small	0.0187	0.102
	(0.175)	(0.172)
Observations	2,583	2,531
R-squared	0.111	0.152
Year FE	NO	YES

Note: Column (1) is the baseline specification. Column (2) adds establishment-level controls, including size, firm age, and capital intensity. Robust standard errors are clustered on Woreda. Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1)

One open question is whether the potential competition, driven by the increased internet access of buyers which helps them find out best alternative prices at their fingertips, yields Bertrand competition (sellers underprice each other to capture higher market share) or vertical differentiation (sellers upgrade product quality to capture higher market share). For example, Kugler and Verhoogen (2012) provide evidence of the realm of quality upgrading for manufacturing competition in Colombia. Our prior is that price competition would be more dominant for relatively homogenous goods (e.g., cement, concrete, flour, bricks, cloth, etc.), and that quality upgrading competition would be more salient for differentiated goods.

Indeed, we use CPI survey data to compare the standard deviations of retail prices for selected commodities based on surveys in 2008 and 2010 for the month of September. We find that the introduction of 3G is associated with the reduction in dispersion in more homogeneous products like cement, imported rice, and some varieties of barley. By contrast, the price dispersions of items such as beer, coffee beans, and cotton have increased. See Table A.5 in the Appendix.

Although it is standard in the trade literature to emphasize the Rauch (1999) Index as a measure of horizontal differentiation, its focus on product homogeneity is better interpreted as reflecting differentiation more generally (i.e., both horizontal and vertical). Indeed, homogenous goods are those traded on a commodity exchange or those that have a quoted price in industry trade publications. Interestingly, the degree of price information accessibility is directly related by Rauch with limited scope for product differentiation. Hence, we explore also the differential impact on homogenous good suppliers, operating in markets mainly with price competition, as opposed to suppliers in differentiated product markets, competing as well through quality upgrading. The results to gauge whether the increase in price competition associated with the 3G rollout is more intense for homogenous good producers who are less likely to engage in quality differentiation and may therefore be expected to be more subject to Bertrand competition reveal a differential productivity effect on homogenous good producers as opposed to differentiated good producers. Table 12 presents the triple-difference estimation results for homogeneous good producers. The coefficients are insignificant suggesting that there are no differential effects on markups between homogenous-good and differentiated good producers operating in woredas with increased mobile access after the introduction of 3G. However, when we include establishment-level controls the sign of the coefficient is the expected one. As shown below, for productivity we do find differential effects pointing to larger TFP gains for homogenous-good establishments, consistent with relatively more intensified competition for those producers in woredas with 3G access.

Table 12 – Homogeneous-good Establishment Triple Differences for Markups (ACF-DLW)

VARIABLES	(1) Base	(2) Establishment-level
MobileAccess*Post*Homogeneous	0.0573	-0.017
	(0.0593)	(0.0587)
Observations	2,583	2,531
R-squared	0.103	0.125
Year FE	NO	YES

Note: Column (1) is the baseline specification. Column (2) adds establishment-level controls, including size, firm age, and capital intensity. Robust standard errors are clustered on Woreda. Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1)

In Table 13, we show the homogeneous-good producer triple differences results for TFP. We find that homogeneous-good producers had a larger productivity boost than differentiated-good producers in woredas that gained 3G access. The additional productivity improvement range is 27-29%. This is consistent with homogenous-good establishments becoming relatively more exposed to competition. This suggests that mobile access may have had a more pronounced effect on price information asymmetry gap elimination and subsequent price competition intensification for producers of homogenous goods as for producers of differentiated goods but that the markup effect is not estimated precisely.

Table 13 – Homogeneous-good Establishment Triple Differences for TFP (ACF)

VARIABLES	(1) Base	(2) Establishment-level
MobileAccess*Post*Homogeneous	0.2763*** (0.1028)	0.2924*** (0.1004)
Observations	2,583	2,531
R-squared	0.251	0.321

Note: Column (1) is the baseline specification. Column (2) adds establishment-level controls, including size, firm age, and capital intensity. Robust standard errors are clustered on Woreda. Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1)

As mentioned above, we found significant differences in the small versus large establishment size margin, and even more interestingly comparing startups and young establishments versus well-established older ones. The establishments with good reputations have larger customer bases, and their price information is more likely to be commonly known through other channels like social networks, operational before data, or internet access expansion. We find the effect of 3G to be more pronounced on the pricing behavior and productivity of the newcomer and small establishments than the older and large established ones. Also, suppliers dedicated to domestic markets and homogeneous good producers, which both experience more intensified competition with mobile coverage expansion, experience larger TFP boosts in woredas where 3G is more accessible.

5. Conclusion

There is considerable promise in developing economies for digital technologies. But there is limited evidence on the mechanisms by which digital technologies yield improved development outcomes. There is a wide gap in evidence on how digital technologies affect economic and social outcomes. In addition, the existing evidence focuses on the supply side – looking at the impacts mainly on firm performance where digital technologies are considered as factors of production. In this study, we examined the impact of digital technologies – the introduction of 3G in Ethiopia – on market competition. This study introduces the demand side mechanism by which improvements in digital technologies improve economic outcomes. This complements existing studies which predominantly focus on the supply side impacts of digital technologies. We show that digital technologies can reduce price information asymmetry, raise competition and improve firm performance and hence aggregate productivity

Using the exogenous introduction of 3G in Ethiopia, we find that in districts with higher mobile broadband access, including household internet access, after the rollout of the 3G broadband network in 2008, manufacturing establishments saw lower markups and higher productivity, as well as more employees and higher wages. Furthermore, manufacturing establishments focused on domestic markets, younger establishments, and small establishments, experienced further reductions in markups and larger productivity boosts in districts (woredas) with increased mobile access after the 3G rollout. This is consistent with mobile access intensifying price competition, as it is precisely the manufacturers most likely to be more impacted by price competition, those not exposed to international competition, and those least well-established (younger and smaller producers), that experience the largest effects on mark-ups and productivity.

