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MOBILE MONEY, INTEROPERABILITY AND FINANCIAL INCLUSION

Abstract

This paper explores the tradeoff between competition and financial inclusion given by the vertical integration between mobile network and money operators. Joining novel data on mobile money fees built through the WayBack machine, with sources on network coverage and financials, we examine the staggering across African operators and countries of platform interoperability – a policy that promotes transactions and competition across mobile money operators. Our findings show that interoperability lowers mobile money fees and reduces network coverage and mobile towers, especially in rural and poor districts. Interoperability also results in a decline in various survey metrics of financial inclusion.

JEL Classification: E42, L14, O10

Keywords: Mobile money, Interoperability, Financial inclusion

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Mobile Money, Interoperability and Financial Inclusion*

Markus K. Brunnermeier† Nicola Limodio‡ Lorenzo Spadavecchia§

April 2023

Abstract

This paper explores the tradeoff between competition and financial inclusion given by the vertical integration between mobile network and money operators. Joining novel data on mobile money fees built through the WayBack machine, with sources on network coverage and financials, we examine the staggering across African operators and countries of platform interoperability – a policy that promotes transactions and competition across mobile money operators. Our findings show that interoperability lowers mobile money fees and reduces network coverage and mobile towers, especially in rural and poor districts. Interoperability also results in a decline in various survey metrics of financial inclusion.

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1 Introduction

Mobile money has emerged as one of the most widespread digital payment systems (Demirguc-Kunt et al., 2018). Its diffusion resulted in tangible changes on various economic and financial indicators like risk-sharing (Jack and Suri (2011); Blumenstock et al. (2016)), remittances (Riley (2018); Aker et al. (2020)), lending (Suri et al., 2021) and savings (Breza et al., 2022), among others. Despite these significant developments, research on the functioning and regulation of the corresponding financial institution, the mobile money company, remains limited.

This paper investigates the role of competition on the behaviour of mobile money companies and its corresponding effects on financial inclusion. Specifically, we examine the effects of a competition-promoting policy, platform interoperability, which facilitates transactions between users of different mobile money operators. By mitigating the barriers to exchange payments, this regulatory intervention can impact the profit margins of mobile money operators and influence their pricing, network, and infrastructure investment.

Our paper proposes conceptually and explores empirically a novel tradeoff between competition and financial inclusion in the context of mobile money. It is crucial first to introduce the typical structure of this market, which comprises two main players: mobile network companies that offer phone and internet services; and mobile money companies that focus on payment exchanges. Typically, these two actors are vertically integrated as discussed by Bourreau and Valletti (2015), which creates a limited competitive environment (Williamson (1979); Grossman and Hart (1986); Hart et al. (1990)) and results in higher fees charged to mobile money users. At the same time, this lack of competition may also provide incentives for mobile network companies to extend their reach to underserved locations, enhancing financial inclusion. Consequently, low levels of competition may increase the size of the mobile network, which may be labelled as the extensive margin of financial inclusion. Nonetheless, this scenario may harm the poorest users within covered areas due to high transaction fees, which weakens the intensive margin of inclusion.

To guide our empirical analysis, we build a compact theoretical framework inspired by the work of Laffont et al. (1997) and Bianchi et al. (2022). These papers examine respectively the role of competition in the telecommunication market and the mechanics of interoperability in mobile money. Our contribution lies in introducing the margin of infrastructure via tower installation. We show theoretically that interoperability breaks the monopoly power of platforms by inducing competition on fees. At the same time, this reduction in the profit margin of the mobile company leads to a decline in tower installation and network provision. One central aspect of this paper is the role of mobile network towers. We model this via the tower infrastructure that moves with economic incentives and is not necessarily fixed and unresponsive to the underlying economic characteristics, as generally assumed. This assumption, which we validate empirically, is inspired by the market structure of mobile towers in Africa, which we describe in detail in Section 2.3. In short, mobile towers in Africa present high variable costs given that most are disconnected from electricity and powered through expensive power-generating commodities, such as diesel fuel. This cost structure implies that companies respond by reducing their tower network in response to a negative shock to mobile revenue.

The empirical challenge is to identify a source of quasi-experimental variation, which increases the competition between mobile money companies and affects the extent of the money-phone integration. To do this, we exploit a unique natural experiment taking place in Africa: the staggered introduction of interoperability across operators and countries that has been taking place between 2010 and 2020. In this context, interoperability is a policy that induces mobile money companies to permit and facilitate the exchange of payments with mobile money users that operate on a different platform. The introduction of interoperability does not appear to be related to specific conditions of the mobile money industry. It is instead a reform initiated by the central bank, which expands the country infrastructure of payment systems involving banks, merchants and correspondingly mobile operators. This fact is documented in the paper appendix and validated by the presence of balance of economic characteristics in our country sample and of parallel trends in the pre-period across most of our empirical specifications.

We combine this source of variation with numerous novel sources of data. Our innovative contribution in terms of data is to construct a panel dataset on mobile money fees per company, which covers more than 120 operators across 40 countries in Africa from 2010 onward. Building this data was particularly challenging, since this information is not publicly available and retrospective surveys asking users for fees tend to be inaccurate. To address these gaps, we used the "Wayback Machine": an online archive that routinely scans most websites and takes screenshots of their pages. We digitized this information and created the panel, which reveals some original descriptive findings on the functioning of this market.

Mobile money fees in Africa are high and penalize small transactions. The average cost of sending a transfer to another user on the same mobile money company accounts for an average 4% of the total, if the user has a different company this fee levitates at 11% and inches at 12% for individuals without a mobile account. As presented in the paper, small payments are particularly hit by high fees, which exceed 30% of the transferred amount for amounts placed in the smallest brackets. These fees are the nominal cost of a transaction, which in this setting transcends from misconducts of financial intermediaries, who may overcharge specific demographics beyond the nominal expenses as noted by Annan (2022).

To join a measure of prices with quantities and network, we partnered with the GSM Association (GSMA), the leading organisation grouping mobile telecommunications operators to access various datasets on mobile network companies. First, we employ data on mobile network for the entire African continent through rasters of 250×250 meters, containing information on the presence of mobile signal and number of companies operating. This information is then aggregated at the district level for all countries in Africa, using maps from the Database of Global Administrative Areas (GADM). Second, we received access to a source of operator-specific information on financials as well as other statistics (towers, market penetration, price for other services). In addition, we use the World Bank Global Findex Survey and IMF Financial Access Survey to shed additional light on the effects of interoperability on financial inclusion.

Our results validate the existence of a tradeoff between financial inclusion and competition. In terms of prices, an event study setting shows that the fees of companies operating in different countries lie on parallel trends prior to the introduction of interoperability and sharply fall thereafter. A difference-in-difference specification quantifies the decline in fees after interoperability to be at 3.5 percentage points for on-network transactions, which are transactions between users on the same network (62% of the mean) and 5 percentage points cross-network transactions, which are transactions between users across the different networks (40% of the mean). This decline is almost entirely due to small payments that become substantially cheaper, with fees falling by 22% for on-network transactions and 44% for cross-network ones.

We exploit the granularity of our data and the ability to measure the network for each operator across multiple districts to study the impact of interoperability at the operator-district level. We document that interoperability induces an overall decline in coverage and probability that a district is covered by a company. This finer-grained variation becomes useful once we identify the companies that are "dominant" in a district, holding more than 30% of the local market before the introduction of interoperability. In fact, we find that non-dominant companies increase their coverage by almost 9%, while dominant companies cut coverage by 5%. These results are confirmed by a different dataset on operators and their yearly financials. Companies operating in countries where interoperability was implemented experienced a decline of 18% in share of population covered, 22% in market penetration, 29% in revenue and 12% in the number of towers. The profits of mobile network companies seem to be negatively affected as well, though the estimates are imprecise.

In addition to this evidence at the operator-district level, we provide further results in terms of network availability at the district level to understand the aggregate effects of this policy. We find that the arrival of interoperability lowers various measures of network coverage. In all cases, we present event study specifications showing the existence of parallel trends before the treatment and use a difference-in-difference specification to quantify the average effects. We find that districts in countries that introduce interoperability experience a 4% drop in the share of the district covered by mobile network coverage (6% of the mean), a 3.6% decline in the probability of presenting any coverage (4% of the mean) and a 20% lower number of mobile network companies operating in the geographic unit. There are two interesting heterogeneities of this result, which are guided by our theoretical framework. First, districts that may present high ex-ante costs of tower installation and therefore be marginal for mobile companies (rural, poorer) before the policy are the ones presenting the strongest hit. In fact, the relative decline in their coverage is severe both in terms of coverage and the number of operators. Second, we observe that companies that presented higher than median fees before the introduction of interoperability respond to this policy by exhibiting a stronger drop in coverage as competition is enforced.

To investigate the effect of interoperability on financial inclusion, we take advantage of the Global Findex dataset and find that individuals in countries introducing interoperability see a reduction in access to emergency funds, remittances and the likelihood of receiving wage on their mobile phone. At the same time, the IMF FAS dataset reveals that as interoperability is launched, countries experience a reduction in the aggregate number of mobile money transactions, outstanding balances and an imprecise decline in mobile money agents and users.

A policy proposal complements our work by introducing an analogy between the temporal expiration of patents in the context of innovation and the timing for the introduction of platform interoperability in mobile money and digital payment systems. The existence of a maximum number of years for patents has the objective of balancing the tradeoff between the welfare costs of giving monopoly rents to companies and the welfare gains of stimulating new ideas. The application of this analogy is straightforward: a temporal term on the introduction of platform interoperability for mobile operators would balance the tradeoff between the welfare cost of monopoly rents to mobile operators (through initially higher tariffs on consumers) and the welfare gains of stimulating the installation of a wide mobile network. To offer insights on the applicability of this proposal, we study the heterogenous effect that interoperability has on districts depending on the number of years in which the mobile operator has been offering coverage. We show that as interoperability is enacted, locations in which an operator had entered more recently experience a starker decrease in mobile network coverage and in the probability of signal, relatively to more developed ones that are significantly less affected.

We conclude our paper with a set of the robustness tests of our results through different approaches: We use the methods for dynamic treatment effects in event studies with heterogeneous treatment effects proposed by Sun and Abraham (2021) and the framework for difference-in-differences designs with staggered treatment adoption and heterogeneous causal effects proposed by Borusyak et al. (2021), we replicate our main results weighting for different measures of the district's population, we propose alternative clustering methods for the standard errors, we verify that the introduction of interoperability does not affect operations of Mergers and Acquisitions between mobile network operators, we provide several heterogeneity analysis using different measures of local urban development.

The main contribution of this paper is to provide evidence that a higher level of competition between mobile money providers has mixed effects on consumers and infrastructure investment. This intuition applies more broadly to telecommunications and tower installation technology, and to digital payment systems and the underlying server infrastructure. Section 2.3 of our paper documents with reports and data that mobile towers present sizeable operating costs in Africa, due to being often disconnected from power grids or being connected to unstable ones, hence requiring expensive diesel generators and servicing. Our work is in line with papers which highlight the mixed effects of competition on consumers and infrastructure, for example Ferrari et al. (2010) show that banks underinvest in building their ATM network in Belgium due to the prohibition to charge additional fees on users of other banks, which resembles the concept of interoperability that we study in this paper. Genakos et al. (2018) study the tradeoff between market power and efficiency in the OECD telecommunication industry, showing that a higher market concentration is associated with both higher mobile telecommunication fees and investment. Through a study of the Rwandan network, Björkegren (2022) relates the role of competition to the intrinsic networked nature of mobile networks to study welfare and investment, finding that the free interconnection of systems can lower the incentives to invest. Related to this literature, there are two important review articles: Bourreau and Valletti (2015) offer a comprehensive analaysis of the economic features of mobile payment systems in developing countries, while Bianchi et al. (2022) connect various streams of academic literature to shed light on how the degree of interoperability in mobile payments affects market outcomes and welfare. This paper advances this literature by combining granular and innovative data on the mobile market with an empirical design exploiting a plausible source of quasi-experimental variation.

At the same time, our paper is related to the growing literature on mobile money. Jack and Suri (2011),Jack et al. (2013) and Jack and Suri (2014) have pioneered this stream of research, by using survey data to understand the role of mobile money in attenuating the effect of negative income shocks by fostering risk sharing. Blumenstock et al. (2016) also studies the response to shocks (in the context of an earthquake in Rwanda) using administrative data on mobile phone records, airtime purchases, and transfers of airtime. Suri and Jack (2016) show that increased access to mobile money has increased long-term consumption in Kenya and reduced the number of households in extreme poverty. Riley (2018) underlines how developing countries have gained increased access to remittances through the introduction of mobile money services. Suri et al. (2021) study how a new digital loans system operating over the rails of mobile money helps households in facing negative income shocks. Breza et al. (2022) finds that a financial technology that allows individuals to automatically receive their wage on their mobile money account leads to higher savings and stronger resilience. Our paper brings a perspective focusing on the supply of mobile money, exploring their functioning and corresponding regulation. This paper is also related to the literature studying how access to mobile network can foster economic development.[1]

[1]Among the prominent contributions in this literature is the work of Jensen (2007), which shows how mobile network and towers can improve market allocation efficiency and lead to uniform prices in the fishing industry in India. Aker and Mbiti (2010) explore the main channels through which mobile phones can affect economic outcomes and appraise current evidence of its potential to improve economic

The rest of the paper is as follows. Section 2 presents a theoretical framework of competition in the mobile money sector, offers details about the institutional aspects of mobile money interoperability, and provides an insight on how the telecommunication infrastructure works in Africa. It describes the data we use, comprehensive of a newly self-collected dataset on mobile money fees across African operators, and offers insights on the the identification strategy that exploits the staggering of interoperability across African countries. Section 3 investigates the effects of interoperability at different levels. It first provides evidence on operators' fees, financials and network coverage. It then presents aggregate results at geographical level, by also showing the implications for financial inclusion. Eventually, it provides several heterogeneity analyses, a policy proposal and a set of robustness checks. Section 4 concludes.

2 Theoretical framework, Data and Identification

The aim of this section is twofold. We first present a theoretical framework relating mobile money interoperability, competition between operators and financial inclusion, and introduce the institutional changes experienced in the mobile money industry across African operators and countries. Through the theoretical framework, we spell out the hypotheses tested in the paper and reconnect these with the literature on the organisational economics of network operators. We also provide an insight on how the telecommunication infrastructure works in Africa, highlighting the relation between phone cell towers and network coverage.

In the remaining part of the section, we describe the data we use, comprehensive of a newly self-collected dataset on mobile money fees across African operators. We eventually offer insights on the identification strategy, that exploits the staggering of interoperability across African countries. In particular, the identification strategy verifies that the introduction of interoperability boosts competition and lead to lower fees, which bene-

development. Blumenstock et al. (2020) present experimental evidence on the economic impacts of mobile phone access: the introduction of mobile phones had large and significant impacts on household income and expenditure, particularly for wage workers. Riley (2022) shows that providing microfinance loan in a private mobile money account positively impacts the businesses of female microfinance borrowers.

fit covered areas and individuals (intensive margin, i.e. poorest within already covered areas), but also lowers the incentives for companies to extend coverage and inclusion to previously underserved locations (extensive margin, i.e. geographic outreach).

2.1 Theoretical Framework

2.1.1 Economic Environment

This theoretical framework is built on the work of Bianchi et al. (2022) and Laffont et al. (1997), it is a simplification meant to guide our empirical analysis and provide a compact and original setting to think about the role of competition in the mobile money sector.

The market for mobile customers is composed by a continuum of locations on a unit line, and each point is populated by a household engaging in a set of mobile money transactions. The mobile company decides how many towers to open, $m \in [0, 1]$, which is costly, but allows it to reach a new locus and to interact with agents. If $m = 1$, then all locations are reached, whereas with $m = 0$, no towers are operating. When a tower is installed, the mobile company interacts with a client and decides on a fee f for transactions.

This model presents the following two stages:

1. the mobile company invests in financial inclusion, deciding on the number of towers, m;
2. the company decides on its fee f given the user demand for mobile services.

The game can be solved by backward induction.

2.1.2 Setting

2.1.2.1 Consumer Utility

The utility function of users reached by a mobile tower can be described by the following expression:

$$U = \tau + \beta m - f$$

in which τ expresses a taste parameter, β is a parameter capturing the network externality of the overall number of connected households and f is the fee to make mobile money transfers.

In principle, users can also keep the same mobile network services, but use an alternative mobile money provider. The utility function in this case can be described by

$$U = \tau + \beta m - f_{other}$$

as users in this case need to pay a fee to the other company, f_{other}, to continue to use their mobile network once they belong to a different mobile money company.

2.1.2.2 Mobile Company Profits

The profit function of the mobile money company in a location conditional on this being reached by a tower m is given by

$$\pi(m) = f - c$$

in which the profit margin of the company is given by the difference between its fee, f, minus the marginal cost of the communication, c, for those on network.

2.1.2.3 Mobile Tower Installation

In the first period, the mobile company decides how many mobile towers m to install, given the profit margin in each location π, the fee f and some convex cost of tower installation $c(m)$. Its convexity is due to the fact that further towers are worse connected to the electricity grid and present higher costs of energy supply and maintenance, as documented in the section describing the functioning of mobile network towers.

This financial inclusion problem can be written as

$$\max_{m \geq 0} \Pi = \pi(m) - \eta \frac{m^2}{2}.$$

Note that in this setting, we introduce a new parameter η: this is a tower-installation technology parameter affecting both the average and marginal cost of branch opening.

2.1.3 Solution

In this subsection, we solve this problem for two cases: 1) the case without interoperability, in which the mobile company is a monopolist; 2) the case with interoperability, in which the mobile company faces competition.

2.1.3.1 No Interoperability

This setting can be interpreted as one in which there is no alternative mobile money platform available. This market structure gives the mobile company the possibility to extract all rents from consumers by setting their utility function to zero, making their participation constraint binding, which defines f^M as the monopoly fee:

$$f^M_{on} = \tau + \beta m$$

in this case the company appropriates not only the utility from using the service, expressed by τ, but also the network externalities reported by βm. As a result, the tower-installation problem simplifies to

$$\max_{m \geq 0} (\tau + \beta m)m - \eta \frac{m^2}{2}$$

leading to the following solution for the decisions of the mobile company

$$m^M = \frac{\tau}{\eta - 2\beta} \quad and \quad f^M = \tau \frac{\eta - \beta}{\eta - 2\beta}$$

this relies on the assumption that the costs of branch installation exceeds the network externalities in the utility, $\eta > 2\beta$, otherwise the problem simplifies to a full installation of towers in all cases and undefined fees.

2.1.3.2 Interoperability

We model interoperability as a policy allowing individuals to operate an alternative mobile money service, without switching the mobile network service. In our setting, this is modelled as a competing company, which offers transactions at a fee $f_{other} = \theta$.

This changes the competitive nature of the market, since the former monopolist can no longer extract all rents from this market and will have to compete on prices. Suppose that individuals pay an individual switching cost κ in moving from the former monopolist to the new company. Then the fee of the former monopolist emerges from solving the following incentive compatibility constraint:

$$\tau + \beta m - f \geq \tau + \beta m - \theta - \kappa$$

stating that the utility of the user remaining on the network of the former monopolist is higher or equal to the utility of an individual swtiching network and paying a fee θ and a switching cost κ. Under the plausible assumptions that this fee exceeds the marginal cost of operating in an area, $\theta + \kappa > c$, and that competition benefits consumers, $\theta + \kappa < \tau$, then this change in the competitive structure leads to a decline in fees and in availability of mobile network, since the optimal f and m are now:

$$m^C = \frac{\theta + \kappa}{\eta} \quad and \quad f^C = \theta + \kappa$$

therefore the arrival of interoperability leads to lower fees since $\theta + \kappa < \tau$ and $\frac{\eta - \beta}{\eta - 2\beta} > 1$ but also to lower mobile tower installation for the same reason. The proposition below summarizes these results and presents two additional heterogeneities.

Proposition

In the presence of a mobile company that decides fees and tower installation, the introduction of interoperability leads to lower mobile money fees and a reduction in tower installation and signal. Two central heterogeneities emerge from this setting. First, locations with higher costs of tower installation experience a stronger decline in towers and coverage. Second, mobile companies with higher fees before the arrival of interoperability exhibit a stronger decline in tower installation and coverage. In Appendix C - Theoretical Framework we provide the derivation of these propositions.

2.2 A new dataset on mobile money fees

The literature on mobile money lacks information on the fee structure of operators. A comprehensive dataset on mobile money operators' tariffs does not exist,[2] and hence for the purpose of this paper we are the first to introduce such a dataset, comprehensive of all mobile money service providers operating in Africa. We collected monthly data on each operator's fees, spanning the year 2010-2022. The main source of our data is the website of each Mobile Money provider, as the tariff plans are usually available not only to the agent offices but also online. However, operators rarely keep their past fees structure publicly available on their website: to overcome this issue, we rely on multiple Wayback Machines, which are a tool that enables the recovery of web pages that are no longer available. For instance, as shown in Figure B.1, if we want to find all the previous "versions" of the Telma (the first operator launched in Madagascar) webpage, we can type the URL of today's webpage in the search bar and choose the year/month we desire.

In most cases, the web pages are available and the tariff plans published, so it is possible to browse the "old" website and find the information needed. However, finding the rates for each year is not easy: different problems can hamper our search, such as images or documents not visible/downloadable, absence of screens for entire years, issues in loading pages, fees not present on the web pages, etc. For this reason, we rely on additional sources to fill in the gaps. Secondary sources are 1) providers' pages in different social networks like Facebook, Twitter, or Linkedin, where photos of tariff plans are often published, 2) articles concerning Mobile Money fees published in newspapers online or blogs.

We build two main datasets, containing the mobile money fees charged by each operator over time. We differentiate between fees charged to transfer money to subscribers

[2]See IPA's two-year pilot at this link.

to the same operator ("on-network") and fees charged to send money to subscribers of other operators ("cross-network")[3]. The first output is a panel data set that includes the operator name, country, year, and the yearly fees' average value for on-network and cross-network transactions. The second data set is more detailed, because it includes tariffs for all transaction ranges defined by companies' tariff plans. To this aim, we take the most disaggregated fee structure in the country and adjust all operators' rates (in that country) accordingly, as explained in the next paragraph.

It is important to highlight that the structure of mobile money tariffs is complex. Different tariffs are in fact applied for sending mobile money on-network or cross-network, and within operation types different tariffs are applied for different amounts of money exchanged. In Panel (a) of Figure 1, for example, we plot the average yearly fees for sending a mobile money transfer between two agents belonging to the same company, i.e. on-network transaction. This is plotted for each operator and is different depending on the amount of the mobile money transaction. Because fees are different by amount transacted and correspondingly by currency, in order to create a simpler measure which makes fees comparable, we create a "bracket" for all companies operating in the same country: bracket 1 reports the fees for transactions of the lowest amount, bracket 2 for the second lowest and so on.

For example, let us consider the case of Madagascar. In Madagascar, Orange Madagascar and Airtel Madagascar are two active operators, among others, offering the Mobile Money services. Orange's Mobile Money tariff plans differ from those of Airtel. Figure B.2 in the Appendix B compares the 2022 tariff plans for these companies. We first notice that the minimum and maximum amounts that can be transferred differ between the two companies: while Orange's subscribers (Panel (a)) can transfer a minimum of 200 and a maximum of 10 million Malagasy ariary (the currency of Madagascar), Airtel's subscribers (Panel (b)) can transfer between 300 and 5 million ariary. Second, it has to be noticed that Airtel's and Orange's amount ranges differ: in particular, Airtel's tariff plans

[3] We also collected fees for other types of operations (such as those for withdrawal of cash from mobile money accounts by operator's subscribers and by non-subscribers, for deposit, for payments to merchants, and for transfer of money from the Mobile Money account to the bank account, and viceversa), but the data happen to be partially lacking.

are more disaggregated. For example, while Orange sets the same tariff for all on-network transactions between 10'000 and 25'000 ariary (hence specifying one tariff for this range), Airtel applies different fees for on-network transactions between 10'000 and 20'000 ariary, and between 20'000 and 25'000 ariary. In order to make tariff plans of different companies within the same country and across different years comparable, we define new country-specific brackets by adopting the shortest common ranges across all companies within the country in all years. For example, we will disaggregate Orange's tariffs for transactions between 10'000 and 25'000 ariary into the new ranges 10'000-20'0000 and 20'000-25'000, so that they match Airtel's tariff ranges: Orange will hence now display two different ranges, to which the same tariff is applied. Obviosuly, transaction ranges will span from the minimum value to the maximum values that can be found across all companies. The country-specific bracket 1, in this example, will range from 200 and 300 ariary: for this range, Airtel does not provide the possibility to exchange money and will be hence shown as missing, while Orange will display the tariff that is applied for its range 200-1000 ariary. Similarly, for brackets ranging between values greater than 5 million ariary, Airtel will be displayed as missing.

In order to make tariffs comparable across countries, we express them as percentage of the transaction values. While in many cases tariff plans are already defined in percentage by mobile money operators, in other cases, as the one we take as example, they are defined as a fixed sum for the transaction whole bracket. In those cases, we express the fee as percentage of the mean value of the bracket. In Panel (b) of Figure 1, we notice not only a higher dispersion of tariffs in the lowest brackets, but also how rates decrease for higher brackets. This fee structure hence burdens on those users who make smaller transactions. Figure 2 shows how average fees for on net transactions vary across countries, over time. We define the same 5 transaction brackets for all countries in year 2015 and 2021, and observe countries shifting bracket both downward and upward.

2.3 Mobile network coverage and infrastructures

Mobile money services are vertically integrated with the network operator providing the service. This means that the mobile money service can be used exclusively where a given mobile network operator's connection covers the area (Bourreau and Valletti, 2015). When studying mobile money, it is hence important to understand the infrastructure enabling the network coverage, and in particular the economics behind the installation and maintenance of towers. It is especially important to clarify that mobile network towers are not necessarily a fixed and long-term investment, as they present sizeable operating costs. As a result, the choice of a network operator to invest in signal in a location takes into account the revenues of a potentially larger pool of users versus the variable costs of maintenance and operations. Africa has a population of over 1.1 billion. However, the population coverage of mobile networks in Africa stands at an average of 70%, leaving around 300 million people without access to mobile communications. The coverage of mobile network has varying range from 10% to nearly 99% across countries in Africa. Within the context of achieving universal access to mobile communications, Africa presents a significant growth opportunity for the mobile industry over the coming years. At the same time, the mobile industry in Africa faces many challenges – both infrastructural, operational and economic - that lead to to higher Operational Expenditures (OPEX) (Houngbonon et al., 2021).

The towers used for the commercial transmission of mobile signals are typically powered through an electrical connection: they are "on-grid", as they receive power from the electrical grid as an input and release signal as an output. However, there are instances in which it is impossible to operate on-grid towers, because the grid may be unreliable or the tower may be in a remote location. In this case, the technology for transmitting the mobile signal is through an "off-grid" system: a power generator using diesel as a main source, or as a backup, is the standard technology.

As a result, mobile operators in Africa face challenges to power their mobile networks, because of unavailable or unreliable power supply and consequential heavy reliance on expensive diesel power generators. Major infrastructural and operational challenges make it extremely costly for mobile network provider to expand their coverage or to keep it active in more marginal areas. The most common costs faced by mobile operators as pointed out by Kumar (2014) are due to: limited or no road access infrastructure which increase Operation and Maintenance (O&M) costs of sites, higher cost of security and monitoring systems to protect assets and infrastructure to prevent diesel theft, equipment theft and vandalism of site equipment, lack of local skilled technical resources that causes a further increase in the costs of operations. These infrastructural impediments translate in the lack of economic incentives for mobile network operators to provide their services in remote areas. In particular, low income levels and poor revenue potential - especially in rural and remote regions - affect the return on investment (ROI) and hinder the expansion of mobile networks requiring a high capital expenditure (CAPEX) and operational expenditure (OPEX). Moreover, rural regions enjoy lower economies of scale (in terms of subscribers per site) for network assets due to dispersed communities and lower density of population. This is reflected in higher cost per subscriber and hence affects the affordability of services leading to lower subscriber penetration.

The limited reach of grid infrastructure and inadequate power generation capacities has greatly affected the availability and quality of electricity supply to mobile network sites, and therefore impacted the configuration and geographic spread of mobile networks in Africa. The majority of telecom tower sites in Africa are deployed in either off-grid areas or problematic grid areas with unreliable power supply (Ahmad et al., 2015). This observation is in line with the fact that the growth in mobile networks has tremendously outpaced the expansion of grid infrastructure across countries in Africa. As a result, many of the tower sites are deployed in off-grid areas. The necessity for diesel generators, and increasingly battery backups, is not limited to off-grid towers in Africa, but includes also a large share of on-grid towers. This is due to the fact that energy provision planning was traditionally ignored by the network expansion teams during the aggressive network roll-out (Kumar, 2014). The limited reach of grid infrastructure and its snail-paced expansion further widened the demand-supply gap and have adversely affected the availability (with more frequent/longer power cuts) as well as quality of power supply.

In this respect, energy costs constitute a major chunk of network OPEX for mobile operators in Africa. As reported by Kumar (2014), for a typical tower site in Africa, the share of energy costs is as high as 40% of the overall network OPEX, and the power consumption from diesel is about a factor 10-20% higher than the power requirements of the cell base stations. This large gap is due to the high inefficiency of diesel generators. Diesel generators can have an efficiency of lower than 15% and with poor maintenance, the efficiency could potentially be much lower.

As a result, the expansion of mobile network coverage hence requires a large investment in network infrastructure including both active network equipment and passive tower infrastructure. Passive infrastructure, including tower and power, forms a major chunk of investment in expanding the mobile networks. In addition to the high CAPEX investment in networks, the costs of operations remain very high in African countries, especially owing to the higher costs of providing energy to the base station sites.

2.4 Data

We employ several different and novel sources of data. We do not only provide new self-collected datasets on mobile money fees and mobile money institutions, but also a new dataset on individual network operators' coverage, as well as their financial and non-financial information. The main databases employed in this research are listed as follows:

1. Mobile Money fees. As explained in Section 2.2, we introduce a new panel dataset on mobile money fees for all mobile money operators providing their service across African countries. We collected yearly data for 121 mobile money operators, operating in 40 African countries, in a time span of 12 years. To make the panel reliable and usable, we spell the mobile money tariffs as percentage of the total transaction. We provide a comprehensive dataset including fees for all types of transactions and for all transaction brackets harmonized at the country level.

2. Mobile network operator coverage. We use a new dataset on mobile network

coverage by operator over the years 2010-2021. This is the first time that Harper Collins and the Global System for Mobile Communications (GSMA) provided this dataset for research purposes. The collection of this dataset works as follows: every year GSMA collects coverage data from each mobile network operator worldwide. We are hence able to see the development of individual operators' coverage over the last decade. Data are detailed for different kind of connections (1G, 2G, 3G, 4G and, now, 5G) and are provided at a raster level of approximately 250 squared meters. This means that we observe for the entire African continent the presence of mobile network signal for each raster by each operator and over time. For our empirical analysis, we aggregate this data for each operator at the smallest administrative unit in each country, as defined by the Database of Global Administrative Areas (GADM).[4]

3. GSMA Intelligence Mobile Network Data. This is the most comprehensive source of mobile industry insights, forecasts and research, available. GSMA collects data on every mobile network operator (MNO) in every country worldwide. They provide yearly data on several financial, usage and performance indicators of MNOs. We exploit data of 253 mobile network operators, operating in 57 African countries over a period of 22 years spanning from 2000 to 2021.[5]

4. Interoperability data. As later explained in Section 2.5, we also construct and provide the first dataset on the introduction of mobile money interoperability across African countries. We register each policy change regarding interoperability, i.e. the possibility to exchange mobile money between different mobile money operators introduced in each African country. We are also able to identify whether mobile money interoperability was initiated by the local Government, or whether interoperability was market-led, hence introduced by the operators themselves without the presence of a clear institutional

[4]The Database of Global Administrative Areas is a comprehensive database of country administrative units, published with the objective of standardizing and uniforming information across countries and time periods. The shapefiles and information are publicly available at https://gadm.org/

[5]While this dataset does not contain information on contribution of mobile money services to the network operators' financials, in Online Appendix E - Mobile Network Operators Balance Sheets we provide, as an example, balance sheets (financial statements and revenue breakdowns) from selected MNOs also reporting revenues and costs of their mobile money service. In this restricted sample, the revenue from mobile money services lies between 7.7% for the overall Airtel group to 38.3% for Safaricom both in 2021.

framework.

5. Global Findex World Bank data. We exploit the Global Findex dataset provided by the World Bank, based on nationally representative surveys and containing updated indicators on access to and use of formal and informal financial services and digital payments. We exploit this dataset to hint at possible effects of the introduction of interoperability on financial inclusion. Data are taken from about 150'000 surveyed adults, in 48 African countries, for the years in which the survey was conducted (2011, 2014, 2017, 2021).

6. IMF Financial Access Survey. To further study the effect of interoperability on financial inclusion, we exploit country level data on measures of finacial access provided by the IMF. The IMF FAS contains yearly data on access to and use of financial services, including mobile money. The dataset covers 189 countries spanning more than 10 years.

7. Geographical data on urban development and nighttime light intensity. We exploit the dataset introduced by Cattaneo et al. (2021) to create a district's measure of urban development. In this dataset, raster pixel are assigned a value ranging from 1 to 30, where 1 identify most urban areas and 30 most rural areas. The district's measure of urban development is hence constructed as the average of the pixel values in the district's itself. We then divide our districts into two different groups following the classification proposed by Cattaneo et al. (2021): those districts with a value of the index lower or equal to 13 are identified as urban, while districts with an index greater than 13 are classified as rural. We also exploit the data on nighttime light intensity provided by the National Centers for Environmental Information. They provide pixels with value ranging from 0 (no light) to 63 (maximum light intensity), all over the globe. We construct a district's measure of light intensity by averaging nighttime light intensity across all pixels contained in the district.

Table 1 reports summary statistics for the main variables used in our analysis. Panel A presents two variables with a subscript iy, which labels a variable that varies by mobile money operator i during year y: *Fees on network* describes the average yearly fee applied to transaction between users of the same operator over the transaction value; *Fees cross network*, instead, represent the relative cost of the transaction when this is done between users of different mobile money networks. Panel B present summary statistics for performance and usage indicators of mobile network providers taken from the GSMA Intelligence dataset. Variables are expressed in log and vary by mobile network operator i over year y. Panel C and Panel D summarize the coverage variable at operator-district level and at district level, respectively. Variables in Panel C vary by operator i in district d over year y, while variable in Panel D vary by district d over year y. These two panels also report summary statistics for *Interoperability*, an indicator of the presence of interoperability in the mobile money market. In Panel C an operator-specific measure of interoperability is reported (which takes value 1 when the operator effectively became interoperable), while Panel D reports a country-specific measure of interoperability (which takes value 1 when the national legislation starts requiring mobile money operators to be interoperable). Panel E reports the summary statistics for the World Bank Global Findex Survey: we report three variables that we use as a proxy of financial inclusion and resilience. Variables vary by individual j in country c in year y. Panel F reports summary statistics for the IMF Financial Access Survey, that contains country-level data on mobile money usage. In Panel F, variables are reported in log, and vary by country c in year y.

2.5 Identification: the staggering of Interoperability

Interoperability is a characteristic of an information system to interact with other information systems without any restriction in the present and future. In application to mobile money systems, this term refers to the ability to exchange payments with mobile money users that operate on a different platform.

In line with Naji (2020), we define Interoperability as the possibility given by Mobile Money Operators to transfer money between two accounts in different mobile money schemes. While mobile money was born as a stand-alone service, in which transfers were allowed only within the same network, in the following years, it experienced an integration process that brought the connection of operators between themselves and other payment services. While we are aware that different types of interoperability exist depending on the level of integration of systems, as explained in Online Appendix D - Interoperability we focus on the case of wallet-to-wallet interoperability, i.e. the possibility to transfer mobile money between users of different operators. Indeed, as we document, institutional regulations about interoperability and bilateral agreements between mobile money providers in African countries always request this level of integration between mobile money systems.

Mobile money interoperability allows customers of different mobile financial services providers to interact with each other, for example by making direct payments from the mobile money account of one provider to the mobile money account of another provider. It can benefit consumers and businesses, and contribute to increased financial inclusion. In recent years, various development organizations, industry bodies, and regulators have embarked on enabling mobile money interoperability between digital financial services providers in different markets across the globe. In September 2014 the mobile financial services industry in Tanzania signed its first agreement on interoperability, making Tanzania one of the first countries in the world with an industry-agreed interoperable market for mobile financial services (Naji, 2020). We exploit the staggered deployment of mobile money interoperability across African countries as main source for our identification scheme.

In the legal system of African countries, in fact, mobile money is generally settled together with other similar payment instruments. This means that mobile money interoperability is defined and enacted within the regulatory framework of financial operators. However, discrepancies between the regulatory framework and the actual adoption of interoperability by mobile money operators might arise. This is due to several causes, that differ across countries. Indeed, we might observe both countries where interoperability is introduced by the regulator but not yet adopted by operators, and countries where operators allow interoperable transactions even in the absence of a institutional regulation. The first case might arise when the new regulatory framework concerning the introduction of interoperability is not clear and does not specify the details through which this policy should be enacted. For example, the Bank of Botswana in 2019 published the “Electronic Payment Services Regulations”, where it was stated that “the resources shall be a system which is interoperate with other payment system within Botswana”: this regulation requires payment systems to be interoperable, but no technical standards for interoperability are prescribed, hence leaving to the operators too much discretion about how and when to enact interoperability. The second case might instead arise when operators themselves see potential benefits from the introduction of interoperability or when they want to precede a regulation that, soon or later, will be enacted by the regulator. This is the case of Airtel Money and Safaricom's MPESA in Kenya, which in January 2018 undertook a pilot phase, enabling the seamless transfer of funds between mobile accounts on different networks. In April 2018, in a press release, the Central Bank of Kenya welcomed the implementation of interoperability of mobile financial services, stressing its benefits and importance to Kenya's mobile money market. Figure 3 presents the staggering of interoperability until 2021. Up to date, 20 African countries have introduced mobile money interoperability. Our empirical strategy relies on three different empirical specifications, which all rely on the economic characteristics of countries adopting and not-adopting interoperability to be balanced both at baseline and over time, as shown respectively in Tables A.1 and A.2. First, we develop an event study design meant to test for pre-trends and to investigate the dynamics of the treatment effect. Second, we implement a staggered difference-in-difference specification using two-way fixed effects regressions. The staggered difference-in-difference provides compact estimates of the average treatment effect under the assumptions of no pretrends. Third, we refine our analysis with the inclusion of a unit-specific heterogeneity. This allows us to draw specific policy implications and bring more clarity in the debate about the effects of mobile money interoperability (Bourreau and Valletti, 2015).

Interoperability, however, is a regulatory framework of the mobile money industry that can either be Government-led, i.e. proposed and enacted by the national political institutions, which tries to furhter develep the mobile money industry and foster financial inclusion (Ahmad et al., 2020), or that can be a feature introduced by operators themselves, which decide to collaborate and allow the exchange of mobile money between users of different providers (Karrar and Rahman, 2015). We are able to identify both cases. By collecting information coming from national law bulletin and from operators' websites, we are able to differentiate whether in a given country the regime of interoperability is Government-led (whether interoperability is introduced at the country level) or market-led (whether interoperability is introduced at the operator level, i.e. if it is the operator itself that makes its system interoperable). In some cases, in fact, bilateral agreements between mobile money providers precede the formal introduction of interoperability by the local political institution. In Online Appendix D - Interoperability we provide details about the introduction of mobile money interoperability for each African country in which such policy was enacted.

In the paper, we will first present results showing the effect of the operator-level introduction of interoperability on operator's fees, mobile network coverage and financial outcomes. We will then move to show how country-specific introduction of interoperability affects both the mobile network coverage at the district level and financial inclusion.

The first specification that we propose is an event study based on the year of introduction of interoperability. The event study allows us to check for pre-trends and, to a lesser extent, to provide evidence on the dynamics of the treatment effect. We have four dimensions of analysis. The first one exploits the variation at the operator's level: we study the effect of interoperability on operator's performance and mobile money tariffs. The second uses operator-district level data: we study the effect of interoperability on operators' coverage at local level. We also include operator-district heteoregeneity, and in particular we exploit the dominance of an operator in a given local market and the number of years during which the operator was active in the local market before the introduction of interoperability. The third exploits variation at the district level: by aggregating data of all operators active in a given geographical unit, we study the effect of interoperability on overall network coverage at geographical level. We also discuss how competition in a given district leads to different effects of interoperability. The fourth exploits national level data, to study how the introduction of interoperability affects financial inclusion. The empirical specification will be explicited in the next section.

In Appendix A, Table A.1 shows that there are no macroeconomics differences at baseline between countries that introduce mobile money interoperability and those which do not introduce it. In this balance table, we compare countries that never introduced interoperability with countries that eventually introduced it, and for this second group we use data for the period before the introduction of interoperability. The data span from 2000 to 2021. In Table A.2, instead, we show that interoperability macroeconomic country-specific characteristics do not change after the introduction of interoperability. Indeed, the column 'Difference' reports the coefficients of a regression where country specific variables are regressed over an interoperability dummy, taking value 1 after the introduction of interoperability at the country level.

3 Empirical Model and Results

Following the structure of the paper, this section is divided into five subsections. In the first, we study the effect of interoperability introduced at the operator level, i.e. we define a measure of interoperability that takes into account the exact moment in which an operator allows interoperable transactions. We show the effect of interoperability on mobile money tariffs, and show how an interoperable system fosters competition between mobile money operators, which lower their tariffs. We show how interoperability affects the individual mobile network coverage and also present the differential effect of interoperability on the mobile network coverage depending on the market power of the network in the local market. We then highlight the effects of interoperability on the financial performances of mobile network operators linked to mobile money services; we present results on how interoperability negatively affect revenues and investments of mobile network companies providing mobile money services. We conclude this subsection with an instrumental variable approach, aimed at ruling out possible endogeneity of interoperability adoption at the operator level.

The second subsection provides aggregate results on the effect of interoperability at the district and at the country level. Here we use a country specific measure of interoperability, that takes into account the moment in which a regulatory legislation concerning mobile money interoperability has been introduced in the country. We first show how interoperability affects mobile network coverage at the district level and then we verify that these effects change depending on the level of competition in the local market. We then propose an analysis aimed at understanding the effect of interoperability on financial inclusion. We first present heterogeneous effects of interoperability on districts' mobile network coverage, depending on the level of urban development of the district. We show that rural areas are more negatively affected, in terms of mobile network coverage, by the introduction of interoperability. We then provide additional results that shed light on the implications of mobile money interoperability on financial inclusion, at the country level. To do this, we explore a difference-in-differences two way fixed effects design on two main datasets: the World Bank Global Findex dataset, which includes survey data from individuals living in developing countries, and the IMF Financial Access Survey, which is a country-level dataset providing information on financial access and inclusion. In addition to these two datasets, we also explore the Demographic and Health Survey (DHS) data, which is a a collection of surveys on individuals in developing countries.

In the third subsection, we provide insights on the differential effects of interoperability in relation to the degree of local market development. To do this, we show heterogeneous effects depending on the length of the presence of the mobile network in the district before interoperability is introduced. We show that the negative effect of interoperability is stronger for less established and consolidated networks.

In the fourth subsection, we provide a policy proposal by introducing an analogy between the temporal expiration of patents in the context of innovation and the timing for the introduction of platform interoperability in mobile money and digital payment systems.

In the last subsection, we present robustness checks on the main results, using some of the latest methods in the difference-in-difference and event study literature proposed by Borusyak et al. (2021) and by Sun and Abraham (2021).

3.1 Evidence at the operator level

3.1.1 Fees

We exploit the staggered introduction of interoperability in African countries to study its effect on the fee structure of mobile money operators. Our main variables of interest are: *On Net Fees*$_{iy}$, the average fee over transaction values for transactions between users of the same operator, *Cross Net Fees*$_{iy}$, the average fee over transaction values for transaction between users of different operators. Averages are not weighted by individual operator's transactions volume by bracket, as this information is not retrievable.

Figure 4 presents a descriptive graph of how tariffs and coverage have changed over time, and of how interoperable operators apply lower fees and reduce their coverage. Panel (b) and (d) show respectively the average tariffs and the average network coverage for non interoperable and interoperable operators: the dotted line includes operators as they become interoperable, while the year 2015 refers only to the operators in the first country introducing interoperability, the year 2021 refers to operators active in all countries which have been adopting interoperability.

The first exercise that we propose is an event study as defined in the following equation:

$$Y_{ict} = \alpha_i + \beta_t + \gamma_{-3} I \left\{ K_{ict} \leq -3 \right\} + \sum_{k=-2}^{2} \gamma_k I \left\{ K_{ict} = k \right\} + \gamma_{3+} I \left\{ K_{ict} \geq 3 \right\} + \varepsilon_{ict} \quad (1)$$

where Y_{ict} represents the dependent variable for operator i in country c in year t; α_i and β_t are operator and year fixed effects; K_{ict} is the relative year from the adoption of interoperability by operator i; γ_{-3} is the single coefficient for far leads; and γ_{3+} is the single coefficient for longer-run effects. The observation window is 2010–2021, while we restrict the event window to be the interval $[-3; +3]$ from the year of the adoption of interoperability by operator i. We assign a value of 1 to the dummies that are at the extremes of the event window, where $-3 \geq K_{ict} \geq 3$, and set the year before the adoption of interoperability as the baseline category, as is standard in the literature. Standard errors are clustered at the operator level. Figure 5 reports the results of Equation 1, in particular those of coefficients γ_j for $j = -3, .., 3$. The left panel refers to on net fees, i.e. fees of transactions between users of the same operator, and shows no pre-trends; this means that before the introduction of interoperability, the point estimates are close to zero, and none of them are statistically significant. However, the coefficients become negative and statistically significant two years after the introduction of interoperability. In particular, we observe a jump at year two, where the on-net fees register a decrease of 1%, followed by a gradual additional decrease in the following years. The right panel refers to cross net fees, i.e. those paid when transacting mobile money to a different operator. Similar to before, no pre-trends can be detected and the coefficients are negative and decreasing starting from year 0, and they are statistically different from zero. The decrease over years is starker in this case: coefficients show a decrease in cross-net fees of 2% after 1 year from the introduction of interoperability, growing in magnitude to 4% after 3 years. Overall, we interpret these results as a negative effect of the introduction of interoperability on tariffs imposed by mobile money providers.

The second exercise we propose is a staggered difference-in-differences specification as specified below:

$$Y_{ict} = \alpha_i + \beta_y + \gamma Interoperability_{ict} + \varepsilon_{ict} \tag{2}$$

where, again, Y_{ict} represents the dependent variable, for operator i in country c in year t; α_i and β_t are operator and and year fixed effects; and $Interoperability_{ict}$ is a dummy variable that equals one after the operator adopts interoperability. Table 2 reports the estimates from the staggered difference-in-difference specification as defined in equation 2. This two-way fixed effects regression provides a compact measure of the average causal effect of interoperability on our two mobile money tariffs outcomes. It imposes no pre-trends and assumes constant treatment effects. The results from Table 2 confirm those from the event studies. Introduction of mobile money interoperability is associated with a significant decrease in mobile money tariffs, both on net and cross net. The estimates are also large in magnitude: introducing interoperability decreases on net tariffs by 65% and cross net by 25%, with respect to the mean value before the policy change. We propose the same analysis of Table 2, but now differentiating between different transaction brackets.

As explained in Section 2.2, mobile money operators apply different tariffs for different transaction values. In particular, these tariffs happen to be regressive, in the sense that fees are relatively higher for lower transactions. We harmonize transaction brackets at country level, for all operators. We define the first bracket as the lowest transaction bracket in a given country. Consequently, the second bracket will be the second lowest bracket, and so on. Table 3 present results for pairs of transaction brackets. We group transaction brackets in seven pairs and obtain estimates of the following equation:

$$Y_{bjict} = \alpha_i + \beta_t + \gamma_b + \sum_{j=1}^{7} \delta_j Interoperability_{ict} \times \mathbf{1}_j + \varepsilon_{ict} \quad (3)$$

where α_i is the operator's specific fixed effects, β_t the year fixed effect, γ_b if bracket b fixed effects. Brackets are paired in seven groups, denoted by j: $\mathbf{1}_j$ indicate whether bracket b belongs to group j. We interact the groups' indicator variables with the Interoperability$_{ict}$ dummy. Our coefficients δ_j will hence show the effect of operator-level interoperability on brackets belonging to group j. In Table 3 and Figure 6 we report the coefficients of Equation 3. We show that our results are driven by the lowest two transaction brackets, corroborating our hypothesis that interoperability foster competition between mobile money operators, which try to attract more people in their network by decreasing the tariffs for the lowest transaction values, that, according to many policy report, are the ones that constitutes the bulk of mobile money transactions (Yao et al., 2022).

3.1.2 Coverage

In this section, we provide an analysis of how operator coverage in districts evolves over time and its response to interoperability. This means, that we consider as unit of analysis the operator-district pair. We define districts as the smallest administrative units available in the GADM database, the main database of shapefiles used in the academic literature. This section shows the main results of our analysis, providing evidence of how

Mobile Network Operators change their coverage after the introduction of mobile money interoperability. This analysis is of particular interest because it also allows us to provide an insight on the heterogeneous effect of interoperability depending on the dominance of a given operator in the local market. Indeed, the same operator might decide to behave differently in different areas, depending on its coverage in the areas before the policy change. We exploit an event study and a difference-in-differences approach. The event study will take the following form:

$$Y_{idct} = \alpha_{id} + \beta_t + \gamma_{-3} I\left\{K_{ict} \leq -3\right\} + \sum_{k=-2}^{2} \gamma_k I\left\{K_{ict} = k\right\} + \gamma_{3+} I\left\{K_{ct} \geq 3\right\} + \varepsilon_{idct} \quad (4)$$

The staggered difference-in-differences will instead be of the following type:

$$Y_{idct} = \alpha_{id} + \beta_t + \gamma \text{Interoperability}_{ict} + \varepsilon_{idct} \quad (5)$$

In both cases the variable Y_{idct} refers to the outcome of operator i in district d in country c at time t. We include operator-district fixed effects α_{id}, and year fixed effects β_t. The outcome variables are: the operator's coverage in a given district, i.e. the share of coverage relative to the district's area, in percentage; and the probability of signal of the operator in the district, which is a dummy that takes value 1 if the operator has signal in the district.

Table 4 provides insights on the behavior of operators at the local level when interoperability is introduced. Both column (1) and column (2) suggest a general decrease in the total coverage of an operator at the district level and its lower probability of keeping signal. In particular, individual operator's coverage decreases by almost 4 percentage points after the introduction of interoperability, while the probability of signal decreases by almost 5 percentage points. Figure 7 reports the results of the event study, which is in line with our difference-in-differences approach. It shows the presence of parallel trends, and the significant effects of the introduction of interoperability for both variables.

Again, to further investigate our mechanism, we provide a heterogenous effect analysis and study whether the effects of interoperability differs depending on the dominance of the operator in the local market. We exploit the following:

$$
\begin{aligned}
Y_{idct} = \alpha_{id} + \beta_t + & \gamma \text{Interoperability}_{ict} + \\
& \rho \text{Interoperability}_{ict} \times \mathbf{1}\left[> \text{Dominant } 30\right]_{idct_0} + \varepsilon_{idct}
\end{aligned}
\tag{6}
$$

where $\mathbf{1}\left[> \text{Dominant } 30\right]_{idct_0}$ indicates whether the operator covered more than 30% of the district's area in which it was operating the year before the introduction of interoperability. Table 5 shows that results on total coverage, column (1), are driven by dominant operators. Those are the ones that drive the drop in total coverage. Indeed, while non dominant operators experience an increase in total coverage of almost 9% after the introduction of interoperability, dominant operators reduce their coverage by 6%.

3.1.3 Operator's performance

In this section, we verify whether the registered drop in coverage of mobile network operators goes parallel with a reduction in operator's market penetration and investment in infrastructure, and whether this has an impact on its financial performances. We exploit the staggered introduction of interoperability to also study the effects on mobile network operators' performance. To this aim, we use the same specification as the one described in Equation 5. Our estimates show how interoperability affects performances, investments and usage of the operator, and explore the response of operators to prices of different services they provide, such as calls, texts and internet.