Access to price information through mobile communications, including the internet (measured at the woreda level as the share of households accessing data through smartphones), can reduce information asymmetry, a fundamental market imperfection predominant in developing economies. We conjecture that this would in turn impact the distribution of product unit values across different woredas in Ethiopia. However, we were not able to obtain unit values from the Ethiopian manufacturing panel data to conduct the price dispersion analysis for a substantial number of products. In future research, we plan to also explore whether household survey data analysis could provide evidence on the variation in price information access across years and districts.

Finally, conditional on future data access, we plan to investigate the role of road connectivity and other infrastructure variables affecting market integration that could influence the geographical variation of product price dispersion and firm performance. The key implication of the study is that the impacts or spillovers from the expansion of digital technologies may be underestimated since they often ignore demand side impacts. Investments in complementary factors such as digital skills could also be central to accentuating the positive spillovers from digital technologies. In addition, the findings imply that digital technologies could substitute for the limited coverage of other types of infrastructure including transport and other connectivity infrastructures in addressing market imperfections.

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Appendix A

Table A.1 – Triple Differences for Log of the Wage

VARIABLES	(1) Base	(2) Establishment-level
MobileAccess*Post*Local	0.230	0.673
	(2.186)	(2.116)
Observations	2,597	2,545
R-squared	0.193	0.265
Year FE	NO	YES

Note: Column (1) is the baseline specification. Column (2) adds firm-level controls, including firm size, firm age, and capital intensity. Robust standard errors are clustered on Woreda. Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1)

Table A.2 – Triple Differences for Log of Employment

VARIABLES	(1) Base	(2) Establishment-level
MobileAccess*Post*Local	0.314	0.672
	(0.535)	(0.501)
Observations	2,597	2,545
R-squared	0.266	0.372
Year FE	NO	YES

Note: Column (1) is the baseline specification. Column (2) adds firm-level controls, including firm size, firm age, and capital intensity. Robust standard errors are clustered on Woreda. Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1)

Table A.3 - Young Establishment Triple Differences for Labor Productivity

Regression Results on Log of Labor Productivity

VARIABLES	(1) Base	(2) Firm-level
2008*Mobile Cards*Young	0.455*	0.467**
	(0.262)	(0.235)
Observations	2,289	2,289
R-squared	0.065	0.265
Year FE	NO	YES

Note: Column (1) is the baseline specification. Column (2) adds establishment-level controls including size and capital intensity. Robust standard errors clustered on Woreda. Robust standard error in parentheses (*** p<0.01, ** p<0.05, * p<0.)

Table A.4 - Small Establishment Triple Differences for Labor Productivity

Regression Results on Log of Labor Productivity

VARIABLES	(1) Base	(2) Firm-level
2008*Mobile Cards*Small	0.044	0.065
	(0.276)	(0.252)
Observations	2,304	2,259
R-squared	0.116	0.277
Year FE	NO	YES

Note: Column (1) is the baseline specification. Column (2) adds firm-level controls including firm age and capital intensity. Robust standard errors clustered on Woreda. Robust standard error in parentheses (*** p<0.01, ** p<0.05, * p<0.)

Table A.5 - Price dispersion for selected products (based on September retail price survey)

Products	Std. dev. 2007	Std. dev. 2008	Std. dev. 2010	Δ 2008 -07	Δ 2010 -08
Barley Black Kg	0.73	1.24	1.28	0.51	0.04
Barley Mixed Kg	0.54	1.25	0.98	0.71	-0.27
Barley White Kg	0.77	1.43	1.32	0.66	-0.11
Barley for Beer Kg	0.71	0.79	1.55	0.08	0.76
Beer (Bedele) 330cc	0.38	0.64	0.79	0.25	0.16
Beer (Harar) 330cc	0.34	0.50	0.77	0.16	0.27
Beer (Meta Abo) 330cc	0.30	0.37	0.71	0.07	0.34
Cement/Bag/(Local) 50Kg	15.59	27.33	20.56	11.75	-6.78
Coffee Beans Kg	4.66	4.87	8.80	0.21	3.93
Cotton Kg	2.07	2.45	4.23	0.38	1.78
Maize (White) Kg	0.51	0.89	0.93	0.38	0.04
Mobile Apparatus (Nokia6200) No.	175.68	98.49	81.69	-77.20	-16.80
Rice (Imported) Kg	0.63	1.20	1.18	0.56	-0.02
Sugar Kg	0.67	0.71	1.25	0.05	0.54
Wheat Black (Red) Kg	0.68	1.19	1.26	0.51	0.07
Wheat White Kg	0.51	0.89	1.08	0.38	0.19

Source: Central Statistics Agency of Ethiopia.