Table 6 confirms that the total coverage of mobile network operators linked to mobile money services drop after the introduction of interoperability: this, of course, has a repercussion on the operator's market penetration as well. The increased competition to which mobile money interoperability leads increases the marginal cost of covering the "last mile", and hence operators disinvest in infrastructure. Column (4) shows that after the introduction of interoperability, the number of towers decreases. This is in line with what we have highlighted in Section 2.3 about the high cost of maintaining infrastructure that allows coverage in more remote areas. In Table 6 outcome variables are expressed in log. Column (1) shows results for the percentage of population covered: we register a decrease of 18% in the country's population covered by the mobile network. Similarly, revenues decrease by 30% and the number of towers decreases by 12%.

In Table 7 we test whether increased competition in mobile money affect also prices for other services provided by mobile network operators. We find no significant effect on prices for calls, messages or internet data. For the three categories of prices coefficients are close to 0 and not significant. In Table A.3 we instead show that interoperability has no effect on the probability of mobile network operators to take part in a M&A operation. We do this to ensure that interoperability does not affect the structure of the mobile network market.

3.1.4 Instrumental Variable approach

We develop an instrumental variable approach, where we instrument our operator-specific measure of interoperability, with the country-specific one. Table A.6 presents the first stage estimates. Tables A.7, A.8 and A.9 reproduce the results from Tables 2, 4 and 6, by adopting the instrumental variable and this IV appears to be relevant and strong, with the first stage F ranging between 30 and 100 depending on the sample size of each regression. At the same time, we note that these results are very close in terms of sign, magnitude and statistical precision. The main reason for which these different estimations yield similar results is to be found in the high correlation between operator-level and country-level mobile money interoperability. In fact, while some companies appear to voluntarily introduce interoperability, sometimes anticipating the official country-wide introduction led by policy-makers, most companies appear to follow the introduction of this policy. In addition to this, the use of the IV allows us to preempt possible concerns related to the determinants of company-level interoperability adoption, by showing that the most relevant proxy, namely the country-level policy, appears to drive the vast majority of our underlying variation.

3.2 Evidence at the District and Country level

3.2.1 Coverage at the District level

This section studies the effect on interoperability on mobile network coverage at the local level. We extend the results presented in Section 3.1.2 by providing aggregate evidence at the district level. Here, we focus on coverage at sub-national units, hence aggregating individual operator level data at the smallest geographical unit as defined by the maps provided by GADM, as explained in Section 2.4. The dataset used for the analysis in this section is hence composed by 54'000 administrative units, over a period of 12 years spanning 2010-2021, for a total of about 650'000 observation. We exploit a more aggregate version of Eq. 1 and Eq. 2, where the unit of analysis is now given by the geographical unit d. In particular, we estimate the following event study design:

$$Y_{dct} = \alpha_d + \beta_t + \gamma_{-3} I\left\{K_{ct} \leq -3\right\} + \sum_{k=-2}^{2} \gamma_k I\left\{K_{ct} = k\right\} + \gamma_{3+} I\left\{K_{ct} \geq 3\right\} + \varepsilon_{dct} \quad (7)$$

and the following two-way fixed effects model:

$$Y_{dct} = \alpha_d + \beta_t + \gamma \text{Interoperability}_{ct} + \varepsilon_{dct} \quad (8)$$

where the dependent variable is defined Y_{dct} and refers to a district d in country c in year t. It represents the following variables: *Total Coverage*$_{dct}$, which is the percentage of district's area covered by any mobile network operator (i.e., 0 means that no mobile network operator has signal in the district, while 100 means that the district is completely covered by mobile connection); *Probability of signal in district*$_{dct}$ is instead a dummy variable taking value 1 whether at least one operator in active in the district, while it takes value 0 when there is no operator covering that given district; *Number of MNOs*$_{dct}$ is the number of operators active in the district. Figure 8 reports the event study specified in Eq. 7, and Table 8 reports the results of Eq. 8. The left panel of Figure 8 shows the negative effect of the introduction of interoperability on mobile network coverage, expressed as percentage of the district's area. After one year, we register a decrease of 2 percentage points in coverage. This decrease grows in the following year, up to 3 percentage points. Similarly, the right panel shows a decrease in the number of operators in the district, after the introduction of interoperability. The number of mobile network operators decreases by almost 15% after one year from the introduction of interoperability, and this decrease remains stable in the following years. In the lower central panel, we show that the probability of signal in the district decreases by 1.5 percentage points in the three years following the introduction of interoperability.

To further investigate our mechanism, we analyse an interesting cross-sectional heterogeneity which allows us to characterise the effect of interoperability in greater detail. We test the assumption that interoperability differentially affect the behaviour of mobile network operators depending on the concentration and competition in a given local market. Such difference is established through a dummy indicating whether in a district there is more than one operator before the introduction of interoperability. Table 9 presents the results of the following specification:

$$\begin{aligned} Y_{dct} = \alpha_d + \beta_t + &\gamma \text{Interoperability}_{ct} + \\ &\rho \text{Interoperability}_{ct} \times \mathbf{1}\left[> 1 \text{ operator}\right]_{dct_{0c}} + \varepsilon_{dct} \end{aligned} \tag{9}$$

where $\mathbf{1}\left[> 1 \text{ operator}\right]_{dct_{0c}}$ is a dummy taking value 1 if the number of operators in a given district in the year before the introduction of interoperability in the country, t_{0c}, was greater than 1. Since $\mathbf{1}\left[> 1 \text{ operator}\right]_{dct_{0c}}$ is a district-specific constant, it is absorbed by the district fixed effects, and hence only it's interaction with the interoperability dummy appears in the regression. The results suggest that coverage shrank less in those districts where a more than one mobile network provider was operating before the introduction of interoperability. Still, the number of operators in a district decreases more. These results hence suggest that interoperability increases competition at local level. In particular, in those districts covered by one only operator, coverage decreases by 8 percentage points, while in those districts where more operators are active coverage decreases by 4 percentage points. Even though coverage decreases less in local markets where competition is higher, we witness a higher reduction in the number of operators in those markets: this means that operators tend to leave more competitive markets. Indeed, the number of operators in a district with more than one operator decreases by 22% after the introduction of interoperability.

3.2.2 Financial Inclusion

The debate around mobile money interoperability has increasingly focused on the effects on financial inclusion (Bourreau and Valletti, 2015). Because mobile money is seen as a tool that enhances financial inclusion and gives access to digital financial services to the poorest and those ones living in the most remote areas of developing countries (Suri and Jack, 2016), any policy change on this payment system needs to take into account the potential implications on individuals that are unbanked and financially-underserved.

To investigate the implication of interoperability for financial inclusion, we present results both from survey data and from country-level data. We use the World Bank Global Findex dataset on the following empirical model:

$$Y_{ict} = \alpha_c + \beta_t + \gamma \text{Interoperability}_{ct} + \varepsilon_{ict} \tag{10}$$

where Y_{ict} refers to answers to the survey questions of individual i living in country c, α_c and β_t are respectively country c and year t fixed effects. Table 10 shows that interoperability negatively affects several measures of financial inclusion, and that access and usage of mobile money transactions for different purposes (e.g. sending and receiving remittances) decreases. We show that after the introduction of interoperability the probability of owning a mobile money account decreases by 4%. This might have a backlash on domestic remittances: individual's probability to send and receive domestic remittances (with any mean, or specifically with mobile money) decrease respectively by 7% and 6%. Also the probability to have access to emergency funds in case of financial distress or calamity decreases by 4%, suggesting a relationship between mobile money and risk sharing as pointed out by Jack and Suri (2014). Individuals are also 2% less likely to be able to save for developing their own business, and 3% less likely to receive Government's aid through mobile phone. While estimates are not precise, we further investigate the underlying mechanism showing that countries with a stronger pre-existent mobile money network are significatively more affected by the introduction of interoperability. In Table 11 we replicate the results of Eq. 10 by adding an interaction term between interoperability and a measure of the strength of the mobile money network before the introduction of the policy:

$$\begin{aligned} Y_{ict} = \alpha_c + \beta_t + &\gamma \text{Interoperability}_{ct} \\ &+\delta \text{Interoperability}_{ct} \times \text{Mobile Money Network}_c + \varepsilon_{ict} \end{aligned} \tag{11}$$

where Mobile Money Network_c is the standardized number of survey respondents with a mobile money account in country c before the introduction of interoperability. We show that our results are hence amplified by network effects. These results can be seen as the consequences of a reduction in mobile network coverage both at the extensive margin (i.e. in terms of geographical outreach) and the intensive margin (i.e. in terms of signal quality) following the introduction of interoperability. In this case, magnitudes are amplified and estimates become significant. Indeed, for one standard deviation increase in the number of mobile money users, we register a significant decrease of about 9% in the probability to have easy access to emergency funds, a 13% decrease in the probability to save for business related activities, a 9% decrease in the probability to receive Governement's aid through mobile money, and a decrease of 2% and 12% respectively for sending and receiving domestic remittances (magnitudes are even higher if we focus only on remittances exchanged through mobile money).

Table 12 provides similar results for data aggregated at country level in the IMF FAS dataset. We first document a decrease in the number of users and outlets (mobile money agents), as well as in the number of transactions. Table 13 provides further evidence that the pre-esisting strength of the mobile money network drives our results. Again, we provide a heterogeneity analysis by interacting the dummy for interoperability with a standardized measure of the number of mobile money accounts in the country before the introduction of interoperability. Also in this case, estimates gain significance and the negative effects of interoperability on all the measures of financial inclusion are amplified by netwrok effects.

To further investigate the underlying mechanism, we provide two different tests aimed at understanding whether the introduction of interoperability changes the propensity and convenience of mobile users to own multiple SIMs, and at understanding whether countries where users hold multiple SIMs are differentially affected by the introduction of interoperability. To tackle the first point, in Table A.4 we present results from a regression where the independent variable is a dummy taking value 1 when interoperability is enacted at the country level, and where the dependent variable is the number of mobile phone subscriptions, both as the number of SIM cards over 100 inhabitants and in absolute terms. No effect of interoperability on the number of SIMs is detected. To tackle the second point, we instead leverage granular data at the operator-district pair. Table A.5 in Appendix A reports an OLS regression where interoperability is interacted with a country specific measure of mobile phone subscriptions (i.e. number of SIM cards over 100 inhabitants). Estimates show that there is no differential effect of interoperability depending on the number of mobile phone subscriptions. Indeed, coefficients of the interaction term, even though significant, are extremely small and close to zero. In Appendix A, we use the DHS data: Table A.10 reports the effect of interoperability on the the probability of having made a transaction using mobile money in the last month. Interoperability has a negative impact on this probability, especially in rural areas.

In Section 3.3.1 and 3.3.2 we eventually provide further heterogeneous analysis confirming the differential effect that interoperability has on rural and urban areas, by exploiting our granular data on network coverage and different measures of local urban development.

3.3 Additional Heterogeneities

This section provides additional heterogeneity analyses aimed at further investigating the mechanism leading our results. In the first two subsections, we confirm the differential effect that interoperability has on urban and rural areas. In the last subsection, instead, we test the proposition obtained in the theoretical framework of Section 2.1, by showing that operators with higher initial fees are more affected by the introduction of interoperability.

3.3.1 Rural

In Table 14 we differentiate between rural and urban areas, to study the differential effect of interoperability depending on local development. We identify rural districts by following the approach proposed by Cattaneo et al. (2021): see Section 2.4 for further details. We create a dummy variable, Rural Area_d, which takes value 1 for rural districts and 0 otherwise. We hence use the following specification:

$$\begin{aligned} Y_{dct} = \alpha_d + \beta_t + &\gamma \text{Interoperability}_{ct} + \\ &\rho \text{Interoperability}_{ct} \times \mathbf{1}\text{Rural Area}_c + \varepsilon_{dct} \end{aligned} \tag{12}$$

where interoperability is now interacted with Rural Area_d. As outcome variables, we still use the mobile network coverage as percentage of the district's area, the probability of signal in the district and the number of mobile network operators active in the district. Table 14 show that less developed rural districts are negatively affected by the introduction of interoperability, which leads to a decrease of 4.5 percentage points in the network coverage, in a 0.4 percentage points decrease in the probability of signal in the district, and in a 23% decrease in the number of operators active in the district.

Eventually, we also provide further analysis showing that the introduction of interoperability slows down development of rural areas. In Table A.11 of Appendix A we show the results of the following:

$$\begin{aligned} Y_{dct} = \alpha_d + \beta_t + &\gamma \text{Growth in Total coverage}_{ct} + \\ &\sum_{i=1}^{5} \rho_i \text{Interoperability}_{ct} \times \mathbf{1}\text{Rural quintile}_d^i + \varepsilon_{dct} \end{aligned} \tag{13}$$

where we create and indicator variable Rural quintile_d^i takes value 1 if the district is in the i-th quintile of the rurality score distribution created following the approach proposed by Cattaneo et al. (2021). Higher quintiles correspond to more rural areas. The dependent variable is the growth in mobile network coverage expressed as percentage of the district's area. Coverage growth allows us to show that the introduction of interoperability does not only affect coverage per se, but also convergence of more rural areas, whose development is hindered by the introduction of interoperability. Indeed, districts in the lowest quintile of the distribution are those driving the negative effect on coverage growth. In particular, coverage growth is slowed down by 20% in more rural districts, and the effect is significant. Figure B.3 in Appendix B reports the coefficients of Table A.11.

3.3.2 Night Lights

Similarly, we exploit Nighttime Lights data to provide a measure of the district's urban development. We exploit the following model:

$$\begin{aligned} Y_{dct} = \alpha_d + \beta_t + &\gamma \text{Interoperability}_{ct} + \\ &\rho \text{Interoperability}_{ct} \times \mathbf{1}\text{Night Lights}_{dc} + \varepsilon_{dct} \end{aligned} \tag{14}$$

where as independent variable we use the dummy for interoperability and its interaction with Night Lights$_{dc}$, a standardized measure of nightime light intensity, as provided by the National Centers for Environmental Information. Table 15 displays the results. An increase in one standard deviation of nighttime lights has a positive impact on the district's mobile network coverage and number of operators. Again, these results confirm the ones already shown comparing rural and urban districts. Similarly, Table A.12 shows the effect of interoperability on mobile coverage growth, differentiating between the five quintiles of the nighttime light intensity distribution of districts before interoperability was introduced in any country. Higher quintiles refer to more illuminated, and hence more populated and developed areas. Column (1) of Table A.12 shows that the introduction of interoperability has a starker and significant negative effect on coverage growth for less developed areas. Again, these results, as the ones presented in Table A.11, show a slowdown in the convergence of less developed districts to the levels of mobile coverage of more developed ones.

3.3.3 Fees

We test the proposition presented in Section 2.1 and Appendix C - Theoretical Framework, by showing that operators with higher initial fees, i.e. operators with higher fees before the introduction of interoperability, are more affected by the policy. In Table 16 we present estimates of the following:

$$\begin{aligned} Y_{dct} = \alpha_i + \beta_t + &\gamma \text{Interoperability}_{ict} + \\ &\rho \text{Interoperability}_{ict} \times \mathbf{1}\text{Fees above median}_{ict_0} + \varepsilon_{dct} \end{aligned} \tag{15}$$

which uses the same specification of Eq. 5 and adds an interaction term between the dummy variable $\text{Interoperability}_{ict}$ and the variable Fees above median_{ict_0}, which is a dummy taking value 1 if the operator's average On Net fees (i.e. fees applied for transfers between users of the same operator) before the introduction of interoperability are above the median value. We show that operators with pre-policy fees above median cut their coverage by 4 percentage points more and are 3.4 percentage points less likely to have signal in a district.

3.4 Policy implications

3.4.1 A proposal: interoperability as patent expiration

As already pointed out, the current literature on interoperability provides several case studies and is controversial about the optimal timing of the introduction of such a policy. Reports by Argent et al. (2013), Maune et al. (2022), Micheni et al. (2015) and Hoernig and Bourreau (2017) provide country-specific recommendation for Zimbabwe, Rwanda, Kenya and Mozambique, drawing different conclusions about the optimal regulatory framework of mobile money. On the one hand, governments across Africa want to provide the best incentive so that mobile mobile providers, and hence mobile network operators, invest in reaching the furthest and more marginal areas of the country in order to foster financial inclusion on the extensive margin. On the other hand, there is also the need to maintain a low cost for this service, to ensure the poorest can still access the service, and hence promoting financial inclusion at the intensive margin as well. It is though extremely complicated for local government to understand how and when a policy such as interoperability has to be introduced, in order to promote the optimal level of competition between mobile money providers.

Despite the decrease in mobile money fees, as we have seen in Section 3.1.1, in Section 3.2.2 we document that financial inclusion is negatively affected by the introduction of interoperability. This lead us to conclude that the disinvestment of mobile network operators in infrastructure that allows to reach more marginal areas following interoperability, with the consequential decrease in coverage we have documented in Sections 3.1.2 and 3.2.1, has a negative effect on financial inclusion at the extensive margin.

We provide a policy proposal by introducing an analogy between the temporal expiration of patents in the context of innovation and the timing for the introduction of platform interoperability in mobile money and digital payment systems. The existence of a maximum number of years for patents has the objective to balance the tradeoff between the welfare costs of giving monopoly rents to companies and the welfare gains of stimulating new ideas. The application of this analogy is straightforward: a temporal term on the introduction of platform interoperability for mobile operators would balance the tradeoff between the welfare cost of monopoly rents to mobile operators (through initially higher tariffs on consumers) and the welfare gains of stimulating the installation of a wide mobile network. To offer insights on the applicability of this proposal, we study the heterogenous effect that interoperability has on districts depending on the number of years in which the mobile operator has been offering coverage. We show that as interoperability is enacted, locations in which an operator had entered more recently experience a starker decrease in mobile network coverage and in the probability of signal, relatively to more developed ones that are significantly less affected.

We hence implement the following empirical model to test whether the effect of interoperability depends on the consolidation of a mobile network operator in the local market. We interact the dummy for interoperability with a variable that accounts for the years of presence of the mobile network operator before the introduction of interoperability. We both use a continuous variable and a categorical variable.

Table 17 present the results of the following equation:

$$\begin{aligned} Y_{dct} &= \alpha_d + \beta_t + \gamma \text{ Interoperability}_{ct} \\ &+ \rho \text{ Interoperability}_{ct} \times \text{Years of presence before interoperability}_{dct_{0c}} + \varepsilon_{dct} \end{aligned} \tag{16}$$

While Table A.13 show the results of:

$$\begin{aligned} Y_{dct} &= \alpha_d + \beta_t + \gamma \text{ Interoperability}_{ct} \\ &+ \rho \text{ Interoperability}_{ct} \times \mathbf{I}\left[\text{Years of presence before interoperability}\right]_{dct_{0c}} + \varepsilon_{dct} \end{aligned} \tag{17}$$

where the term Years of presence before interoperability$_{dct_{0c}}$ is a continuous variable for the years of presence of the mobile network in a given district before the introduction of interoperability, and $\mathbf{1}$ [Years of presence before interoperability]$_{dct_{0c}}$ is the same variable, discretized as follows: 1 year, 2-3 years, 4-7 years, 8-9 years, 10-11 years before the introduction of interoperability. From Table 17 it is clear how the longer the presence of the mobile network, i.e. the more the mobile network is consolidated in the local market, the smaller the negative effect of the introduction of interoperability. Indeed, introducing interoperability too early in the market induces operators to cut coverage, while the still negative effect on operators that are long operating in the district is reduced. An additional three years of presence of the mobile money network in the district attenuates the negative effect of interoperability by 1%. Figure B.4 shows the coefficient of Equation 17. The reference category is the 0-1 years pair. The coefficient becomes positive for the category 8-9 year and 10-11 years. These results hint that it might be optimal to introduce interoperability in those markets that are already developed and consolidated.

3.5 Robustness Checks

In this section, we include additional checks to test the robustness of our results. In Appendix A we show that our key results are robust to a variety of alternative specifications: 1) we first replicate our main results using the latest methods for dynamic treatment effects in event studies with heterogeneous treatment effects proposed by Sun and Abraham (2021); 2) we then apply the framework for difference-in-differences designs with staggered treatment adoption and heterogeneous causal effects proposed by Borusyak et al. (2021); 3) we propose alternative clustering methods of standard errors; 4) we account for sample misrepresentation by weighting our main regression specifications with different measures of district's population. These robustness checks complement the ones already presented in previous sections. As explained in Section 3.1.3, we construct a novel dataset on network operators' M&A activities, and show that the introduction of interoperability has no effect on the probability of mobile network operators in taking part in mergers and acquisitions. In 3.1.4 we replicated our analyses at the operator level adopting an instrumental variable approach. In Section 3.3 we provided several heterogeneity analyses, showing also that our estimates are robust to different measures of local urban development.

We replicate our main results of Tables 2, 3, 4, 6 and 8 using the methods proposed by Sun and Abraham (2021) and Borusyak et al. (2021). Estimates do not differ from the ones previously obtained, nor in their sign, nor in their magnitude, neither in their significance. Figure B.5 replicates the event studies on the different measures of coverage at the operator-district level and at the district level with similar findings.

In Table A.14, A.15, A.16 and A.17 we replicate our main results using the method proposed by Sun and Abraham (2021). Our coefficient of interest is the average treatment effect, which is obtained by averaging the estimation weighted estimators for the first four years after the introduction of interoperability.

Table A.18, A.19, A.20 and A.21, and Figure B.5 respectively present the treatment effect estimation and the pre-trend testing in event studies obtained from the difference-in-differences designs with staggered adoption of treatment, using the imputation approach of Borusyak et al. (2021). This method is particularly adapt to our setting, as it is designed to estimate the effects of a binary treatment with staggered rollout allowing for arbitrary heterogeneity and dynamics of causal effects. The benchmark case of this method considers each unit i getting treated as of period t and remaining treated forever: indeed, when interoperability is deployed, it is never retracted in our case.

We conclude this section with three additional robustness checks on our main results at the operator and at the district level. First, in Tables A.22, A.23, A.24 and A.25 we replicate the results of Tables 2, 3, 4 and 8 by clustering standard errors at the country-level. As we were suggesting in Section 3.1.4, operator-level introduction of interoperability might be the response to a changing local market or institutional framework at the country level. The staggering of interoperability between operators in the same country might hence be correlated with country specific characteristics. We do this to clean out all possible country-time specific variations from our estimates.

Second, in Tables A.26, A.27 and A.28 we replicate the results of Tables 2, 4 and 8 computing standard errors using the wild cluster bootstrap methodology. Estimates remain highly significance.

Last, in Tables A.29, A.30, A.31, A.32 we replicate the results of Tables 4 and 8 using weighted least squares, where we weight for the district's population count and the district's population density. We retrieve data from Warszawski et al. (2017) to construct our measures of population and population density at the district level. Warszawski et al. (2017) provide data at raster level. We hence aggregate raster level data at the district level: population count is the sum of people living in each raster contained in the district, while population density is the average population density of all rasters in the districts. The weighting allows us to account for sample misrepresentation. Estimates maintain significance but present smaller magnitudes, especially when weighting for the population count.

4 Conclusions

This paper investigates the effects of competition on the behavior of mobile money companies and its corresponding effects on financial inclusion. The study focuses on competition induced by a specific policy framework: the introduction of platform interoperability, a regulatory intervention that facilitates transactions between users of different mobile money operators. The objective is to relate this change in competition to the profit margins of mobile money operators and their investment in pricing, network, and infrastructure.

Our study finds that there is a trade-off between competition and financial inclusion in the context of mobile money. The vertical integration between mobile network and mobile money companies results in higher fees charged to mobile money users, which lowers consumer welfare and financial inclusion on the intensive margin. At the same time, this lack of competition also provides incentives for mobile network companies to extend their reach to underserved locations, enhancing financial inclusion on the extensive margin.

To test this hypothesis, we construct a novel panel which collects information on more than 120 mobile operators across all African countries from 2010 onward. This is done by using multiple "Wayback Machines", which are digital repositories that systematically scan a vast number of websites and capture screenshots of their pages. By digitizing this information, we have constructed a panel that presents novel descriptive insights into the operation of this market. This information has been further combined with extensive documentation on companies network coverage across all districts of Africa and financial and non-financial documentation. This empirical exercise requires the identification of a source of quasi-experimental variation that generates higher competition between mobile money companies. For this reason, we leverage a natural experiment that has unfolded in Africa over the period spanning from 2010 to 2020: the staggered deployment of platform interoperability.

In line with the main hypothesis, our findings show that the introduction of this policy lowers fees on mobile money transactions and this particularly large for small-value payments. At the same time, interoperability also has negative effects on network availability, as districts in countries that introduce interoperability experience a drop in their coverage, which is particularly severe for rural districts.

Overall, the study highlights the need for policymakers to strike a balance between competition and financial inclusion in the mobile money market. The findings suggest that competition-promoting policies such as platform interoperability can have a positive effect on inducing lower fees but also have negative effects on network availability. Policymakers should take into account these trade-offs when designing regulations to promote competition in the mobile money market. Additionally, the study provides valuable insights into the functioning and regulation of mobile money companies, an area that remains largely unexplored in the literature. By proposing and exploring a novel trade-off between competition and financial inclusion in the context of mobile money, the study contributes to a better understanding of the implications of digital payment systems for financial inclusion.

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Tables

Table 1: Summary statistics

	Observations	Mean	Std. Dev.	Min	Max
Panel A: Mobile Money Fees (US $)					
Fees on network$_{it}$	737	.04	.1	0	1.18
Fees cross network$_{it}$	552	.11	.14	0	.98
Panel B: GSMA Intelligence Mobile Network data					
Total cellular connections$_{it}$	2335	13.75	2.36	4.06	18.18
3G connections$_{it}$	1810	12.7	2.25	3.3	17.79
Total cellular network coverage; by population$_{it}$	210	4.31	.32	2.71	4.61
Recurring revenue; cellular$_{it}$	3007	17.43	2.07	7.69	22.1
Total revenue; cellular$_{it}$	3015	17.53	2.08	7.72	22.53
Non-Recurring revenue; cellular$_{it}$	2950	14.46	2.3	4.29	21.1
Total Capex$_{it}$	683	17.36	1.67	9.07	20.71
Panel C: Network coverage at company-district level					
Total coverage$_{idt}$	1340928	75.41	33.72	0	100
Probability of signal in district$_{idt}$	1340928	.97	.18	0	1
Interoperability$_{it}$	1340928	.25	.43	0	1
Panel D: Network coverage at district level					
Total coverage$_{dt}$	645936	66.78	36.12	0	100
Coverage in covered areas$_{dt}$	645936	83.8	25.52	0	100
Probability of signal$_{dt}$	645936	.89	.31	0	1
Number MNOs$_{dt}$	645936	2.01	1.23	0	5
Interoperability$_{ct}$	645936	.18	.39	0	1
Panel E: WB Global Findex Survey					
Possibility to find emergency fund$_{jct}$	91172	.46	.5	0	1
Sent domestic remittances in last year$_{jct}$	104310	.31	.46	0	1
Received wage through mobile in last year$_{jct}$	24423	.16	.37	0	1
Panel F: IMF Financial Access Survey					
Number of mobile money transactions$_{ct}$	267	16.48	3.51	0	21.98
Outstanding balances on active mobile money accounts, Domestic Cur$_{ct}$	157	20.23	4.09	9.15	29.26
Number of registered mobile money agent outlets$_{ct}$	271	8.89	2.42	1.1	13.4
Number of registered mobile money accounts$_{ct}$	293	14.18	2.36	6.79	18.01

Notes: This table reports the summary statistics for the main datasets used in the analysis. The columns respectively report the variable's name, the number of observations (Observations), its mean value (Mean), its standard deviation (Std. Dev.), its minimum (Min) and maximum (Max) value. All datasets are observed at the yearly frequency. We report six different panels. Panel A summarizes the dataset we constructed containing information on the fees structure of Mobile Money Operators. Fees are reported as transaction value share. Panel B reports the summary statistics of the main variables (in log) in the GSMA Intelligence dataset. Panel C and D report summary for mobile network operators' coverage and interoperability. Panel E and Panel F reports survey based individual- and country-level data on financial inclusion, respectively.

Table 2: Fees and interoperability

	Fees	
	On Net (1)	Cross Net (2)
$\text{Interoperability}_{ict}$	-0.033**	-0.050**
	(0.015)	(0.024)
Operator FE	Yes	Yes
Year FE	Yes	Yes
N. of MNOs	107	83
Obs.	734	550
Adj. R sq.	0.051	0.191
Mean Dep. Var.	0.053	0.125

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is operator i in year t. Operator and year fixed effects are present in all columns and standard errors are clustered at the operator level. The dependent variables are On Net, which is the operator's fees for mobile money transactions to subscribers of the same operator (1); and Cross Net, which is the operator's fees for mobile money transactions to subscriber of different operators (2). Both dependent variables are expressed as percentage of transaction value. These are regressed over $Interoperability_{ict}$, a dummy variable taking value 1 if the operator i is subject to mobile money interoperability. The dependent variable's mean in the pre-policy period is reported in the last row of the table. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table 3: Fees by bracket and Interoperability

	On net	Cross net
	(1)	(2)
$\text{Interoperability}_{ict} \times$		
Bracket 1-2	-0.215***	-0.442**
	(0.078)	(0.196)
Bracket 3-4	-0.021	-0.084*
	(0.014)	(0.049)
Bracket 5-6	-0.015*	-0.027
	(0.008)	(0.023)
Bracket 7-8	-0.005	-0.001
	(0.008)	(0.017)
Bracket 9-10	0.002	0.011
	(0.007)	(0.016)
Bracket 11-12	0.005	0.016
	(0.007)	(0.015)
Bracket 13+	0.004	0.018
	(0.007)	(0.015)
Operator FE	Yes	Yes
Year FE	Yes	Yes
Bracket FE	Yes	Yes
N. of MNOs	115	89
Obs.	16129	11883
Adj. R sq.	0.082	0.303
Mean Dep. Var.	0.048	0.122

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is fee bracket b of operator i in country c in year t. We report the δ_j coefficients of Equation 3. Bracket, operator and year fixed effects are included in all columns and standard errors are clustered at the operator level. The dependent variables are the operator's fees for mobile money transactions to subscribers of the same operator, in Column (1); the operator's fees for mobile money transactions to subscriber of different operators, in Column (2). Both dependent variables are expressed as share of transaction value. We pair brackets in seven groups, and show the differential effect that the introduction of interoperability at the operator level has on different transaction brackets, where brackets represent cross-country harmonized transaction value ranges as explained in Section 2.2. Dependent variables are regressed over the interaction between $Interoperability_{ict}$, a dummy variable taking value 1 if the operator i is subject to mobile money interoperability, and an indicator variable $\mathbf{1}_j$, indicating to which pair bracket b belongs. The table hence reports the estimates of coefficients δ_j of Equation 3. The dependent variable's mean in the pre-policy period is reported in the last row of the table. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table 4: Network Coverage and Interoperability - Operator-District Level

	Total coverage	Probability of signal in district
	(1)	(2)
$\text{Interoperability}_{ict}$	-3.976***	-0.053***
	(0.074)	(0.000)
Operator-District FE	Yes	Yes
Year FE	Yes	Yes
Obs.	1340928	1340928
Adj. R sq.	0.802	0.255
Mean Dep. Var.	69.221	0.881

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is the pair operator i district d, in year t. Operator-district and year fixed effects are present in all columns and standard errors are clustered at the operator-district level. Districts are defined as the smallest administrative unit in each country, as defined by the Database of Global Administrative Areas (GADM). The dependent variables are the individual mobile network operator i coverage in district d, expressed as percentage of the district d area (1); the probability that the mobile network operator is active in the district, i.e. a dummy taking value 1 whether the operator i has signal in the district d (2). Dependent variables are regressed over $Interoperability_{ict}$, a dummy variable taking value 1 if the pair operator-district id is subject to mobile money interoperability, i.e. if operator i is interoperable. The dependent variable's mean in the pre-policy period is reported in the last row of the table. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table 5: Network Coverage, Dominant Operators and Interoperability - Operator-District Level

	Total coverage	Probability of signal in district
	(1)	(2)
$\text{Interoperability}_{ict}$	8.681***	-0.061***
	(0.288)	(0.001)
$\text{Interoperability}_{ict} \times$	-14.665***	0.009***
Dominant 30_{jdct_0}	(0.293)	(0.000)
Operator-District FE	Yes	Yes
Year FE	Yes	Yes
Obs.	1340928	1340928
Adj. R sq.	0.805	0.255
Mean Dep. Var.	69.221	0.881

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is the pair operator i district d, in year t. Operator-district and year fixed effects are present in all columns and standard errors are clustered at the operator-district level. Districts are defined as the smallest administrative unit in each country, as defined by the Database of Global Administrative Areas (GADM). The dependent variables are the individual mobile network operator i coverage in district d, expressed as percentage of the district d area (1); the probability that the mobile network operator is active in the district, i.e. a dummy taking value 1 whether the operator i has signal in the district d (2). Dependent variables are regressed over two variables. The first is $Interoperability_{ict}$, a dummy variable taking value 1 if the pair operator-district id is subject to mobile money interoperability, i.e. if operator i is interoperable. The second is the interaction between $Interoperability_{ict}$ and Dominant 30_{idt_0}, a dummy taking value 1 if the operator i was covering more than 30% of the district d's area before the arrival of interoperability at t_0. The dependent variable's mean in the pre-policy period is reported in the last row of the table. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table 6: Mobile Operators and Interoperability

	Total network coverage	Market penetration mobile connections	Total Revenue	Towers	EBIT	EBITDA
	(1)	(2)	(3)	(4)	(5)	(6)
$\text{Interoperability}_{ict}$	-0.186***	-0.224**	-0.293**	-0.123*	-0.097	-0.062
	(0.033)	(0.112)	(0.134)	(0.063)	(0.336)	(0.224)
Operator FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N. of MNOs	29	95	93	54	38	54
Obs.	125	1842	1684	280	366	565
Adj. R sq.	0.789	0.884	0.866	0.974	0.811	0.861
Mean Dep. Var.	4.296	1.523	17.451	6.819	15.992	16.019

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is operator i in year t. Operator and year fixed effects are present in all columns and standard errors are clustered at the operator level. The dependent variables are the operator's share of population covered in country c (1); the operator's market penetration of mobile connection in country c (2); the operator's total revenue (3); the number of towers used by the operator for its coverage (4); the operator's earnings before interest and taxes (EBIT) and the operator's earnings before interest, taxes, depreciation and amortization (EBITDA) in column (5) and (6), respectively. Dependent variables are expressed in log. These are regressed over $Interoperability_{ct}$, a dummy variable taking value 1 if the operator i is subject to mobile money interoperability. The dependent variable's mean in the pre-policy period is reported in the last row of the table. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table 7: Mobile Network Fees and Interoperability

	Voice Price per minute	Data Price per GB	Messages Price per SMS
	(1)	(2)	(3)
$\text{Interoperability}_{ict}$	-0.002	0.003	0.001
	(0.008)	(0.002)	(0.002)
Operator FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Obs.	392	52	121
Adj. R sq.	0.681	0.767	0.736
Mean Dep. Var.	0.077	0.011	0.018

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is operator i in year t. Operator and year fixed effects are present in all columns and standard errors are clustered at the operator level. The dependent variables are the operator's price per minute of call (1); the operator's price per megabyte of Internet usage (2); the operator's cost of text messages (3). Dependent variables are expressed in dollars. These are regressed over $Interoperability_{ct}$, a dummy variable taking value 1 if the operator i is subject to mobile money interoperability. The dependent variable's mean in the pre-policy period is reported in the last row of the table. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table 8: Network Coverage and Interoperability - District Level

	Total coverage	Probability of signal in district	Number of MNOs
	(1)	(2)	(3)
$\text{Interoperability}_{ct}$	-4.318***	-0.036***	-0.207***
	(0.087)	(0.000)	(0.002)
District FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N. of Districts	53828	53828	53828
Obs.	645936	645936	645936
Adj. R sq.	0.908	0.873	0.914
Mean Dep. Var.	64.078	0.845	2.009

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is district d in year t. District and year fixed effects are present in all columns and standard errors are clustered at the district level. Districts are defined as the smallest administrative unit in each country, as defined by the Database of Global Administrative Areas (GADM). The dependent variables are the total mobile network coverage, expressed as percentage of the district c area (1); the probability of mobile network signal in the district, i.e. a dummy taking value 1 whether at least one Mobile Network Operator (MNO) is active in the district (2); the number of Mobile Network Operators active in the district (3). Dependent variables are regressed over $Interoperability_{ct}$, a dummy variable taking value 1 if the district d is subject to mobile money interoperability, i.e. if interoperability is active in country c. The dependent variable's mean in the pre-policy period is reported in the last row of the table. In column (3) we report the mean of the number of Mobile Network Operators active in the district, not expressed in log. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table 9: Network Coverage, Competition and Interoperability - District Level

	Total coverage	Probability of signal in district	Number of MNOs
	(1)	(2)	(3)
$\text{Interoperability}_{ct}$	-8.270***	-0.008***	-0.089***
	(0.411)	(0.001)	(0.004)
$\text{Interoperability}_{ct}$ ×	4.563***	-0.032***	-0.136***
> 1 operator_{dct_0}	(0.420)	(0.001)	(0.004)
District FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N. of Districts	53828	53828	53828
Obs.	645936	645936	645936
Adj. R sq.	0.909	0.873	0.914
Mean Dep. Var.	64.078	0.845	2.009

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is district d in year t. District and year fixed effects are present in all columns and standard errors are clustered at the district level. Districts are defined as the smallest administrative unit in each country, as defined by the Database of Global Administrative Areas (GADM). The dependent variables are the total mobile network coverage, expressed as percentage of the district c area (1); the probability of mobile network signal in the district, i.e. a dummy taking value 1 whether at least one Mobile Network Operator (MNO) is active in the district (2); the number of Mobile Network Operators active in the district (3). Dependent variables are regressed over two variables. The first is $Interoperability_{ct}$, a dummy variable taking value 1 if the district d is subject to mobile money interoperability, i.e. if interoperability is active in country c. The second is the interaction between $Interoperability_{ct}$ and > 1 operator_{dt_0}, a dummy taking value 1 if more than one operator was active in the district before the arrival of interoperability at t_0. $\mathbf{1}\left[> 1 \text{ operator}\right]_{dt_0}$ is a district-specific constant, it is absorbed by the district fixed effects, and hence only its interaction with the interoperability dummy appears in the regression. The dependent variable's mean in the pre-policy period is reported in the last row of the table. In the column (3) we report the mean of the number of Mobile Network Operators active in the district, not expressed in log. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table 10: WB Global Findex

	Mobile Money Account	Saved for business	Access Emergency Fund	Sent remittances	Sent remittances w mobile phone	Received remittances	Received remittances w mobile phone	Received Gov Transf w mobile phone
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\text{Interoperability}_{ct}$	-0.042	-0.018	-0.040	-0.078***	-0.069	-0.055	-0.062	-0.031
	(0.035)	(0.044)	(0.038)	(0.019)	(0.078)	(0.037)	(0.080)	(0.034)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	71953	77258	76041	75188	21380	75206	25613	6898
Adj. R sq.	0.229	0.078	0.152	0.154	0.365	0.085	0.358	0.078
Mean Dep. Var.	0.137	0.208	0.504	0.293	0.335	0.368	0.286	0.089

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is individual respondent's i in year t. Country and year fixed effects are present in all columns and standard errors are clustered at the country level. Data are taken from the WB Global Findex Survey. Observations span the years 2011-2021. The impossibility to trace respondents through years impedes the usage of individual respondent's fixed effects. In order to partially overcome this issue we control for individual respondent's specific characteristics, such as gender, education, age and income. The dependent variables are dummy variables taking value 1 if the last month the respondent has a mobile money account (1); has saved for investing in business (2); has the possibility to access to emergency funds in case of financial distress (3); has sent domestic remittances (4); has sent domestic remittances through mobile money (5); has received domestic remittances (6); has received domestic remittances through mobile money (7); has received government transfers through mobile money (8). These are regressed over $Interoperability_{ct}$, a dummy variable taking value 1 if the individual i is subject to mobile money interoperability, i.e. if interoperability is active in country c. The dependent variable's mean in the pre-policy period is reported in the last row of the table. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table 11: WB Global Findex

	Mobile Money Account	Saved for business	Access Emergency Fund	Sent remittances	Sent remittances w mobile phone	Received remittances	Received remittances w mobile phone	Received Gov Transf w mobile phone
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\text{Interoperability}_{ct}$	-0.064*	-0.063*	-0.071*	-0.087***	-0.118**	-0.096***	-0.111**	-0.055*
	(0.034)	(0.036)	(0.041)	(0.018)	(0.045)	(0.024)	(0.047)	(0.030)
$\text{Interoperability}_{ct}$ ×	-0.063	-0.128**	-0.088*	-0.024*	-0.254**	-0.118***	-0.226*	-0.090***
Mobile Money Network_{ct_0}	(0.043)	(0.056)	(0.046)	(0.013)	(0.110)	(0.007)	(0.124)	(0.029)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	71953	77258	76041	75188	21380	75206	25613	6898
Adj. R sq.	0.229	0.078	0.152	0.154	0.367	0.086	0.359	0.079
Mean Dep. Var.	0.137	0.208	0.504	0.293	0.335	0.368	0.286	0.089

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is individual respondent's i in year t. Country and year fixed effects are present in all columns and standard errors are clustered at the country level. Data are taken from the WB Global Findex Survey. Observations span the years 2011-2021. The impossibility to trace respondents through years impedes the usage of individual respondent's fixed effects. In order to partially overcome this issue we control for individual respondent's specific characteristics, such as gender, education, age and income. The dependent variables are dummy variables taking value 1 if the last month the respondent has a mobile money account (1); has saved for investing in business (2); has the possibility to access to emergency funds in case of financial distress (3); has sent domestic remittances (4); has sent domestic remittances through mobile money (5); has received domestic remittances (6); has received domestic remittances through mobile money (7); has received government transfers through mobile money (8). These are regressed over two variables. The first is $Interoperability_{ct}$, a dummy variable taking value 1 if the individual i is subject to mobile money interoperability, i.e. if interoperability is active in country c. The second is an interaction between $Interoperability_{ct}$ and Mobile Money Network_{ct_0}, which is the standardized number of survey respondents who own a mobile money account, before the introduction of interoperability. Mobile Money Network_{ct_0} is a country-specific variable, hence it is absorbed by country fixed effects, and hence only its interaction with the interoperability dummy is estimated. The dependent variable's mean in the pre-policy period is reported in the last row of the table. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table 12: IMF Financial access Survey

	MM Outlets	MM Outlets over 100k adults	MM Accounts	MM Accounts over 1k adults	MM Transactions	MM Transactions over 1k adults
	(1)	(2)	(3)	(4)	(5)	(6)
$\text{Interoperability}_{ct}$	-0.147	-0.235	-0.042	-0.104	-0.256***	-0.317***
	(0.117)	(0.155)	(0.117)	(0.160)	(0.088)	(0.110)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	264	265	287	288	261	262
Adj. R sq.	0.892	0.823	0.902	0.825	0.902	0.864
Mean Dep. Var.	0.012	60.1	3.3	180.8	72.0	3297.5

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is country c in year t. Country and year fixed effects are present in all columns and standard errors are clustered at the country level. Data are taken from the IMF Financial Access Survey (FAS). Observations span the years 2010-2021. The dependent variables are the total number of Mobile Money outlets in country c in year t (1); the number of Mobile Money outlets over 100'000 adults c in year t (2); the total number of Mobile Money accounts in country c in year t (3); the number of Mobile Money accounts over 1'000 adults c in year t (4); the total number of Mobile Money transactions in country c in year t (5); the number of Mobile Money transactions over 1'000 adults c in year t (6). Variables are expressed in log and standardized. These are regressed over $Interoperability_{ct}$, a dummy variable taking value 1 if interoperability is active in country c. The dependent variable's (expressed in absolute value) mean in the pre-policy period is reported in the last row of the table. Column (1), (3) and (5) report the mean in millions. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table 13: IMF Financial access Survey

	MM Outlets	MM Outlets over 100k adults	MM Accounts	MM Accounts over 1k adults	MM Transactions	MM Transactions over 1k adults
	(1)	(2)	(3)	(4)	(5)	(6)
$\text{Interoperability}_{ct}$	-0.052	-0.105	0.115	0.151	-0.145	-0.178
	(0.101)	(0.128)	(0.103)	(0.138)	(0.119)	(0.147)
$\text{Interoperability}_{ct}$ ×	-0.290***	-0.431***	-0.453***	-0.612***	-0.181	-0.219
Mobile Money network_{ct_0}	(0.099)	(0.100)	(0.104)	(0.122)	(0.131)	(0.158)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	255	256	276	277	252	253
Adj. R sq.	0.902	0.841	0.915	0.850	0.902	0.864
Mean Dep. Var.	0.012	60.1	3.3	180.8	72.0	3297.5

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is country c in year t. Country and year fixed effects are present in all columns and standard errors are clustered at the country level. Data are taken from the IMF Financial Access Survey (FAS). Observations span the years 2010-2021. The dependent variables are the total number of Mobile Money outlets in country c in year t (1); the number of Mobile Money outlets over 100'000 adults c in year t (2); the total number of Mobile Money accounts in country c in year t (3); the number of Mobile Money accounts over 1'000 adults c in year t (4); the total number of Mobile Money transactions in country c in year t (5); the number of Mobile Money transactions over 1'000 adults c in year t (6). Variables are expressed in log and standardized. These are regressed over two variables. The first is $Interoperability_{ct}$, a dummy variable taking value 1 if interoperability is active in country c. The second is the interaction between $Interoperability_{ct}$ and Mobile Money Network_{ct_0}, which is the standardized number of mobile money accounts c before the introduction of interoperability. Since Mobile Money Network_{ct_0} is a country-specific variable, it is absorbed by country fixed effects, hence only its interaction with the interoperability dummy is estimated. The dependent variable's (expressed in absolute value) mean in the pre-policy period is reported in the last row of the table. Column (1), (3) and (5) report the mean in millions. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table 14: Network Coverage, Rural area and Interoperability - District Level

	Total coverage	Probability of signal in district	Number of MNOs
	(1)	(2)	(3)
Interoperability$_{ct}$	-4.154***	-0.034***	-0.185***
	(0.092)	(0.000)	(0.002)
Interoperability$_{ct}$ ×	-0.374**	-0.005***	-0.051***
Rural area$_c$	(0.178)	(0.000)	(0.001)
District FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Obs.	645936	645936	645936
Adj. R sq.	0.908	0.873	0.914
Mean Dep. Var.	64.078	0.845	2.009

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is district d in year t, as specified in Eq. 12. In all columns we include district and year fixed effects and standard errors are clustered at the district level. Districts are defined as the smallest administrative unit in each country, as defined by the Database of Global Administrative Areas (GADM). The dependent variable is the mobile network coverage as percentage of the district's area, the probability of signal in the district and the number of mobile network operators active in the districts. The dependent variable is regressed over two variables. The first is $Interoperability_{ct}$, a dummy variable taking value 1 if the district d is subject to mobile money interoperability, i.e. if interoperability is active in country c. The second is the interaction between $Interoperability_{ct}$ and Rural area$_d$, a dummy taking value 1 if the district is classified as rural using geographical characteristics as proposed by Cattaneo et al. (2021). Rural area$_d$ is a district-specific constant, it is absorbed by the district fixed effects, and hence only its interaction with the interoperability dummy appears in the regression. The dependent variable's mean in the pre-policy period is reported in the last row of the table. In column (3) we report the mean of the number of Mobile Network Operators active in the district, not expressed in log. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table 15: Network Coverage, Lights and and Interoperability - District Level

	Total coverage	Probability of signal in district	Number of MNOs
	(1)	(2)	(3)
$\text{Interoperability}_{ct}$	-4.275***	-0.036***	-0.049***
	(0.085)	(0.000)	(0.000)
$\text{Interoperability}_{ct}$ ×	0.549***	-0.002***	0.001***
Night Light Intensity_d	(0.031)	(0.000)	(0.000)
District FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Obs.	645936	645936	645936
Adj. R sq.	0.908	0.873	0.959
Mean Dep. Var.	66.775	0.889	2.009

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is district d in year t, as specified in Eq. 14. In all columns we include district and year fixed effects and standard errors are clustered at the district level. Districts are defined as the smallest administrative unit in each country, as defined by the Database of Global Administrative Areas (GADM). The dependent variable is the mobile network coverage as percentage of the district's area, the probability of signal in the district and the number of mobile network operators active in the districts. The dependent variable is regressed over two variables. The first is $Interoperability_{ct}$, a dummy variable taking value 1 if the district d is subject to mobile money interoperability, i.e. if interoperability is active in country c. The second is the interaction between $Interoperability_{ct}$ and Night Light_d, a continuous variables that represents the standardized nighttime light intensity of the district, according to the data on Nighttime lights provided by the National Centers for Environmental Information, kept fixed at the year 2012, i.e. before that interoperability was introduced in any country. Night Light Intensity_d is a district-specific constant, it is absorbed by the district fixed effects, and hence only its interaction with the interoperability dummy appears in the regression. The dependent variable's mean and standard deviation are reported as the last two rows of the table. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table 16: Network Coverage, Fees and Interoperability - Operator-District Level

	Total coverage	Probability of signal in district
	(1)	(2)
$\text{Interoperability}_{ict}$	-3.153***	-0.056***
	(0.106)	(0.000)
$\text{Interoperability}_{ict}$ ×	-4.025***	-0.034***
Fees above median_{ict_0}	(0.154)	(0.000)
Operator-District FE	Yes	Yes
Year FE	Yes	Yes
Obs.	1007592	1007592
Adj. R sq.	0.769	0.256
Mean Dep. Var.	66.116	0.862

Notes: This table presents ordinary least squares (OLS) estimates of Equation 15, where the unit of observation is the pair operator i district d, in year t. Operator-district and year fixed effects are present in all columns and standard errors are clustered at the operator-district level. Districts are defined as the smallest administrative unit in each country, as defined by the Database of Global Administrative Areas (GADM). The dependent variables are the individual mobile network operator i coverage in district d, expressed as percentage of the district d area (1); the probability that the mobile network operator is active in the district, i.e. a dummy taking value 1 whether the operator i has signal in the district d (2). Dependent variables are regressed over two variables. The first is $Interoperability_{ict}$, a dummy variable taking value 1 if the pair operator-district id is subject to mobile money interoperability, i.e. if operator i is interoperable. The second is the interaction between $Interoperability_{ict}$ and Fees above median $_{ict_0}$, a dummy taking value 1 if the operator's average On Net fees (i.e. for mobile money transfers to users of the same network) before the introduction of interoperability are above the median value. The dependent variable's mean in the pre-policy period is reported in the last row of the table. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

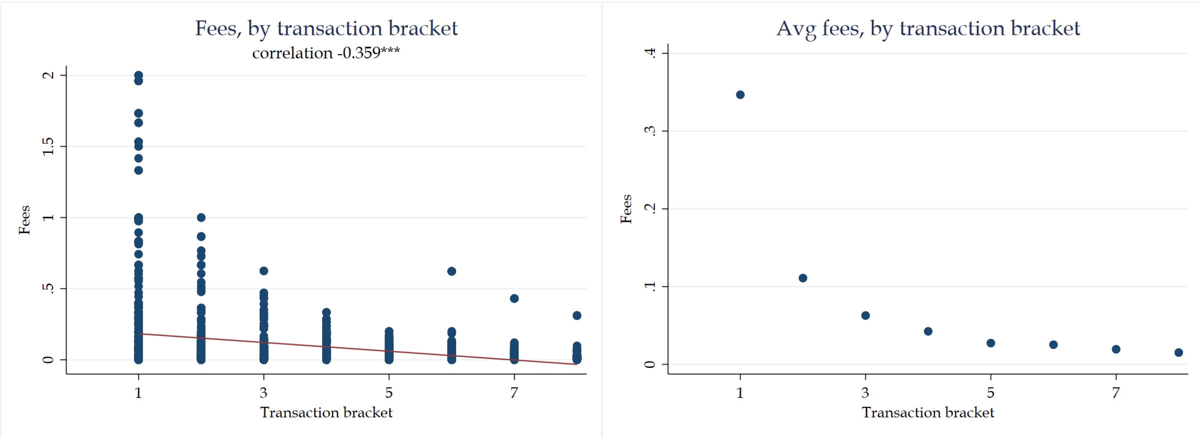
Table 17: Network Coverage and Interoperability - A Proposal for Patent Expiration

	Total coverage	Probability of signal in district	Number of MNOs
	(1)	(2)	(3)
Interoperability$_{ct}$	-7.066***	-0.063***	-0.512***
	(0.207)	(0.001)	(0.005)
Interoperability$_{ct}$ ×	0.391***	0.004***	0.043***
Years presence before interoperability$_{dct_0}$	(0.021)	(0.000)	(0.001)
District FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N. of Districts	53828	53828	53828
Obs.	645936	645936	645936
Adj. R sq.	0.909	0.873	0.914
Mean Dep. Var.	64.078	0.845	2.009

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is district d in year t. District and year fixed effects are present in all columns and standard errors are clustered at the district level. Districts are defined as the smallest administrative unit in each country, as defined by the Database of Global Administrative Areas (GADM). The dependent variables are the total mobile network coverage, expressed as percentage of the district c area (1); the probability of mobile network signal in the district, i.e. a dummy taking value 1 whether at least one Mobile Network Operator (MNO) is active in the district (2); the number of Mobile Network Operators active in the district (3). Dependent variables are regressed over two variables. The first is $Interoperability_{ct}$, a dummy variable taking value 1 if the district d is subject to mobile money interoperability, i.e. if interoperability is active in country c. The second is the interaction between $Interoperability_{ct}$ and Years of presence before interoperability $_{dt_0}$, a variable which corresponds to the number of years of presence of the mobile network in the district before the introduction of interoperability at t_0. Years of presence before interoperability $_{dt_0}$ is a district-specific constant, it is absorbed by the district fixed effects, and hence only its interaction with the interoperability dummy appears in the regression. The dependent variable's mean in the pre-policy period is reported in the last row of the table. In column (3) we report the mean of the number of Mobile Network Operators active in the district, not expressed in log. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Figures

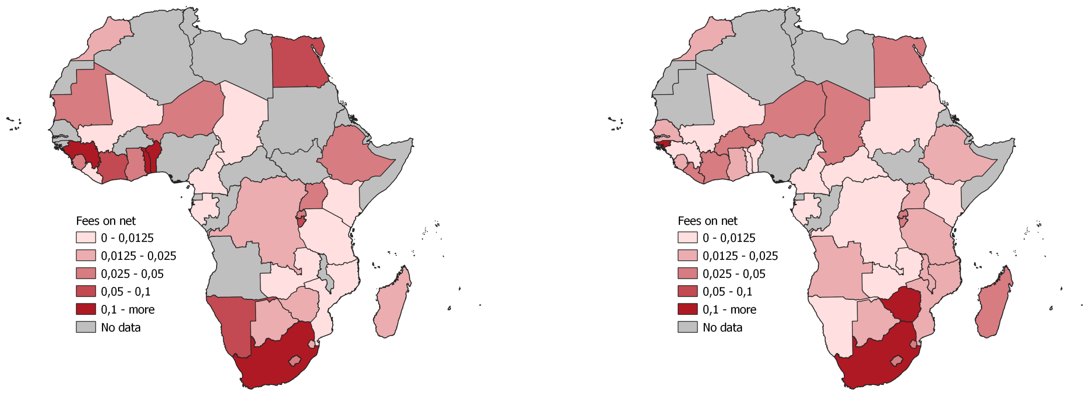
Figure 1: Fees and brackets



(a) Fees, by transaction bracket (b) Fees, by transaction bracket

Notes: This figure plot the yearly fees for sending a mobile money transfer between two agents belonging to the same operator, i.e. on-network transaction. Fees are expressed as percentage of transaction values. In Panel (a) each dot within a bracket corresponds to an operator-year observation. Brackets represent cross-country harmonized transaction value ranges as explained in Section 2.2. Panel (b) shows the average fees across all operators and all years, for each bracket.

Figure 2: The Geography of Fees



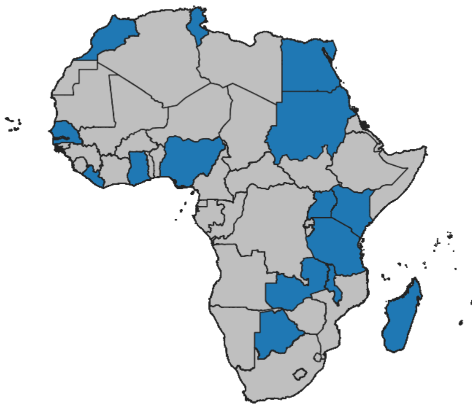
(a) Fees in 2015 (b) Fees in 2021

Notes: This maps show the average fees applied to transactions between subscribers of the same operator, i.e. on-network transactions, at country level. A darker shade of red corresponds to higher average fees. Countries in grey are those for which no data are available. Fees are expressed as share of transaction value. Panel (a) refers to the year 2015, while Panel (b) to year 2021. Color brackets are kept homogeneous across the two years.

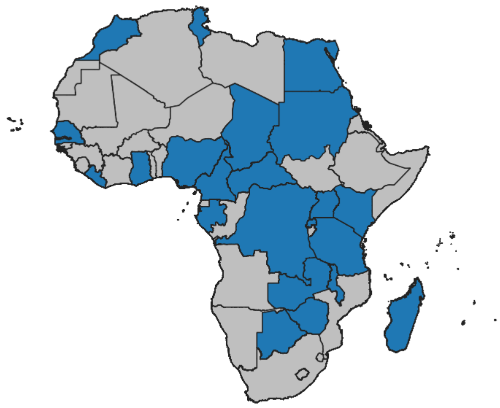
Figure 3: Interoperability

(a) Year 2015

(b) Year 2017



(c) Year 2019



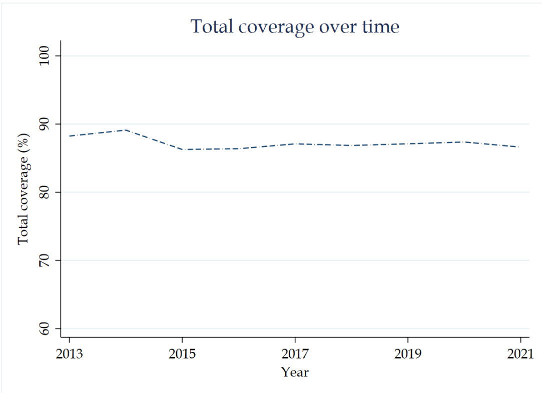
(d) Year 2021

Notes: These maps show the staggered introduction of interoperability across African countries. Interoperability is currently active in 20 Africa countries. The first country to introduce the possibility to exchange mobile money between subscribers of different operators is Nigeria at the end of 2012. The maps present four reference years, 2015 (a), 2017 (b), 2019 (c) and 2021 (d), in which countries colored in blue are those ones in which interoperability is active. Interoperability is never retracted in those countries where it is introduced.

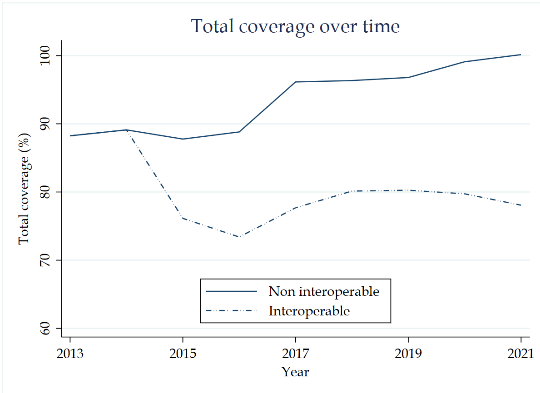
Figure 4: Fees, Coverage and Interoperability - A Descriptive Analysis

(a) Fees, average

(b) Fees, average



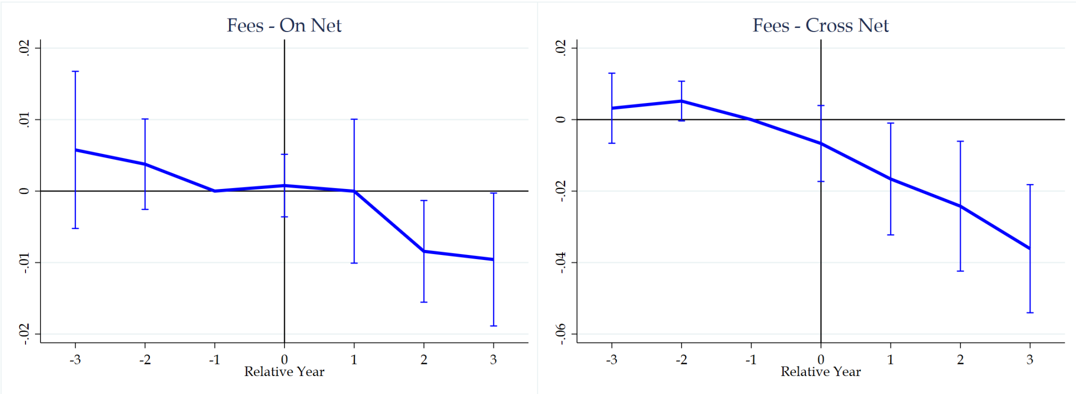
(c) Coverage, average



(d) Coverage, average

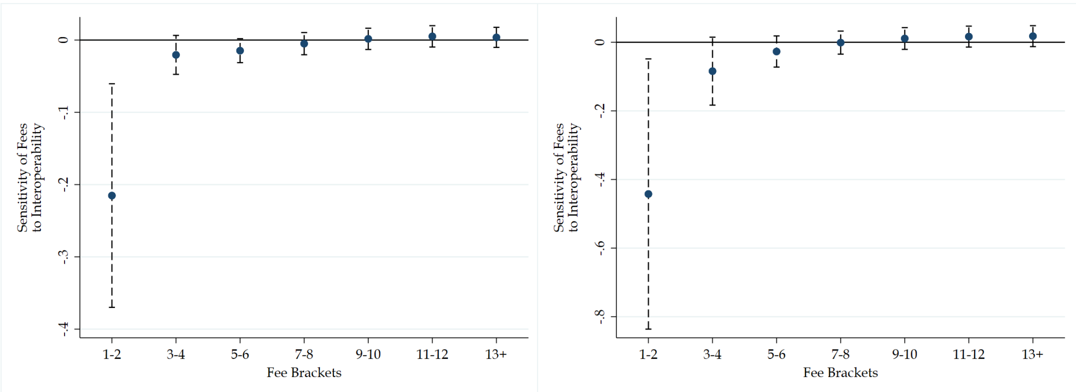
Notes: This figure presents the average fees for mobile money transactions between subscribers of the same operator, i.e. on-network transactions, over time, and the average mobile network coverage. Fees are expressed as share of transaction value. Coverage is expressed as percentage of the district's area covered by the the mobile network operator. Districts are the smallest geographical units that can be retrieved from the the GADM dataset. The top left panel (a) shows the average on network fees for all operators over the sample period; the top right panel (b) shows the average tariffs for non interoperable and interoperable operators. The bottom left panel (c) shows the average coverage for all operators over the sample period; the bottom right panel (bd shows the average coverage for non interoperable and interoperable operators. The dotted line includes operators as they become interoperable, hence it will include more and more operators over time, as a more and more countries has adopt interoperability. The figure shows a general decrease in mobile money tariffs and coverage over time for those operators that become interoperable.

Figure 5: Fees and interoperability



Notes: This figure reports the coefficients of the event study specification described in Equation 1. Both left and right panels display the value of the coefficients, γ_k, which describe differential evolution of the fees applied by mobile money operators operating under interoperability relative to operators operating in the absence of interoperability. In the left panel we present results for fees applied to transactions between subscribers of the same operator, i.e. on-network transactions. The right panel present results for fess applied to transaction between subscribers of different operators, i.e. cross-network transactions. The year marking the introduction of interoperability is year 0 on the x-axis and exhibits a vertical black line. The reference year is the year -1. The bars around each observation represent the 95% confidence interval. Standard errors are clustered at the operator level, and the empirical specification includes year and operator fixed effects.

Figure 6: Fees and interoperability

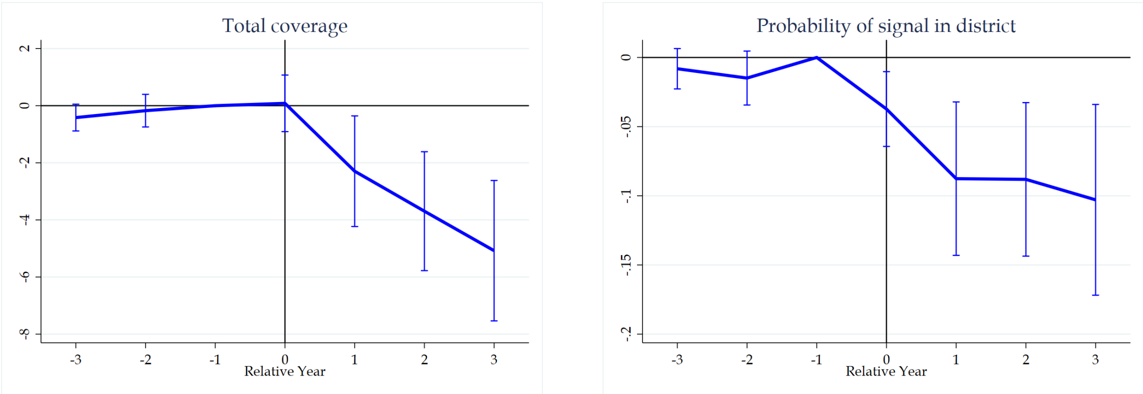


(a) On Net Fees

(b) Cross Net Fees

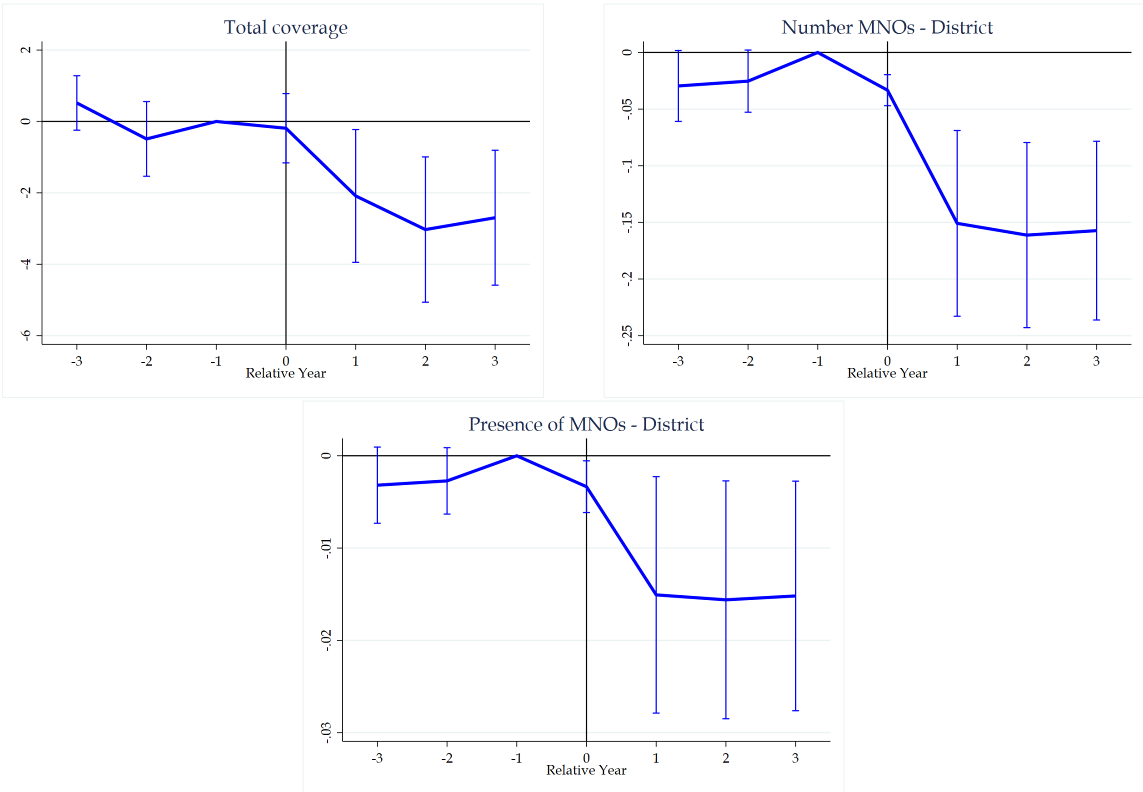
Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is fee bracket b of operator i in country c in year y. We report the δ_j coefficients of Equation 3, which are displayed in Table 3. Bracket, operator and year fixed effects are included in all columns and standard errors are clustered at the operator level. The dependent variables are the operator's fees for mobile money transactions to subscribers of the same operator, in the left panel; the operator's fees for mobile money transactions to subscriber of different operators, in the right panel. Both dependent variables are expressed as share of transaction value. We pair brackets in seven groups, and show the differential effect that the introduction of interoperability at the operator level has on different transaction brackets, where brackets represent cross-country harmonized transaction value ranges as explained in Section 2.2. Dependent variables are regressed over the interaction between $Interoperability_{ict}$, a dummy variable taking value 1 if the operator i is subject to mobile money interoperability, and an indicator variable $\mathbf{1}_j$, indicating to which pair bracket b belongs. The table hence reports the estimates of coefficients δ_j of Equation 3. The bars around each observation represent the 95% confidence interval. Standard errors are clustered at the operator level.

Figure 7: Event Study - Operator-District analysis



Notes. This figure reports the coefficients of the event study specification described in Equation 4. The three panels display the value of the coefficients, γ_k, which describe differential evolution of the outcome variables for the pairs operator-district for which interoperability is active relative to operator-districts with no interoperability. In the left panel we present results for operator's i network coverage in district d, i.e. the percentage of district's d area covered by mobile network operator i. The right panel presents results for the probability that the operator i is active in district d. The year marking the introduction of interoperability is year 0 on the x-axis and exhibits a vertical black line. The reference year is the year -1. The bars around each observation represent the 95% confidence interval. Standard errors are clustered at the district level, and the empirical specification includes year and operator-district fixed effects.

Figure 8: Event Study - District level



Notes: This figure reports the coefficients of the event study specification described in Equation 7. Both left, right and central panels display the value of the coefficients, γ_k, which describe differential evolution of the outcome variables for district where interoperability is active relative to districts with no interoperability. In the left panel we present results for district's mobile network coverage, i.e. the percentage of district's area covered by mobile network operators. The right panel present results for the number of mobile network operators active in the district. The central panel presents results for the probability of mobile network signal in the district. The year marking the introduction of interoperability is year 0 on the x-axis and exhibits a vertical black line. The reference year is the year -1. The bars around each observation represent the 95% confidence interval. Standard errors are clustered at the district level, and the empirical specification includes year and district fixed effects.

Appendix A

A.1 Balance Tables

Table A.1: Balance Table - Selection into interoperability

	Non Interoperable			Interoperable			Difference
	Mean	St. Dev.	N	Mean	St. Dev.	N	
Real GDP (Log Mn)	8.07	4.53	565	9.49	2.10	219	1.364
GDP growth (%)	1.62	18.06	532	-1.03	21.40	201	-3.133
Export of Goods and Services (Log Mn)	6.77	5.07	431	8.95	1.30	105	2.222*
Import of Goods and Services (Log Mn)	7.23	5.04	413	9.19	1.30	105	2.027
Government Consumption Exp (Log Mn)	6.25	5.03	412	8.38	1.44	101	2.209
Gross Fixed Capital Formation (Log Mn)	6.76	4.93	407	8.55	1.02	89	1.778
Households Expenditure (Log Mn)	8.66	2.35	353	9.82	1.60	105	1.165
Unemployment rate (%)	11.12	8.52	192	8.20	5.21	97	-3.772
Domestic Claims (Log Mn)	7.42	2.23	600	8.14	1.88	240	0.929
Net Foreign Assets (Log Mn)	7.19	2.07	631	7.40	1.76	255	0.309
Broad Money Liabilities (Log Mn)	2.49	0.22	632	2.54	0.19	258	0.073

Notes: This table is the balance table for interoperability. We compare African countries that never introduced interoperability (Non Interoperable), with African countries that eventually introduced interoperability (Interoperable). For Interoperable countries we use data only on the years before the introduction of interoperability. Our data span from 2000 to 2021. The table shows averages for baseline (Mean), their standard deviation (St. Dev.) and the number of observations (N). The Difference column is the coefficient of an OLS regression of a dummy taking value 1 for those countries that eventually introduced mobile money interoperability (and 0 otherwise) on the reported variable, with clustered standard errors at the country level. Regressions include year fixed effects. Country fixed effects are not included as the interoperability dummy, as here defined, is constant at the country level. This table shows that there is no selection into introducing interoperability at the country level, as country specific characteristics do not differ between countries in the two groups. The variables we take into consideration are, in order, Real GDP, the GDP growth, the value of Exports of goods and Services, the value of Import of goods and services, the value of Government Consumption Expenditure, the Gross fixed Capital Formation, the Household Expenditures, the Unemployment rate, the Domestic claims, the Net Foreign Assets and the Broad Money Liabilities. All variables are expressed as the logarithm of the US $ value in Millions. GDP growth and Unemployment rate are expressed as percentage. The Difference column is the coefficient of an ordinary least squares (OLS) regression of the interoperability dummy as above defined on the variable, with year fixed effects and standard errors clustered at the country level. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table A.2: Balance Table - Interoperability in time series

	Non Interoperable			Interoperable			Difference
	Mean	St. Dev.	N	Mean	St. Dev.	N	
Real GDP (Log Mn)	8.47	4.05	784	9.98	1.95	73	-0.186
GDP growth (%)	0.89	19.05	733	-2.68	17.46	73	1.114
Export of Goods and Services (Log Mn)	7.20	4.66	536	9.51	1.29	42	0.048
Import of Goods and Services (Log Mn)	7.62	4.61	518	9.52	1.04	42	-0.191
Government Consumption Exp (Log Mn)	6.67	4.63	513	8.72	1.26	42	-0.243
Gross Fixed Capital Formation (Log Mn)	7.08	4.54	496	9.44	1.20	38	0.120
Households Expenditure (Log Mn)	8.93	2.26	458	10.56	1.44	42	-0.119
Unemployment rate (%)	10.14	7.69	289	7.18	5.21	28	1.516
Domestic Claims (Log Mn)	7.63	2.16	840	9.53	1.86	66	0.027
Net Foreign Assets (Log Mn)	7.25	1.99	886	8.05	1.77	70	-0.120
Broad Money Liabilities (Log Mn)	2.50	0.21	890	2.68	0.15	67	0.024

Notes: This table shows the difference in country specific characteristics between interoperable and non-interoperable countries. We compare African countries that never introduced interoperability or that have not introduced interoperability yet (Non Interoperable), with African countries that have introduced interoperability (Interoperable). Our data span from 2000 to 2021. The table shows averages for baseline (Mean), their standard deviation (St. Dev.) and the number of observations (N). The Difference column is the coefficient of an OLS regression of a dummy taking value 1 when interoperability is enacted at the country level (and 0 otherwise) on the reported variable, with clustered standard errors at the country level. Regressions include year and country fixed effects. The interoperability dummy varies across time, as it takes value 1 only when the country introduces interoperability. This table shows that country-specific characteristics do not differ between countries in the two groups. The variables we take into consideration are, in order, Real GDP, the GDP growth, the value of Exports of goods and Services, the value of Import of goods and services, the value of Government Consumption Expenditure, the Gross fixed Capital Formation, the Household Expenditures, the Unemployment rate, the Domestic claims, the Net Foreign Assets and the Broad Money Liabilities. All variables are expressed as the logarithm of the US $ value in Millions. GDP growth and Unemployment rate are expressed as percentage. The Difference column is the coefficient of an ordinary least squares (OLS) regression of the interoperability dummy as above defined on the variable, with country and year fixed effects and standard errors clustered at the country level. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table A.3: M&As in the mobile network market and Interoperability

	Mergers and Acquisitions	
	(1)	(2)
$\text{Interoperability}_{ict}$	-0.018	
	(0.017)	
$\text{Interoperability}_{ct}$		-0.010
		(0.007)
Operator FE	Yes	Yes
Year FE	Yes	Yes
N. of Operators	284	284
Obs.	3408	3408
Adj. R sq.	0.023	0.022
Mean Dep. Var.	0.009	0.009

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is the mobile network operator i in year y. In all columns we include operator and year fixed effects and standard errors are clustered at the operator level. The dependent variable is a dummy taking value 1 when a mobile network operator is involved in an M&A operation. The dependent variable is regressed over two different measures of interoperability. Column (1) uses as independent variable an operator-specific dummy, that takes value 1 when the operator provides an interoperable mobile money service. Column (2), that presents the estimates for $Interoperability_{ct}$, uses a country-specific dummy that takes value 1 when interoperability is enacted by the national regulatory framework. The table suggests no relation between interoperability and the probability of mobile network operators to take part in a M&A operation. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table A.4: Mobile subscriptions and Interoperability

	Mobile (SIMs) subscriptions		Fixed telephone subscriptions	
	100 inhabitants (1)	Total (Log) (2)	100 inhabitants (3)	Total (Log) (4)
Interoperability$_{ct}$	-2.210	-0.043	-0.324	0.024
	(3.746)	(0.059)	(0.309)	(0.219)
Country FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N. of Countries	55	55	55	55
Obs.	640	640	629	629
Adj. R sq.	0.894	0.983	0.968	0.867
Mean Dep. Var.	79.617	15.600	3.754	10.750

Notes: This table shows ordinary least squares (OLS) estimates, where the unit of observation is country c in year t. We regress outcome variables over interoperability, a dummy taking value 1 after interoperability is introduced in country c. Regressions include year and country fixed effects, and standard errors are clustered at the country level. Outcome variables include: the number of registered mobile users (i.e. the number of SIM cards) per 100 inhabitants (1); the log of the number of total mobile phone subscriptions (2); the number of registered fixed phone users per 100 inhabitants (3); the log of the number of total fixed phone subscriptions (4). Data on phone subscriptions are taken from the World Bank Data Portal. This table shows that there is no relation between the number of mobile phone subscribers (i.e. number of SIM cards) and interoperability at the country level. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table A.5: Network Coverage, Mobile Subscriptions and Interoperability - District Level

	Total coverage	Probability of signal in district	Number of MNOs
	(1)	(2)	(3)
Interoperability$_{ct}$	-10.132***	-0.034***	-0.201***
	(0.264)	(0.000)	(0.002)
Interoperability$_{ct}$ $\times$ SIMs (100 inhab)$_c$	0.106***	-0.000***	-0.000***
	(0.004)	(0.000)	(0.000)
District FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N. of Districts	53824	53824	53824
Observations	645888	645888	645888
Adj. R sq.	0.909	0.873	0.914
Mean Dep. Var.	64.078	0.845	2.009

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is district d in year t, as specified in Eq. 12. In all columns we include district and year fixed effects and standard errors are clustered at the district level. Districts are defined as the smallest administrative unit in each country, as defined by the Database of Global Administrative Areas (GADM). The dependent variable is the mobile network coverage as percentage of the district's area, the probability of signal in the district and the number of mobile network operators active in the districts. The dependent variable is regressed over two variables. The first is $Interoperability_{ct}$, a dummy variable taking value 1 if the district d is subject to mobile money interoperability, i.e. if interoperability is active in country c. The second is the interaction between $Interoperability_{ct}$ and SIMs$_c$, a continuous variable for the number of mobile phone subscriptions over 100 inhabitants in country c prior to the introduction of interoperability. SIMs$_c$ is a country-specific constant, it is absorbed by the district fixed effects, and hence only its interaction with the interoperability dummy appears in the regression. Coefficients are extremely small, suggesting almost no differential effects of interoperability on countries, depending on their number of mobile phone subscriptions. The dependent variable's mean in the pre-policy period is reported in the last row of the table. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

A.2 Robustness check: Instrumental Variable approach

Table A.6: First stage - IV

	First stage
	(1)
Interoperability$_{ct}$	0.330***
	(0.102)
Operator FE	Yes
Year FE	Yes
Obs.	2340
Adj. R sq.	0.435
F-stat	14.680
Mean Dep. Var.	0.034

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is the operator i in year t. Operator and year fixed effects are included and standard errors are clustered at the country level. The dependent variable is a dummy variable taking value 1 if the mobile network operator i is interoperable. The dependent variables is regressed over $Interoperability_{ct}$, a dummy variable taking value 1 if the country c where operator i is present is subject to mobile money interoperability, i.e. if interoperability is active in country c. The dependent variable's mean and standard deviation are reported as the last two rows of the table. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table A.7: Fees and interoperability - IV

	IV		Reduced form	
	On Net (1)	Cross Net (2)	On Net (3)	Cross Net (4)
$\text{Interoperability}_{ict}$	-0.057*	-0.048		
	(0.031)	(0.030)		
$\text{Interoperability}_{ct}$			-0.040*	-0.035
			(0.020)	(0.023)
Operator FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Obs.	591	485	591	485
F-stat	178.590	152.311		
Mean Dep. Var.	0.053	0.125	0.053	0.125

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is operator i in year t. Operator and year fixed effects are present in all columns and standard errors are clustered at the country level. The dependent variables are On Net, which is the operator's fees for mobile money transactions to subscribers of the same operator (1, 3); and Cross Net, which is the operator's fees for mobile money transactions to subscriber of different operators (2, 4). Both dependent variables are expressed as percentage of transaction value. In Column (1) ans (2) we present the results of the Instrumental Variable approach, where the independent variable $Interoperability_{ict}$, a dummy taking value 1 if operator i is interoperable, is instrumented by $Interoperability_{ct}$, a dummy variable taking value 1 if interoperability is active in country c. In Column (3) and (4) we present the results of the reduced form, where the dependent variables are regressed over $Interoperability_{ct}$. The dependent variable's mean in the pre-policy period is reported in the last row of the table. Column (1) and (2) report the F statistic of the First Stage. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table A.8: Network Coverage and Interoperability - Operator-District Level - IV

	IV		Reduced form	
	Total coverage	Probability of signal in district	Total coverage	Probability of signal in district
	(1)	(2)	(3)	(4)
$\text{Interoperability}_{ict}$	-8.288*	-0.107*		
	(4.710)	(0.054)		
$\text{Interoperability}_{ct}$			-5.181***	-0.067***
			(0.067)	(0.000)
Operator-District FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Obs	1340928	1340928	1340928	1340928
F-stat	55.993	55.993		
Mean Dep. Var.	69.221	0.881	69.221	0.881

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is the pair operator i district d, in year t. Operator-district and year fixed effects are present in all columns and standard errors are clustered at the country level. Districts are defined as the smallest administrative unit in each country, as defined by the Database of Global Administrative Areas (GADM). The dependent variables are the individual mobile network operator i coverage in district d, expressed as percentage of the district d area (1); the probability that the mobile network operator is active in the district, i.e. a dummy taking value 1 whether the operator i has signal in the district d (2). In Column (1) ans (2) we present the results of the Instrumental Variable approach, where the independent variable $Interoperability_{ict}$, a dummy taking value 1 if operator i is interoperable, is instrumented by $Interoperability_{ct}$, a dummy variable taking value 1 if interoperability is active in country c. In Column (3) and (4) we present the results of the reduced form, where the dependent variables are regressed over $Interoperability_{ct}$. The dependent variable's mean in the pre-policy period is reported in the last row of the table. Column (1) and (2) report the F statistic of the First Stage. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table A.9: Mobile Operators and Interoperability - IV

	Total network coverage	Market penetration mobile connections	Total Revenue	Towers	EBIT	EBITDA
	(1)	(2)	(3)	(4)	(5)	(6)
Interoperability$_{ict}$	-0.186***	-0.333*	-0.168	-0.218*	0.466	0.143
	(0.033)	(0.173)	(0.209)	(0.118)	(0.512)	(0.388)
Operator FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	125	1842	1684	280	366	565
F-stat	.	97.870	77.976	36.110	56.901	64.122
Mean Dep. Var.	4.358	2.270	17.989	7.179	16.284	16.404

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is operator i in year t. Operator and year fixed effects are present in all columns and standard errors are clustered at the country level. The dependent variables are the operator's share of population covered in country c (1); the operator's market penetration of mobile connection in country c (2); the operator's total revenue (3); the number of towers used by the operator for its coverage (4); the operator's earnings before interest and taxes (EBIT) and the operator's earnings before interest, taxes, depreciation and amortization (EBITDA) in column (5) and (6), respectively. Dependent variables are expressed in log. We present the results of the Instrumental Variable approach, where the independent variable $Interoperability_{ict}$, a dummy taking value 1 if operator i is interoperable, is instrumented by $Interoperability_{ct}$, a dummy variable taking value 1 if interoperability is active in country c. The dependent variable's mean in the pre-policy period is reported in the last row of the table. All columns report the F statistic of the First Stage. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

A.3 Financial inclusion

Table A.10: DHS

	Transactions with mobile phone	
	(1)	(2)
Interoperability$_{ct}$	-0.203***	-0.200***
	(0.004)	(0.005)
Rural$_{ict}$		-0.242***
		(0.004)
Interoperability$_{ct}$ × Rural$_{ict}$		0.034***
		(0.006)
Country FE	Yes	Yes
Year FE	Yes	Yes
Obs.	105478	105478
Adj. R sq.	0.135	0.185
Mean Dep. Var.	0.480	0.480

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is individual respondent's i in year t. Country and year fixed effects are present in all columns and standard errors are clustered at the country level. Data are taken from the Demographic and Health Survey (DHS). Observations span the years 2008-2021. The impossibility to trace respondents through years impedes the usage of individual respondent's fixed effects. In order to partially overcome this issue we control for individual respondent's specific characteristics, such as gender, education and income. The dependent variable is a dummy variable taking value 1 if the last month the respondent has done any transaction through mobile phone. In Column (1), this is regressed over $Interoperability_{ct}$, a dummy variable taking value 1 if the individual i is subject to mobile money interoperability, i.e. if interoperability is active in country c. In Column (2), we include the interaction with the variable Rural$_{ict}$, which is a dummy indicating whether the respondent lives in a rural area. The dependent variable's mean and standard deviation are reported as the last two rows of the table. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

A.4 Additional Heterogeneities: Rural areas

Table A.11: Network Coverage, Rural area and Interoperability - District Level

	Growth in Total coverage		
	(1)	(2)	(3)
Total Coverage $(\%)_{dt}$	-0.026***		-0.025***
	(0.008)		(0.008)
Interoperability$_{ct}$ ×			
× Rural Area$_d$			
1st quintile	-0.047	-0.011	
	(0.034)	(0.025)	
2nd quintile	-0.083	0.010	
	(0.056)	(0.033)	
3rd quintile	-0.049	0.002	
	(0.043)	(0.030)	
4th quintile	-0.182	-0.110	
	(0.126)	(0.108)	
5th quintile	-0.196**	-0.124*	
	(0.085)	(0.065)	
District FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Obs.	525693	525693	525693
Adj. R sq.	-0.001	-0.002	-0.001
Mean Dep. Var.	0.043	0.043	0.043

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is district d in year t, as specified in Eq. 13. In all columns we include district and year fixed effects and standard errors are clustered at the district level. Districts are defined as the smallest administrative unit in each country, as defined by the Database of Global Administrative Areas (GADM). The dependent variable is the growth rate in mobile network coverage, expressed in yearly growth of the percentage of the district c area covered by mobile network operators' signal. The dependent variable is regressed over two variables. The first is $Total\ Coverage$, which represents the percentage of district d's area covered by mobile networks in year y. The other five dependent variables show the differential effect of interoperability on the five quintiles of the distribution districts according to the rural index as proposed by Cattaneo et al. (2021), i.e. are the coefficients ρ_i for $i \in \{1., 2, 3, 4, 5\}$ of Eq. 13, that refer to the interaction of the Interoperability dummy with five dummies identifying the five rurality quintiles. We use these quintiles as a proxy of the district's development. Higher quintiles correspond to more rural areas. The dependent variable's mean and standard deviation are reported as the last two rows of the table. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table A.12: Network Coverage, Lights and and Interoperability - District Level

	Growth in Total coverage		
	(1)	(2)	(3)
Total Coverage (%)$_{dt}$	-0.026***		-0.025***
	(0.008)		(0.008)
Interoperability$_{ct}$ $\times$			
$\times$ Night Light Intensity$_d$			
1st quintile	-0.141*	-0.056	
	(0.076)	(0.051)	
2nd quintile	-0.065	-0.031	
	(0.043)	(0.034)	
3rd quintile	-0.090	-0.049	
	(0.055)	(0.047)	
4th quintile	-0.042	-0.020	
	(0.038)	(0.032)	
5th quintile	-0.033	-0.024	
	(0.035)	(0.032)	
District FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Obs.	525693	525693	525693
Adj. R sq.	-0.001	-0.002	-0.001
Mean Dep. Var.	0.043	0.043	0.043

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is district d in year t. It presents coefficients from a variation of Eq. 13, where quintiles are defined over the distribution of nighttime light intensity across district in 2012. In all columns we include district and year fixed effects and standard errors are clustered at the district level. Districts are defined as the smallest administrative unit in each country, as defined by the Database of Global Administrative Areas (GADM). The dependent variable is the mobile network coverage as percentage of the district's area, the probability of signal in the district and the number of mobile network operators active in the districts. The dependent variable is regressed over several variables. The first is $Total\ Coverage$, which represents the percentage of district d's area covered by mobile networks in year y. The other five dependent variables show the differential effect of interoperability on the five quintiles of the distribution of districts according to the standardized nighttime light intensity of the district, i.e. are the coefficients ρ_i for $i \in \{1., 2, 3, 4, 5\}$ of Eq. 13, where in this case they refer to the interaction of the Interoperability dummy with five dummies identifying the five quintiles of districts in terms of nighttime light intensity. We use these quintiles as a proxy of the district's development. Higher quintiles correspond to more developed areas. Districts' nighttime light intensity is constructed using data on Nighttime lights provided by the National Centers for Environmental Information, kept fixed at the year 2012, i.e. before that interoperability was introduced in any country. The dependent variable's mean and standard deviation are reported as the last two rows of the table. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

A.5 Policy implications

Table A.13: Geographical level analysis

	Total coverage	Probability of signal in district	Number of MNOs
	(1)	(2)	(3)
$\text{Interoperability}_{ct}$	-2.499***	-0.038***	-0.240***
	(0.042)	(0.0)	(0.002)
Interop_{ct} × Years before presence_{dt_0}			
2-3 years	-1.185***	-0.059***	-0.395***
	(0.190)	(0.001)	(0.003)
4-7 years	-3.399***	-0.002***	-0.022***
	(0.129)	(0.0)	(0.001)
8-9 years	0.403***	0.031***	0.169***
	(0.116)	(0.001)	(0.004)
10-11 years	2.150***	0.007***	0.199***
	(0.093)	(0.0)	(0.002)
District FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N. of Districts	53828	53828	53828
Obs.	645936	645936	645936
Adj. R sq.	0.909	0.873	0.914
Mean Dep. Var.	66.775	0.889	0.117

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is district d in year t. District and year fixed effects are present in all columns and standard errors are clustered at the district level. Districts are defined as the smallest administrative unit in each country, as defined by the Database of Global Administrative Areas (GADM). The dependent variables are the total mobile network coverage, expressed as percentage of the district c area (1); the probability of mobile network signal in the district, i.e. a dummy taking value 1 whether at least one Mobile Network Operator (MNO) is active in the district (2); the number of Mobile Network Operators active in the district (3). Dependent variables are regressed over two variables. The first is $Interoperability_{ct}$, a dummy variable taking value 1 if the district d is subject to mobile money interoperability, i.e. if interoperability is active in country c. The second is the interaction between $Interoperability_{ct}$ and Years of presence before interoperability $_{dt_0}$, an indicator variable which corresponds to the number of years of presence of the mobile network in the district before the introduction of interoperability at t_0. The dependent variable's mean and standard deviation are reported as the last two rows of the table. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

A.6 Robustness check: Sun & Abraham

Table A.14: Fees and Interoperability

	Fees	
	On Net (1)	Cross Net (2)
ATE	-0.043**	-0.073***
	(0.018)	(0.027)
Operator FE	Yes	Yes
Year FE	Yes	Yes
N. of MNOs	64	47
Obs.	734	550
Mean Dep. Var.	.04	.11

Notes: This table presents estimates obtained from the method proposed by Sun and Abraham (2021). The coefficient of interest is the average treatment effect, which is obtained by averaging the estimation weighted estimators for the first four years after the introduction of interoperability. The unit of observation is operator i in year t. Operator and year fixed effects are present in all columns and standard errors are clustered at the operator level. The dependent variables are the operator's fees for mobile money transactions to subscribers of the same operator (1); the operator's fees for mobile money transactions to subscriber of different operators (2). Both dependent variables are expressed as share of transaction value. These are regressed over $Interoperability_{ict}$, a dummy variable taking value 1 if the operator i is subject to mobile money interoperability. The dependent variable's mean in the pre-policy period is reported in the last row of the table. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table A.15: Operator-district level geographical analysis

	Total coverage	Probability of signal in district
	(1)	(2)
ATE	-2.036***	-0.035***
	(0.083)	(0.000)
Operator-District FE	Yes	Yes
Year FE	Yes	Yes
Obs.	1340928	1340928
Mean Dep. Var.	75.41	.97

Notes: This table presents estimates obtained from the method proposed by Sun and Abraham (2021). The coefficient of interest is the average treatment effect, which is obtained by averaging the estimation weighted estimators for the first four years after the introduction of interoperability. The unit of observation is the pair operator i district d, in year t. Operator-district and year fixed effects are present in all columns and standard errors are clustered at the operator-district level. Districts are defined as the smallest administrative unit in each country, as defined by the Database of Global Administrative Areas (GADM). The dependent variables are the individual mobile network operator i coverage in district d, expressed as percentage of the district d area (1); the probability that the mobile network operator is active in the district, i.e. a dummy taking value 1 whether the operator i has signal in the district d (2). Dependent variables are regressed over $Interoperability_{ict}$, a dummy variable taking value 1 if the pair operator-district id is subject to mobile money interoperability. The dependent variable's mean in the pre-policy period is reported in the last row of the table. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table A.16: GSMA Intelligence yearly outcomes

	Total network coverage	Market penetration mobile connections	Total Revenue	Towers	EBIT	EBITDA
	(1)	(2)	(3)	(4)	(5)	(6)
ATE	-0.230***	-0.251*	-0.316*	-0.115**	-0.020	-0.060
	(0.087)	(0.148)	(0.171)	(0.058)	(0.425)	(0.275)
Operator FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N. of MNOs	29	95	93	54	38	54
Obs.	125	1842	1684	280	366	565
Mean Dep. Var.	4.36	2.27	17.99	7.18	16.28	16.4

Notes: This table presents estimates obtained from the method proposed by Sun and Abraham (2021). The coefficient of interest is the average treatment effect, which is obtained by averaging the estimation weighted estimators for the first four years after the introduction of interoperability. The unit of observation is operator i in year t. Operator and year fixed effects are present in all columns and standard errors are clustered at the operator level. The dependent variables are the operator's share of population covered in country c (1); the operator's market penetration of mobile connection in country c (2); the operator's total revenue (3); the number of towers used by the operator for its coverage (4); the operator's earnings before interest and taxes (EBIT) and the operator's earnings before interest, taxes, depreciation and amortization (EBITDA) in column (5) and (6), respectively. Dependent variables are expressed in log. These are regressed over $Interoperability_{ict}$, a dummy variable taking value 1 if the operator i is subject to mobile money interoperability. The dependent variable's mean in the pre-policy period is reported in the last row of the table. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table A.17: Sub-national unit geographical analysis

	Total coverage	Probability of signal in district	Number of MNOs
	(1)	(2)	(3)
ATE	-5.069***	-0.059***	-0.291***
	(0.079)	(0.001)	(0.003)
District FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N. of Districts	53828	53828	53828
Obs.	645936	645936	645936
Mean Dep. Var.	66.78	.89	.12

Notes: This table presents estimates obtained from the method proposed by Sun and Abraham (2021). The coefficient of interest is the average treatment effect, which is obtained by averaging the estimation weighted estimators for the first four years after the introduction of interoperability. The unit of observation is district d in year t. District and year fixed effects are present in all columns and standard errors are clustered at the district level. Districts are defined as the smallest administrative unit in each country, as defined by the Database of Global Administrative Areas (GADM). The dependent variables are the total mobile network coverage, expressed as percentage of the district c area (1); the probability of mobile network signal in the district, i.e. a dummy taking value 1 whether at least one Mobile Network Operator (MNO) is active in the district (2); the number of Mobile Network Operators active in the district (3). Dependent variables are regressed over $Interoperability_{ct}$, a dummy variable taking value 1 if the district d is subject to mobile money interoperability, i.e. if interoperability is active in country c. The dependent variable's mean in the pre-policy period is reported in the last row of the table. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

A.7 Robustness check: Borusyak, Jaravel & Spiess

Table A.18: Fees and interoperability

	Fees	
	On Net (1)	Cross Net (2)
ATE	-0.032**	-0.045**
	(0.014)	(0.018)
Operator FE	Yes	Yes
Year FE	Yes	Yes
Obs.	725	534
Mean Dep. Var.	0.041	0.108

Notes: This table presents the treatment effect estimation obtained from the difference-in-differences designs with staggered adoption of treatment, using the imputation approach of Borusyak et al. (2021). The unit of observation is operator i in year t. Operator and year fixed effects are present in all columns and standard errors are clustered at the operator level. The dependent variables are the operator's fees for mobile money transactions to subscribers of the same operator (1); the operator's fees for mobile money transactions to subscriber of different operators (2). Both dependent variables are expressed as share of transaction value. These are regressed over $Interoperability_{ict}$, a dummy variable taking value 1 if the operator i is subject to mobile money interoperability. The dependent variable's mean in the pre-policy period is reported in the last row of the table. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table A.19: Operator-district level geographical analysis

	Total coverage	Probability of signal in district
	(1)	(2)
ATE	-5.055***	-0.061***
	(0.084)	(0.000)
Operator-District FE	Yes	Yes
Year FE	Yes	Yes
Obs.	1340928	1340928
Mean Dep. Var.	75.408	0.968

Notes: This table presents the treatment effect estimation obtained from the difference-in-differences designs with staggered adoption of treatment, using the imputation approach of Borusyak et al. (2021). The unit of observation is the pair operator i district d, in year t. Operator-district and year fixed effects are present in all columns and standard errors are clustered at the operator-district level. Districts are defined as the smallest administrative unit in each country, as defined by the Database of Global Administrative Areas (GADM). The dependent variables are the individual mobile network operator i coverage in district d, expressed as percentage of the district d area (1); the probability that the mobile network operator is active in the district, i.e. a dummy taking value 1 whether the operator i has signal in the district d (2). Dependent variables are regressed over $Interoperability_{ct}$, a dummy variable taking value 1 if the pair operator-district id is subject to mobile money interoperability, i.e. if interoperability is active in country c. The dependent variable's mean and standard deviation are reported as the last two rows of the table. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table A.20: GSMA Intelligence yearly outcomes

	Total network coverage	Market penetration mobile connections	Total Revenue	Towers	EBIT	EBITDA
	(1)	(2)	(3)	(4)	(5)	(6)
ATE	-0.196***	-0.227**	-0.307**	-0.128**	-0.060	-0.057
	(0.021)	(0.111)	(0.128)	(0.064)	(0.374)	(0.220)
Operator FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	137	1842	1684	282	369	570
Mean Dep. Var.	4.362	2.270	17.989	7.071	16.268	16.396

Notes: This table presents the treatment effect estimation obtained from the difference-in-differences designs with staggered adoption of treatment, using the imputation approach of Borusyak et al. (2021). The unit of observation is operator i in year t. Operator and year fixed effects are present in all columns and standard errors are clustered at the operator level. The dependent variables are the operator's share of population covered in country c (1); the operator's market penetration of mobile connection in country c (2); the operator's total revenue (3); the number of towers used by the operator for its coverage (4); the operator's earnings before interest and taxes (EBIT) and the operator's earnings before interest, taxes, depreciation and amortization (EBITDA) in column (5) and (6), respectively. Dependent variables are expressed in log. These are regressed over $Interoperability_{ict}$, a dummy variable taking value 1 if the operator i is subject to mobile money interoperability. The dependent variable's mean and standard deviation are reported as the last two rows of the table. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table A.21: Sub-national unit geographical analysis

	Total coverage	Probability of signal in district	Number of MNOs
	(1)	(2)	(3)
ATE	-4.700***	-0.041***	-0.243***
	(0.088)	(0.000)	(0.002)
District FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Obs.	645936	645936	645936
Mean Dep. Var.	66.775	0.889	0.117

Notes: This table presents the treatment effect estimation obtained from the difference-in-differences designs with staggered adoption of treatment, using the imputation approach of Borusyak et al. (2021). The unit of observation is district d in year t. District and year fixed effects are present in all columns and standard errors are clustered at the district level. Districts are defined as the smallest administrative unit in each country, as defined by the Database of Global Administrative Areas (GADM). The dependent variables are the total mobile network coverage, expressed as percentage of the district c area (1); the probability of mobile network signal in the district, i.e. a dummy taking value 1 whether at least one Mobile Network Operator (MNO) is active in the district (2); the number of Mobile Network Operators active in the district (3). Dependent variables are regressed over $Interoperability_{ct}$, a dummy variable taking value 1 if the district d is subject to mobile money interoperability, i.e. if interoperability is active in country c. The dependent variable's mean in the pre-policy period is reported in the last row of the table. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

A.8 Additional robustness: Country Clustering

Table A.22: Fees and Interoperability

	Fees	
	On Net (1)	Cross Net (2)
$\text{Interoperability}_{ict}$	-0.033	-0.050*
	(0.027)	(0.029)
Operator FE	Yes	Yes
Year FE	Yes	Yes
Obs.	734	550
Adj. R sq.	0.052	0.192
Mean Dep. Var.	0.053	0.125

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is operator i in year t. Operator and year fixed effects are present in all columns and standard errors are clustered at the country level. The dependent variables are On Net, which is the operator's fees for mobile money transactions to subscribers of the same operator (1); and Cross Net, which is the operator's fees for mobile money transactions to subscriber of different operators (2). Both dependent variables are expressed as percentage of transaction value. These are regressed over $Interoperability_{ict}$, a dummy variable taking value 1 if the operator i is subject to mobile money interoperability. The dependent variable's mean and standard deviation are reported as the last two rows of the table. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table A.23: Fees and Interoperability

	On net	Cross net
	(1)	(2)
Bracket 1-2	-0.215*	-0.442
	(0.123)	(0.289)
Bracket 3-4	-0.021	-0.084
	(0.018)	(0.062)
Bracket 5-6	-0.015	-0.027
	(0.014)	(0.027)
Bracket 7-8	-0.005	-0.001
	(0.012)	(0.024)
Bracket 9-10	0.002	0.011
	(0.012)	(0.022)
Bracket 11-12	0.005	0.016
	(0.012)	(0.022)
Bracket 13+	0.004	0.018
	(0.011)	(0.024)
Operator FE	Yes	Yes
Year FE	Yes	Yes
Bracket FE	Yes	Yes
Obs.	16129	11883
Adj. R sq.	0.082	0.303
Mean Dep. Var.	0.048	0.122

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is fee bracket b of operator i in country c in year y. We report the δ_j coefficients of Equation 3. Bracket, operator and year fixed effects are included in all columns and standard errors are clustered at the country level. The dependent variables are the operator's fees for mobile money transactions to subscribers of the same operator, in Column (1); the operator's fees for mobile money transactions to subscriber of different operators, in Column (2). Both dependent variables are expressed as share of transaction value. We pair brackets in seven groups, and show the differential effect that the introduction of interoperability at the operator level has on different transaction brackets, where brackets represent cross-country harmonized transaction value ranges as explained in Section 2.2. Dependent variables are regressed over the interaction between $Interoperability_{ict}$, a dummy variable taking value 1 if the operator i is subject to mobile money interoperability, and an indicator variable $\mathbf{1}_j$, indicating to which pair bracket b belongs. The table hence reports the estimates of coefficients δ_j of Equation 3. The dependent variable's mean and standard deviation are reported as the last two rows of the table. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table A.24: Operator-district level geographical analysis

	Total coverage	Probability of signal in district
	(1)	(2)
$\text{Interoperability}_{ict}$	-3.976**	-0.053**
	(1.689)	(0.021)
Operator-District FE	Yes	Yes
Year FE	Yes	Yes
Obs.	1340928	1340928
Adj. R sq.	0.802	0.255
Mean Dep. Var.	75.408	0.968

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is the pair operator i district d, in year t. Operator-district and year fixed effects are present in all columns and standard errors are clustered at the country level. Districts are defined as the smallest administrative unit in each country, as defined by the Database of Global Administrative Areas (GADM). The dependent variables are the individual mobile network operator i coverage in district d, expressed as percentage of the district d area (1); the probability that the mobile network operator is active in the district, i.e. a dummy taking value 1 whether the operator i has signal in the district d (2). Dependent variables are regressed over $Interoperability_{ct}$, a dummy variable taking value 1 if the pair operator-district id is subject to mobile money interoperability. The dependent variable's mean and standard deviation are reported as the last two rows of the table. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table A.25: Network Coverage and Interoperability - District Level

	Total coverage	Probability of signal in district	Number of MNOs
	(1)	(2)	(3)
$\text{Interoperability}_{ct}$	-4.318*	-0.036***	-0.207*
	(0.087)	(0.000)	(0.002)
District FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N. of Districts	53828	53828	53828
Obs.	645936	645936	645936
Adj. R sq.	0.908	0.873	0.914
Mean Dep. Var.	64.078	0.845	2.009

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is district d in year t. District and year fixed effects are present in all columns and standard errors are clustered at the country level. Districts are defined as the smallest administrative unit in each country, as defined by the Database of Global Administrative Areas (GADM). The dependent variables are the total mobile network coverage, expressed as percentage of the district c area (1); the probability of mobile network signal in the district, i.e. a dummy taking value 1 whether at least one Mobile Network Operator (MNO) is active in the district (2); the number of Mobile Network Operators active in the district (3). Dependent variables are regressed over $Interoperability_{ct}$, a dummy variable taking value 1 if the district d is subject to mobile money interoperability, i.e. if interoperability is active in country c. The dependent variable's mean in the pre-policy period is reported in the last row of the table. In column (3) we report the mean of the number of Mobile Network Operators active in the district, not expressed in log. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

A.9 Additional robustness: Wild Cluster Bootstrap

Table A.26: Fees and interoperability

	Fees	
	On Net (1)	Cross Net (2)
$\text{Interoperability}_{ict}$	-0.033*	-0.050**
	(0.017)	(0.025)
Operator FE	Yes	Yes
Year FE	Yes	Yes
Obs.	734	550
Adj. R sq.	0.052	0.192
Mean Dep. Var.	0.053	0.125

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is operator i in year t. Operator and year fixed effects are present in all columns. Standard errors are computed through the wild cluster bootstrap method and clustered at the operator level. The dependent variables are On Net, which is the operator's fees for mobile money transactions to subscribers of the same operator (1); and Cross Net, which is the operator's fees for mobile money transactions to subscriber of different operators (2). Both dependent variables are expressed as percentage of transaction value. These are regressed over $Interoperability_{ict}$, a dummy variable taking value 1 if the operator i is subject to mobile money interoperability. The dependent variable's mean in the pre-policy period is reported in the last row of the table. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table A.27: Network Coverage and Interoperability - Operator-District Level

	Total coverage	Probability of signal in district
	(1)	(2)
$\text{Interoperability}_{ict}$	-3.976***	-0.053***
	(0.083)	(0.000)
Operator-District FE	Yes	Yes
Year FE	Yes	Yes
Obs.	1340928	1340928
Adj. R sq.	0.802	0.255
Mean Dep. Var.	69.221	0.881

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is the pair operator i district d, in year t. Operator-district and year fixed effects are present in all columns. Standard errors are computed through the wild cluster bootstrap method and clustered at the operator-district level. Districts are defined as the smallest administrative unit in each country, as defined by the Database of Global Administrative Areas (GADM). The dependent variables are the individual mobile network operator i coverage in district d, expressed as percentage of the district d area (1); the probability that the mobile network operator is active in the district, i.e. a dummy taking value 1 whether the operator i has signal in the district d (2). Dependent variables are regressed over $Interoperability_{ict}$, a dummy variable taking value 1 if the pair operator-district id is subject to mobile money interoperability, i.e. if operator i is interoperable. The dependent variable's mean in the pre-policy period is reported in the last row of the table. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table A.28: Network Coverage and Interoperability - District Level

	Total coverage	Probability of signal in district	Number of MNOs
	(1)	(2)	(3)
Interoperability$_{ct}$	-4.318***	-0.036***	-0.207***
	(0.082)	(0.000)	(0.002)
District FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N. of Districts	53828	53828	53828
Obs.	645936	645936	645936
Adj. R sq.	0.908	0.873	0.914
Mean Dep. Var.	64.078	0.845	-0.178

Notes: This table presents ordinary least squares (OLS) estimates, where the unit of observation is district d in year t. District and year fixed effects are present in all columns. Standard errors are computed through the wild cluster bootstrap method and clustered at the district level. Districts are defined as the smallest administrative unit in each country, as defined by the Database of Global Administrative Areas (GADM). The dependent variables are the total mobile network coverage, expressed as percentage of the district c area (1); the probability of mobile network signal in the district, i.e. a dummy taking value 1 whether at least one Mobile Network Operator (MNO) is active in the district (2); the number of Mobile Network Operators active in the district (3). Dependent variables are regressed over $Interoperability_{ct}$, a dummy variable taking value 1 if the district d is subject to mobile money interoperability, i.e. if interoperability is active in country c. The dependent variable's mean in the pre-policy period is reported in the last row of the table. In column (3) we report the mean of the number of Mobile Network Operators active in the district, not expressed in log. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

A.10 Additional robustness: Weighting for district's population

Table A.29: Network Coverage and Interoperability - Operator-District Level

	Total coverage	Probability of signal in district
	(1)	(2)
$\text{Interoperability}_{ict}$	-2.572***	-0.028***
	(0.185)	(0.002)
Operator-District FE	Yes	Yes
Year FE	Yes	Yes
Observations	1340796	1340796
Adj. R sq.	0.909	0.264
Mean Dep. Var.	69.223	0.881

Notes: This table presents weighted ordinary least squares (OLS) estimates, where the unit of observation is the pair operator i district d, in year t. Operator-district and year fixed effects are present in all columns and standard errors are clustered at the operator-district level. Districts are defined as the smallest administrative unit in each country, as defined by the Database of Global Administrative Areas (GADM). The dependent variables are the individual mobile network operator i coverage in district d, expressed as percentage of the district d area (1); the probability that the mobile network operator is active in the district, i.e. a dummy taking value 1 whether the operator i has signal in the district d (2). Dependent variables are regressed over $Interoperability_{ict}$, a dummy variable taking value 1 if the pair operator-district id is subject to mobile money interoperability, i.e. if operator i is interoperable. The dependent variable's mean in the pre-policy period is reported in the last row of the table. Estimations are weighted for the district's population. Data on population are retrieved from Warszawski et al. (2017). ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table A.30: Network Coverage and Interoperability - District Level

	Total coverage	Probability of signal in district	Number of MNOs
	(1)	(2)	(3)
Interoperability$_{ct}$	-0.284*	-0.003***	-0.034***
	(0.146)	(0.000)	(0.002)
Distric FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Number of Districts	53820	53820	53820
Obs.	645840	645840	645840
Adj. R sq.	0.968	0.994	0.994
Mean Dep. Var.	64.084	0.845	-0.177

Notes: This table presents weighted ordinary least squares (OLS) estimates, where the unit of observation is district d in year t. District and year fixed effects are present in all columns and standard errors are clustered at the district level. Districts are defined as the smallest administrative unit in each country, as defined by the Database of Global Administrative Areas (GADM). The dependent variables are the total mobile network coverage, expressed as percentage of the district c area (1); the probability of mobile network signal in the district, i.e. a dummy taking value 1 whether at least one Mobile Network Operator (MNO) is active in the district (2); the number of Mobile Network Operators active in the district (3). Dependent variables are regressed over $Interoperability_{ct}$, a dummy variable taking value 1 if the district d is subject to mobile money interoperability, i.e. if interoperability is active in country c. The dependent variable's mean in the pre-policy period is reported in the last row of the table. In column (3) we report the mean of the number of Mobile Network Operators active in the district, not expressed in log. Estimations are weighted for the district's population. Data on population are retrieved from Warszawski et al. (2017). ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table A.31: Network Coverage and Interoperability - Operator-District Level

	Total coverage	Probability of signal in district
	(1)	(2)
$\text{Interoperability}_{ict}$	-4.281***	-0.053***
	(0.106)	(0.001)
Operator-District FE	Yes	Yes
Year FE	Yes	Yes
Observations	1340796	1340796
Adj. R sq.	0.703	0.247
Mean Dep. Var.	69.223	0.881

Notes: This table presents weigthed ordinary least squares (OLS) estimates, where the unit of observation is the pair operator i district d, in year t. Operator-district and year fixed effects are present in all columns and standard errors are clustered at the operator-district level. Districts are defined as the smallest administrative unit in each country, as defined by the Database of Global Administrative Areas (GADM). The dependent variables are the individual mobile network operator i coverage in district d, expressed as percentage of the district d area (1); the probability that the mobile network operator is active in the district, i.e. a dummy taking value 1 whether the operator i has signal in the district d (2). Dependent variables are regressed over $Interoperability_{ict}$, a dummy variable taking value 1 if the pair operator-district id is subject to mobile money interoperability, i.e. if operator i is interoperable. The dependent variable's mean in the pre-policy period is reported in the last row of the table. Estimations are weighted for the district's population density. Data on population are retrieved from Warszawski et al. (2017). ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Table A.32: Network Coverage and Interoperability - District Level

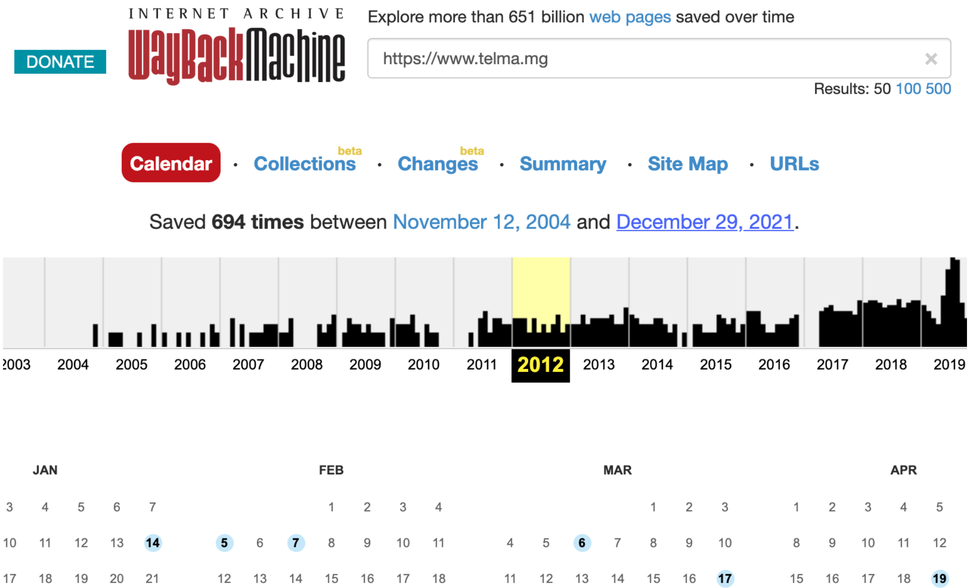
	Total coverage	Probability of signal in district	Number of MNOs
	(1)	(2)	(3)
$\text{Interoperability}_{ct}$	-2.673***	-0.029***	-0.178***
	(0.061)	(0.001)	(0.003)
Distric FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Number of Districts	53820	53820	53820
Obs.	645840	645840	645840
Adj. R sq.	0.925	0.876	0.920
Mean Dep. Var.	64.084	0.845	-0.177

Notes: This table presents weighted ordinary least squares (OLS) estimates, where the unit of observation is district d in year t. District and year fixed effects are present in all columns and standard errors are clustered at the district level. Districts are defined as the smallest administrative unit in each country, as defined by the Database of Global Administrative Areas (GADM). The dependent variables are the total mobile network coverage, expressed as percentage of the district c area (1); the probability of mobile network signal in the district, i.e. a dummy taking value 1 whether at least one Mobile Network Operator (MNO) is active in the district (2); the number of Mobile Network Operators active in the district (3). Dependent variables are regressed over $Interoperability_{ct}$, a dummy variable taking value 1 if the district d is subject to mobile money interoperability, i.e. if interoperability is active in country c. The dependent variable's mean in the pre-policy period is reported in the last row of the table. In column (3) we report the mean of the number of Mobile Network Operators active in the district, not expressed in log. Estimations are weighted for the district's population density. Data on population are retrieved from Warszawski et al. (2017). ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively.

Appendix B

B.1 Fees data set construction

Figure B.1: Wayback Machine



Notes: This figure shows a screenshot of the online tool we epxloited in order to retrieve webpages that are no longer available and that contained information regarding mobile money operators' tariff plans, as explained in Section 2.2. In this example, we are retrieving the webpage of Telma Madagascar in 2012.

Figure B.2: Tariff plans for different companies in the same country.

Rising		Transfer	
Minimum	Maximum	To Orange Money subscribers	To other operators and financial institutions *
200	1,000	50	25
1,001	5,000	50	120
5,001	10,000	100	250
10,001	25,000	200	400
25,001	50,000	400	880
50,001	100,000	800	1,300
100,001	250,000	1,500	3,000
250,001	500,000	1,500	4,500
500,001	1,000,000	2,500	6,900
1,000,001	2,000,000	3,000	11,500
2,000,001	3,000,000	3,000	14,000
3,000,001	4,000,000	3,000	17,600
4,000,001	5,000,000	3,000	18,600
5000001	6000000	3,000	21,000
6000001	7000000	3,000	24,000
7000001	8000000	3,000	28,000
8000001	9000000	3,000	32,000
9000001	10000000	3,000	37,000

(a) Orange Madagascar

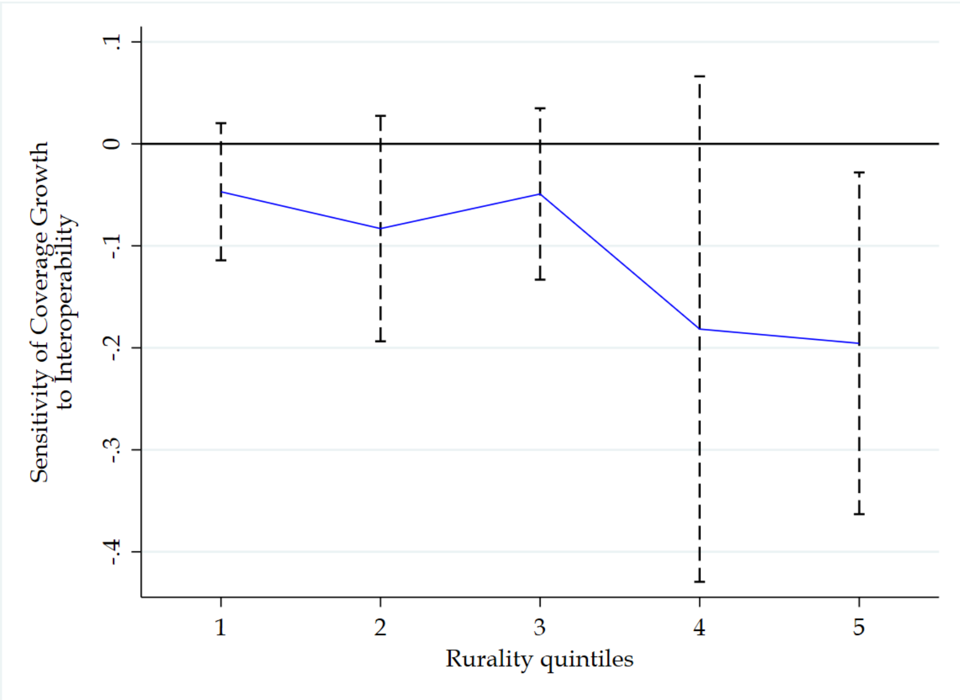
Rising		Money transfer fees	
Minimum	Maximum	To Airtel Money subscribers	To other operators
300	1 000	50	300
1 001	5 000	50	700
5 001	10 000	100	800
10 001	20 000	200	1 200
20 001	25 000	300	1 400
25 001	30 000	300	2 800
30 001	40 000	400	2 800
40 001	50 000	600	2 800
50 001	60 000	600	3 600
60 001	80 000	800	3 600
80 001	100 000	800	3 600
100 001	150 000	1 500	7 600
150 001	250 000	1 500	7 600
250 001	500 000	1 500	10 000
500 001	1 000 000	2 500	13 600
1 000 001	2 000 000	3 000	23 000
2 000 001	3 000 000	3 000	30 000
3 000 001	4 000 000	3 000	38 000
4 000 001	5 000 000	3 000	44 000

(b) Airtel Madagascar

Notes: This figure compares the tariff plans of two mobile money operators in the same country, Orange Madagascare (a) and Airtel Madagascar (b). These tariff plans are relative to the year 2012. As pointed out in Section 2.2, we can notice that the transaction ranges specified by the two operators differ, and, in particular, Airtel's tariff plan is more disaggregated.

B.2 Additional Heterogeneities: Rural areas and Interoperability

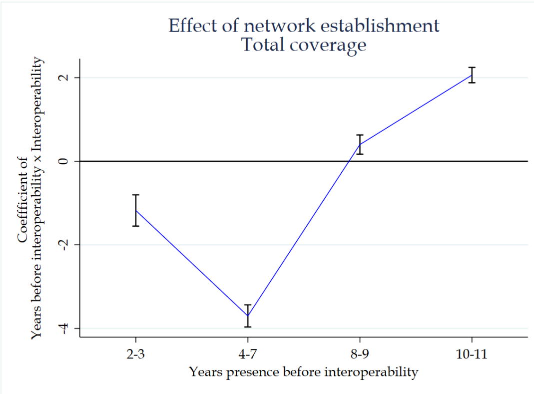
Figure B.3: Coverage growth in rural area



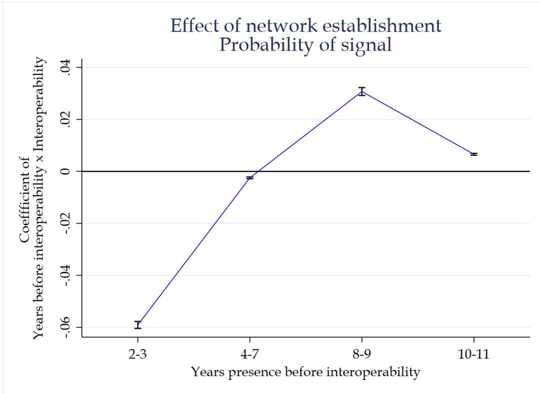
Notes: This figure shows plots coefficients ρ_i for $i \in \{1, 2, 3, 4, 5\}$ from Eq. 13. They represent the coefficient of the regression which has as outcome variable the growth in coverage in district d, expressed as percentage of the district's area covered, and as independent variables the interaction between Interoperability$_{cy}$, a dummy taking value 1 when interoperability is enacted in district's d, and an indicator variable that groups districts in the five quintiles of the distribution of the index of rurality as proposed by Cattaneo et al. (2021). Higher quintiles correspond to more rural areas. The bars around each observation represent the 95% confidence interval. Standard errors are clustered at the district level, and the empirical specification includes year fixed effects.

B.3 Policy implications

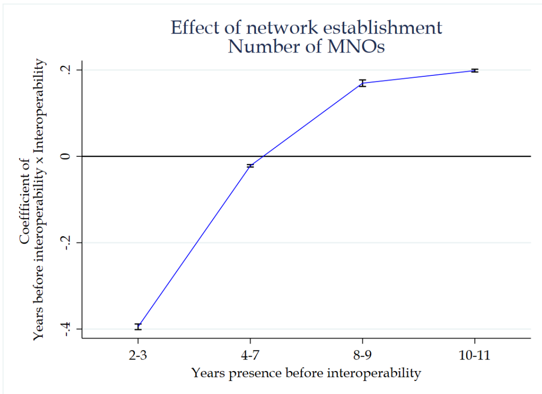
Figure B.4: Effect of network establishment.



(a)



(b)

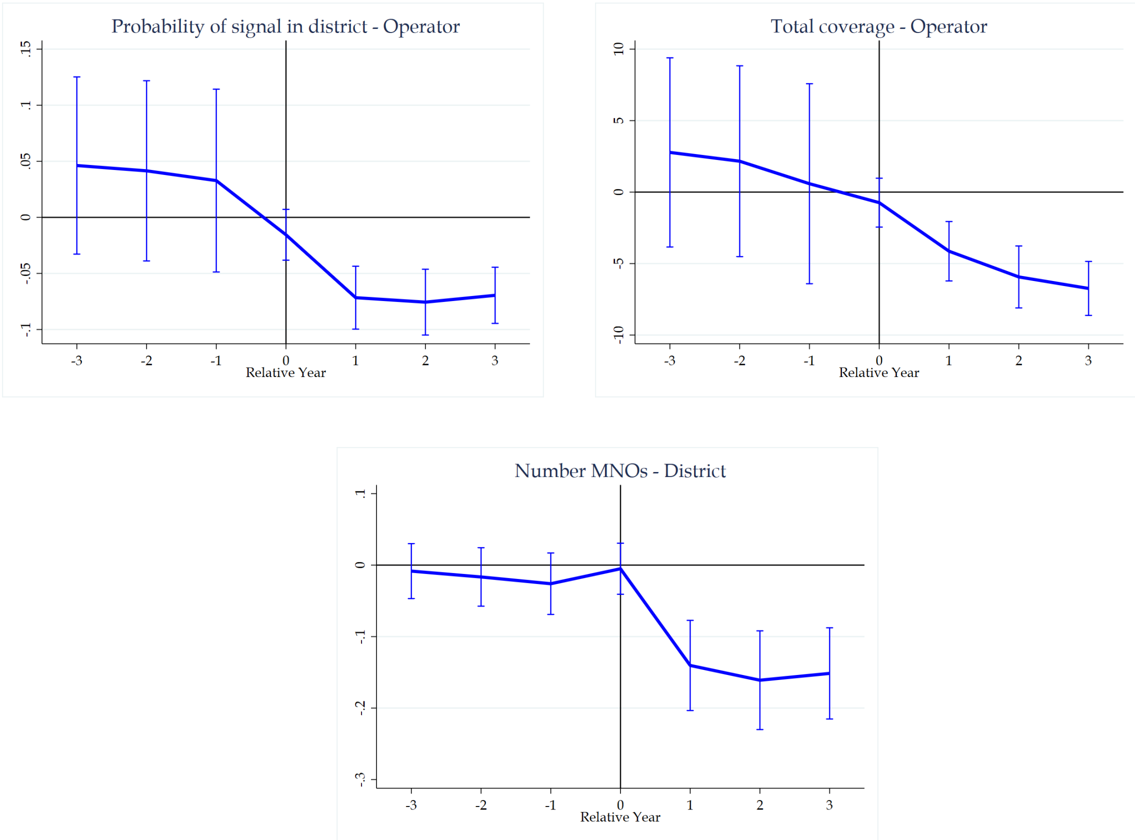


(c)

Notes: This figure plots the ordinary least squares (OLS) coefficients of Table A.13, where the unit of observation is district d in year t. Districts are defined as the smallest administrative unit in each country, as defined by the Database of Global Administrative Areas (GADM). The dependent variables are the total mobile network coverage, expressed as percentage of the district c area (a); Column (b) uses the same dependent variable as in (a), but restricting the sample to only those district that were already covered before the arrival of interoperability; the probability of mobile network signal in the district, i.e. a dummy taking value 1 whether at least one Mobile Network Operator (MNO) is active in the district (c); the number of Mobile Network Operators active in the district (d). The coefficients plotted are the ones of the interaction between $Interoperability_{ct}$, a dummy taking value 1 if interoperability is active in the district, and Years of presence before interoperability $_{dt_0}$, an indicator variable which corresponds to the number of years of presence of the mobile network in the district before the introduction of interoperability at t_0. The bars around each observation represent the 95% confidence interval. Standard errors are clustered at the district level, and the empirical specification includes year fixed effects.

B.4 Robustness check: Borusyak, Jaravel & Spiess

Figure B.5: Event Study Robustness Borjusak



Notes: This figure reports the coefficients of the event study design with staggered adoption of treatment, using the imputation approach of Borusyak et al. (2021). The three panels display the value of the coefficients which describe differential evolution of the outcome variables for the unit of observation for which interoperability is active relative to units with no interoperability. In the right panel we present results for operator's i network coverage in district d, i.e. the percentage of district's d area covered by mobile network operator i. The left panel present results for the probability of signal of the operator in the district. The central panel present results for the evolution of the number of mobile network operators in a given district. The bars around each observation represent the 95% confidence interval. Standard errors are clustered at the operator-district level, and the empirical specification includes year fixed effects.

Appendix C - Theoretical Framework

We can define the change in mobile tower installation induced by the arrival of interoperability as follows

$$\Delta m = \frac{\theta + \kappa}{\eta} - \frac{\tau}{\eta - 2\beta} = (\eta - 2\beta)(\theta + \kappa - \tau) + 2\beta\tau$$

by taking the difference in the equilibrium number of towers between the post-policy amount, $\frac{\theta+\kappa}{\eta}$, and the pre-policy variable, $\frac{\tau}{\eta-2\beta}$. Our analysis of the heterogeneous effects of the policy is developed as a comparative static over this expression.

Result 1: locations with higher cost of tower installation before interoperability, see a more extensive decline in signal.

$$\frac{\partial \Delta m}{\partial \eta} = -\frac{\theta + \kappa}{\eta^2} + \frac{\tau}{(\eta - 2\beta)^2} < 0$$

This result is always true if tower installation costs are especially high and exceed a threshold $\eta > \widetilde{\eta}$, with $\widetilde{\eta} = 2\beta \left[1 - \left(\frac{\tau}{\theta+\kappa}\right)^{\frac{1}{2}}\right]^{-1}$.

Result 2: companies with higher fees before the policy cut tower installation more strongly.

We can take the first derivative of Δm with respect to the change in the fees

$$\frac{\partial \Delta m}{\partial(\theta + \kappa - \tau)} = \eta - 2\beta > 0$$

this is a positive amount since $\eta > 2\beta$, however recall that $\theta + \kappa < \tau$ and therefore that the overall effect is negative: companies that cut their fees more extensively after the introduction of interoperability see a stronger decline in towers and presence.

Online Appendix D - Interoperability

A core concept of our analysis is mobile money interoperability. In line with the GSMA (2020) report, we define account-to-account (A2A) Interoperability as the possibility given by Mobile Money Providers (MMPs) for customers to transfer money between two accounts in different mobile money schemes. While mobile money was born as a stand-alone service, in which transfers were allowed only within the same network, in the latest years, it experienced an integration process that brought the connection of MMPs between themselves. By studying the development of the Mobile Money market in each African country, we aim to identify where the regulatory environment provides requirements or recommendations for interoperability. It is not a trivial effort as the regulatory frameworks vary widely between African countries, and the role of authorities in obliging the adoption of interoperability is sometimes uncertain. For each country, we report a brief overview of the introduction of interoperability from a regulatory perspective. In Table D.1 we summarize key information regarding the introduction of interoperability and its initiator for the African countries in which mobile money interoperability is active. Table D.1 clearly shows the growing involvement of institutional regulators in interoperability matters. In Naji (2020) and Mhella (2020) we can find different definitions of interoperability, depending on the level at which the integration of systems is developed. In particular, we can distinguish between (a) wallet-to-wallet interoperability: i.e. the possibility to exchange mobile money between accounts of different operators; (b) agent interoperability: which consists in the removal of exclusivity of agents, i.e. the possibility for agents to serve more than one operator; (c) wallet-to-bank (or other financial services) interoperability: i.e. the possibility to exchange money between a mobile money account and a bank account or other financial technologies. In our paper, we consider the case of wallet-to-wallet interoperability, which allows account-to-account transfers between users of different mobile money operators. As it can be seen below from country specific regulations, the introduction of mobile money interoperability in African countries has always entailed wallet-to-wallet interoperability.

Table D.1: Interoperability proponents in Africa

Reason for interoperability	Country	Year effective
Central Bank regulation	Botswana	2019
	Cameroon (BEAC)	2020
	Chad (BEAC)	2020
	Central African Republic (BEAC)	2020
	Egypt	2016
	Equatorial Guinea (BEAC)	2020
	Gabon (BEAC)	2020
	Ghana	2018
	Liberia	2014
	Malawi	2017
	Morocco	2018
	Nigeria	2013
	Rwanda	2021
	Republic of Congo (BEAC)	2020
	Sudan	2016
	Tanzania	2015
	Uganda	2018
	Zimbabwa	2020
Agreement between providers	Kenya (Airtel, Safaricom, Telkom)	2018
	Madagascar (Airtel, mVola, Orange)	2016

Notes: This table reports information about the proponent of interoperability in the African countries were interoperability is currently active. While the majority of countries introduce interoperability following an institutional regulation issued by the national Central Bank, there are cases in which agreements between mobile money operators preceded the regulator. Cameroon, Central African Republic, Equatorial Guinea, Gabon and the Republic of Congo are part of The Economic and Monetary Community of Central Africa (CEMAC), an organization of states of Central Africa that share a common currency: In their case, interoperability was proposed by the Bank of Central African States (Banque des États de l'Afrique Centrale, BEAC).

D.1 Botswana

The relevant regulatory framework in Botswana, which applies to mobile money providers, is the Electronic Payment Service Regulations, issued in January, 2019, by Bank of Botswana (the Central Bank of Botswana). According to the GSMA report "Mobile Money Regulatory Index 2021", the Mobile Network Operators (MNOs) in Botswana can offer mobile money and to provide this service they must apply for a license directly from Bank of Botswana and comply with the Electronic Payment Services Regulations (2019). As regards Interoperability, Part III, Art. 16 (2) (c) of the regulation reads: [...] *The resources shall be a system which is interoperate with other payment system within Botswana.* This regulation hence requires payment systems to be interoperable.

D.2 Cameroon

Being Cameroon a member of the Economic ad Monetary Community of Central Africa (CEMAC), its mobile money market is regulated by The Bank of Central African States (BEAC). In 2012, the Groupement Interbancaire Monétique d'Afrique Centrale (GIMAC) was created by the CEMAC with the purpose of promoting interbank electronic banking, regulation, supervision and the provision of processing services. Since 2018, GIMAC has been in charge of implementing full mobile money interoperability in accordance with instruction 001/GR/2018 from the Governor of BEAC.[6] In April 2020, after a pilot phase, an integrated electronic payment service, known as GIMACPAY, was introduced in all six countries of the Economic and Monetary Community of Central Africa. [7] Among other services, this platform allows people to transfer money between mobile money accounts of different operators, therefore, guarantees mobile money interoperability within the region. Since we found no evidence for any CEMAC countries of the introduction of domestic interoperability and since this regional interoperability also implies interoperability within each country (the possibility to transfer money between different MNOs in the same country), we consider April 2020 as the date of the launch of Interoperability for all countries in the region.

D.3 Central African Republic

Although the Central African Republic is a member of the CEMAC, we do not consider the presence of Interoperability since just one mobile operator (Orange) is providing mobile money services.

D.4 Egypt

According to the 2013 Regulations Governing Provision of Payment Orders through Mobile Phones issued by the Central Bank of Egypt (CBE), only banks operating under the supervision of the CBE may, subject to CBE's approval, issue electronic money units. Accordingly, to offer mobile money services, the MNOs must contract with the banks as only banks can be responsible for customer accounts.[8] In a bank-led model, a bank is the service provider. The role of the MNO is peripheral, limited to providing either the communications infrastructure, agency services or both Consistently with GSMA (2021), we consider applicable to mobile money services the "Regulations for the Provision of Mobile Payment Services (2016)", issued by the Central Bank of Egypt in November 2016. These regulations determine the activation of interoperability between different

[6] See link

[7] Cameroon, Republic of Congo, Chad, Central African Republic, Equatorial Guinea, and Gabon

[8] See link

payment schemes. Specifically, they require all banks providing mobile payment services with the CBE authorization to guarantee the interoperability service within six months.[9]

In addition, in June 2017, the Central Bank of Egypt, in collaboration with the the Ministry of Finance and the Egyptian Banks Company (EBC), introduced the mobile Interoperability scheme Ta7weel .[10] Through this platform, users of different mobile payment schemes are able to transact with each other directly. We set as Interoperability introduction the date of the issuance of the "Regulations for the Provision of Mobile Payment Services (2016)", i.e., November 2016, since they explicitly require providers of mobile banking services (and therefore mobile money) to become interoperable.

D.5 Ghana

The commitment to achieve payment systems Interoperability began in 2007 when the Ghana Interbank Payment and Settlement Systems Limited (GhIPSS) was established by Bank of Ghana (the Central Bank of Ghana). This wholly-owned subsidiary of the Bank of Ghana is responsible for implementing and managing interoperable payment system infrastructures for banks and non-bank financial institutions in Ghana.[11] According to GSMA (2020), Bank of Ghana's 2008 and 2015 Branchless Banking Guidelines mandated a "many-to-many" model whereby MNOs were required to interconnect with a minimum of three banks to issue electronic money, as well as share agents. In 2015, more progressive guidelines were introduced replacing those of 2008. Ghana has reached full interoperability in May 2018 through the Interbank Payment and Settlement Systems (GhIPSS). Indeed, the existing payment switch Gh-Link was upgraded to give access also to Mobile Money Operators (MMOs). The connection to this platform enabled the link of different payment systems, such as mobile money accounts, bank accounts, and e-zwitch cards. Therefore, mobile money users can seamlessly transfer money wallet-to-wallet across networks. Although payment aggregator Nsano has enabled interoperability between MNOs since 2016,[12] we take the launch of hub-based mobile money interoperability by GhIPSS as the starting date.

D.6 Kenya

In January 2018, the three mobile money providers networks, Airtel, Safaricom, and Telkom, reached an agreement regarding the implementation of interoperability. On the 22nd of the same month, Safaricom's M-Pesa and Airtel Money undertook a pilot phase, enabling the seamless transfer of funds between mobile accounts on different networks.

[9] See link
[10] See link
[11] See link
[12] See link

In a press release, the Central Bank of Kenya welcomed the implementation of interoperability of mobile financial services on the 10th of April 2018, stressing its benefits and importance to Kenya's mobile money market: accordingly, we set April 2018 as the date of the introduction of interoperability.

D.7 Liberia

In May 2014, the Central Bank of Liberia (CBL) issued the Mobile Money Regulations, requiring all authorized institutions to provide interoperable systems. In this regards, Part III, Art. 17 reads: *All Authorized Institutions should endeavor to render systems interoperable with systems provided by other Authorized Institutions, in such a way that transactions between Authorized Institutions are executed to allow a realtime customer experience for customers of both Institutions, as the services mature [...]*

D.8 Madagascar

Intending to reduce cash in the Madagascar economy, in 2014 the Mobile Money Providers (MMPs) engaged GSMA, a project facilitator, to advance sector-wide discussions on account-to-account (A2A) interoperability.[13] According to GSMA in September 2016 Airtel Money, mVola, and Orange Money signed a deal to launch interoperable mobile money services across the entire country; this made Madagascar the second market in Africa, after Tanzania, to allow seamless transactions on all MMPs.[14] Similarly to Tanzania, the implementation of Interoperability in Madagascar was market-led, with the presence of a facilitator (GSMA) that helped the providers to finalize bilateral agreements and connections. Although there was no mandate from the judicial authorities, we set September 2016 as Interoperability, as it is the date of the formal launch.

D.9 Malawi

In September 2017, the Reserve Bank of Malawi (RBM) passed the Payment System Act, mandating interoperability of Payment Systems through the connection to a National Switch. Specifically, Part IV, Art. (6) (1) states: *Any authorized or licensed payment service provider offering payment services on auto-teller machines, point of sale devices, mobile payment systems, internet based payments and all other related payment channels as approved by the Bank, shall connect its infrastructure that supports interoperability to the National Switch.*

[13] See link
[14] See link

D.10 Morocco

In November 2018, The Morocco's Central Bank Al-Maghrib and the National Telecommunications Regulatory Agency (ANRT) launched *m-wallet*, a new means of payment by mobile phone, in collaboration with banks, payment institutions, telecom operators and Hightech Payment Systems (HPS) Switch. The "Décision Réglementaire Relative au Paiement Mobile Domestique"[15] issued by the Central Bank of Morocco includes the rules and specifies the technical standards for interoperability. Article 5 reads: *The payment services offered by m-wallet are interoperable and instantaneous.* This tool entails not only interoperability between mobile money operators but also across all payment systems.

D.11 Nigeria

With the aim of ensuring the interoperability of all authorized schemes, in December 2012 the Central Bank of Nigeria required the Mobile Money Operators to connect to the National Central Switch (NCS).[16] In particular, the "Timeline for Interoperability and Interconnectivity" released by the Central Bank of Nigeria reads: *In furtherance of the CBN's efforts at ensuring effective and robust mobile payments system, all MMOs are hereby directed to fully connect to the National Central Switch (NCS) on or before February 28, 2013, to ensure interoperability and interconnectivity of their schemes.*

D.12 Rwanda

As early as 2012, the National Bank of Rwanda (BNR) issued Regulation N°06/2012 governing Payment Service Providers concerning interoperability. Specifically, Article 21 requires that *Financial institutions and Mobile Network Operators shall be interconnected to offer services to virtually all banked and unbanked customers in order to achieve interoperability and to substantially increase the financial services outreach to the unbanked communities*. In addition, Article 26 outlined the timeframe for this clause implementation: it provided that the connection would take place within one year of the effect of the regulation.[17] However, according to the "Interoperability Policy" issued in June 2014, the Bank of Rwanda recognizes the complexity of achieving interoperability given the differences among the several payment streams, schemes, and systems: *The implementation of this regulation has lagged while the complexity and diversity of the Rwandan payment market have grown. BNR recognizes that the question of how to promote interoperability in payment systems is a complex one that may be considered in the general case but must*

[15] See link
[16] See link
[17] See link

rather be defined and addressed in respect of particular payment types. BNR has therefore decided to review its policy approach towards interoperability so that it can achieve the objectives set out in this policy. In response to this recognition, the policy document was aimed at setting the general guidelines for promoting greater interoperability over the five year period from 2014 to 2019. In October 2015, Airtel and Tigo launched a six-month bilateral pilot project for interoperability, an initiative strongly supported by the National Bank of Rwanda. In December 2017, Airtel signed an agreement with Millicom to acquire Tigo Rwanda, creating a duopoly in the mobile money market. The two market leaders MTN and Airtel did not reach interoperability until 2021. Indeed, the New Times (Rwanda's leading daily) [18] reports that in June 2021, a draft law governing payment systems proposed a new provision that allows the Central Bank to impose interoperability and that the government was in negotiations with RSwitch to provide the interoperability system, operational in a short time. In December 2021, the national e-payment switch of Rwanda, RSwitch, was upgraded to connect all payment schemes, including MNOs.

D.13 Sudan

According to GSMA (2021) the Central Bank of Sudan is the only entity allowed to issue money in Sudan. Banks, by purchasing e-money directly from the Central Bank, play the role of Financial Service Providers (FSP), while the MNOs play most the customer facing functions. As far as it concerns interoperability, GSMA report reads: *The mobile payment system in Sudan is centralised thereby imposing on technical requirements for all financial system operators are required to inter-link their platforms to be interoperable.* Moreover, the 2017 Alliance for Financial Inclusion (AFI) report "National retail payment systems to support financial inclusion" claims that the Central Bank of Sudan implemented the National Switch in 2006 that provides interoperable, robust national payments infrastructure, to provide payment services for all cardholders through ATMs and POS terminals, across the nation; as well through Short Messaging Service (SMS). Among the terminals integrated with this National Switch, Mobile payments are included. Following these sources, we consider the regulation requiring all the payment systems to be interoperable. As a result, since their launch year in 2016, the mobile money platforms have been meeting the interoperability requirements.

D.14 Tanzania

Tanzania has been the first country to reach full mobile money Interoperability in Africa. Discussion on account-to-account innteroperability started as early as 2013, mandated by

[18] See link

the Bank of Tazania, after the intergration between the MMPs and the banking sector (GSMA, 2016). The interconnection between the four MMPs, Tigo, Airtel, Zantel, and Vodacom, took place the following years through bilateral/multilateral agreements. First, Airtel and Tigo signed a deal on interoperability in September 2014. Then in December 2014, Tigo connected with Zantel, and, in February 2016, Vodacom announced the joining of the interoperability agreement. In terms of legislation, the National Payment Systems (NPS) Act 2015 and the Bank of Tanzania Act 2006 assign to Bank of Tanzania the responsibility to regulate and supervise the payment systems services and products offered by both banks and non-bank institutions in Tanzania.[19] As far as it concerns interoperability, the National Payment Systems (NPS) Act, passed in May 2015, reads "*A payment system that may be eligible to be licenced by the Bank shall have any of the following objects: [...] facilitation of interoperability of payment systems and services between payment systems providers and consumers.*" In addition to the interoperability standard, the legislation mandates non-discriminatory pricing for cross-net and on-net person-to-person (P2P) transactions (GSMA, 2020). As interoperability has been market-driven and achieved gradually, we set as introduction of interoperability the date on which the National Payment Systems (NPS) law was passed.

D.15 Uganda

In 2013 the Bank of Uganda issued some guidelines[20] to mobile money service providers, recommending to "*utilize systems capable of becoming interoperable with other payment systems in the country and internationally in order to facilitate full interoperability*". In September 2017, this recommendation became more pressing as the Bank of Uganda issued the National Payment System (NPS) Policy Framework[21], which required all mobile money providers to achieve interoperability within a few months, without providing technical standards. The two market leaders, MTN and Airtel, initially used the Pegasus aggregator and then connected bilaterally in 2019. They still make use of Pegasus for interconnection with smaller MMPs (GSMA, 2020).

D.16 Zimbabwe

The Statutory Instrument 80 of 2020 (Banking Money Transmission, Mobile Banking and Mobile Money Interoperability) Regulations released by the Reserve Bank of Zimbabwe, in section 4 " Additional requirements for provision of money transmission and mobile banking services" reads: "*It shall be mandatory for every money transmission provider and mobile banking provider shall be connected to a national payment switch, as shall be*

[19] See link
[20] See link
[21] See link

directed by written notice by the Reserve Bank from time to time that enables interoperability of payments systems and services." In a press statement of June 2020, The Reserve Bank of Zimbabwe announced the designation of Zimswitch as a national payment switch with immediate effect. Therefore, as required by section 4 of the Regulations above, all money transmission providers and mobile money providers had to complete the necessary installation or deployment, or commissioning of infrastructure and connection protocols, credentials, and documentation to connect to Zimswitch, by no later than 15 August 2020.

Online Appendix E - Mobile Network Operators Balance Sheets

In this appendix we report the financial statement and revenue breakdown for the Fiscal Years 2020-2021 and 2021-2022 for the main mobile network operators (MNOs) in Africa offering mobile money services.

Table E.1: Summary of financial revenues of MNOs

Mobile Network Operator (MNO)	**Mobile Money Company**	**Countries**	**Financial Services Revenues 2020-2021 (as % of Total Revenues)**	**Financial Services Revenues 2021-2022 (as % of Total Revenues)**
Vodacom	M-Pesa	Democratic Republic of Congo, Tanzania Mozambique, Lesotho	34.2%	37.7%
Safaricom	M-Pesa	Kenya	33%	38.3%
MTN	MTN MoMo	Sudan, South Sudan, Rwanda, Cameroon, Eswatini, Guinea Bissau, Uganda, Ivory Coast, Liberia, Nigeria, Benin	10.6%	10%
Airtel	Airtel Money	Madagascar, Nigeria, Rwanda, Uganda, Kenya Chad, Congo, Democratic Republic of Congo, Gabon, Malawi, Niger, Seychelles, Uganda, Tanzania, Zambia	7.7%	9%

Notes: This table summarizes information about the financial revenues of major mobile network operators in Africa. The last two columns of the table report the financial service revenues as percentage of total revenues. We also report the countries in which MNOs operate and the name of the mobile money service they provide.

In Table E.1 we summarize the information about the revenues of financial services offered by these MNOs.

Airtel Money, the mobile money service provided by Airtel in Chad, Congo, Democratic Republic of Congo, Gabon, Kenya, Madagascar, Malawi, Niger, Nigeria, Rwanda, Seychelles, Uganda, Tanzania, Zambia, accounted for 9% of total revenues of Airtel in the Fiscal Years 2022.

MTN MoMo, in 2022, accounted for 10% of total revenues in the countries where MTN operates (Sudan, South Sudan, Rwanda, Cameroon, Côte d'Ivoire, Liberia, Eswatini, Guinea Bissau, Uganda, Nigeria, Benin).

Vodacom in the Democratic Republic of Congo, Lesotho, Mozambique and Tanzania, and Safaricom in Kenya, instead, registered revenues for about 38% from their mobile money service M-Pesa. Vodacom and Safaricom have the same mobile money service because Vodacom is the major owner of Safaricom's stocks, holding the 35% of its shares.

Below, we attach the financial statements and revenue breakdowns of these mobile network operators.[22]

[22] We also information for Orange, which, in Africa, operates in following countries: Botswana, Burkina

Figure E.1: Airtel's Financial Statements - Fiscal Year 2020-2021

Consolidated statement of comprehensive income

(All amounts are in US$ millions unless stated otherwise)

		For the year ended	
	Notes	**31 March 2021**	31 March 2020
Income			
Revenue	6	**3,908**	3,422
Other income		**11**	17
		3,919	3,439
Expenses			
Network operating expenses		**694**	628
Access charges		**376**	376
Licence fee/spectrum usage charges		**198**	189
Employee benefits expense	7	**275**	234
Sales and marketing expenses		**187**	148
Impairment loss/(reversal) on financial assets		**7**	(2)
Other operating expenses		**382**	333
Depreciation and amortisation	9	**681**	632
		2,800	2,538
Operating profit		**1,119**	901
Finance costs	10	**432**	440
Finance income	10	**(9)**	(67)
Non-operating income	11	**–**	(70)
Share of profit of associate		**(1)**	(0)
Profit before tax		**697**	598
Income tax expense	12	**282**	190
Profit for the year		**415**	408
Profit before tax (as presented above)		**697**	598
Less: Exceptional items (net)	11	**(14)**	(65)
Underlying profit before tax		**683**	533
Profit after tax (as presented above)		**415**	408
Less: Exceptional items (net)	11	**(50)**	(112)
Underlying profit after tax		**365**	296
Other comprehensive income (OCI)			
Items to be reclassified subsequently to profit or loss:			
Net losses due to foreign currency translation differences		**(138)**	(219)
Net (loss)/gain on net investments hedge		**(11)**	5
Net loss on cash flow hedge		**–**	(2)
		(149)	(216)
Items not to be reclassified subsequently to profit or loss:			
Re-measurement (loss)/gain on defined benefit plans		**(0)**	1
Tax credit/(expense) on above		**0**	(0)
		(0)	1
Other comprehensive loss for the year		**(149)**	(215)
Total comprehensive income for the year		**266**	193
Profit for the year attributable to:		**415**	408
Owners of the company		**339**	370
Non-controlling interests		**76**	38
Other comprehensive loss for the year attributable to:		**(149)**	(215)
Owners of the company		**(140)**	(224)
Non-controlling interests		**(9)**	9
Total comprehensive income for the year attributable to:		**266**	193
Owners of the company		**199**	146
Non-controlling interests		**67**	47
Earnings per share			
Basic	13	**9.0c**	10.3c
Diluted	13	**9.0c**	10.3c

Notes: Year ended 31 March 2021

Faso, Cameroon, Central African Repuclic, Guinea Bissau, Ivory Coast, Liberia, Morocco, DRC, Senegal, Sierra Leone, Madagascar, Tunisia, Egypt. However, the Financial Statement of Orange is consolidated for all the countries where the company operates, including European ones, and as a consequence there is not a clear entry for Mobile Money Revenues.

Figure E.2: Airtel's Revenue Breakdown - Fiscal Year 2020-2021

6. Revenue continued

Investment elimination upon consolidation and resulting goodwill impacts are reflected in the 'eliminations/adjustment' column.

Summary of the segmental information and disaggregation of revenue for the year ended and as of 31 March 2021 is as follows:

	Nigeria	East Africa	Francophone Africa	Unallocated	Eliminations	Total
Revenue from external customers						
Voice revenue	896	649	558	0	–	2,103
Data revenue	549	354	254	–	–	1,157
Mobile money revenue[1]	0	227	74	–	–	301
Other revenue[2]	104	147	96	–	–	347
	1,549	1,377	982	0	–	3,908
Inter-segment revenue	3	4	3	–	(10)	–
Total revenue	1,552	1,381	985	0	(10)	3,908
Segment results: Underlying EBITDA	839	631	364	(30)	(12)	1,792
Less:						
Depreciation and amortisation	236	221	207	2	15	681
Finance costs						432
Finance income						(9)
Share of profit of associate						(1)
Charitable donation	1	2	1	2	–	6
Exceptional items pertaining to operating profit	–	–	(14)	–	–	(14)
Profit before tax						697
Other segment items						
Capital expenditure	275	249	88	2	–	614
As of 31 March 2021						
Segment assets	1,889	2,042	1,791	25,622	(21,352)	9,992
Segment liabilities	1,192	2,989	2,715	16,895	(17,152)	6,639
Investment in associate (included in segment assets above)	–	–	4	–	–	4

1 Intra-segment elimination of $100m adjusted with mobile money revenue. It includes $64m pertaining to East Africa and balance $36m pertaining to Francophone Africa

2 This includes messaging, value added services, enterprise, site sharing and handset sale revenue

Notes: Year ended 31 March 2021

Figure E.3: Airtel's Financial Statements - Fiscal Year 2021-2022

Consolidated statement of comprehensive income

(All amounts are in US$ millions unless stated otherwise)

	Notes	For the year ended 31 March 2022	31 March 2021
Income			
Revenue	6	**4,714**	3,908
Other income		**10**	11
		4,724	3,919
Expenses			
Network operating expenses		**817**	694
Access charges		**407**	376
Licence fee and spectrum usage charges		**244**	198
Employee benefits expense	7	**297**	275
Sales and marketing expenses		**224**	187
Impairment loss on financial assets		**5**	7
Other operating expenses		**451**	382
Depreciation and amortisation	9	**744**	681
		3,189	2,800
Operating profit		**1,535**	1,119
Finance costs	10	**441**	432
Finance income	10	**(19)**	(9)
Other non-operating income	11	**(111)**	–
Share of profit from associate		**(0)**	(1)
Profit before tax		**1,224**	697
Income tax expense	12	**469**	282
Profit for the year		**755**	415
Profit before tax (as presented above)		**1,224**	697
Less: exceptional items (net)	11	**(60)**	(14)
Underlying profit before tax		**1,164**	683
Profit after tax (as presented above)		**755**	415
Less: exceptional items (net)	11	**(62)**	(50)
Underlying profit after tax		**693**	365
Other comprehensive income (OCI)			
Items to be reclassified subsequently to profit or loss:			
Loss due to foreign currency translation differences		**(4)**	(147)
Tax (expense)/credit on above		**(3)**	9
Share of OCI of associate		**1**	0
Net loss on net investments hedge		**(8)**	(11)
		(14)	(149)
Items not to be reclassified subsequently to profit or loss:			
Remeasurement loss on defined benefit plans		**(0)**	(0)
Tax credit on above		**0**	0
		(0)	(0)
Other comprehensive loss for the year		**(14)**	(149)
Total comprehensive income for the year		**741**	266
Profit for the year attributable to:		**755**	415
Owners of the Company		**631**	339
Non-controlling interests		**124**	76
Other comprehensive loss for the year attributable to:		**(14)**	(149)
Owners of the Company		**(12)**	(140)
Non-controlling interests		**(2)**	(9)
Total comprehensive income for the year attributable to:		**741**	266
Owners of the Company		**619**	199
Non-controlling interests		**122**	67
Earnings per share			
Basic	13	**16.8 cents**	9.0 cents
Diluted	13	**16.8 cents**	9.0 cents

Notes: Year ended 31 March 2022

Figure E.4: Airtel's Revenue Breakdown - Fiscal Year 2021-2022

Summary of the segmental information and disaggregation of revenue for the year ended and as of 31 March 2022 is as follows:

	Nigeria	East Africa	Francophone Africa	Unallocated	Eliminations	Total
Revenue from external customers						
Voice revenue	**984**	**782**	**592**	**–**	**–**	**2,358**
Data revenue	**734**	**457**	**334**	**–**	**–**	**1,525**
Mobile money revenue[1]	**0**	**326**	**98**	**–**	**–**	**424**
Other revenue[2]	**157**	**146**	**104**	**–**	**–**	**407**
	1,875	**1,711**	**1,128**	**–**	**–**	**4,714**
Inter-segment revenue	**3**	**6**	**3**	**–**	**(12)**	**–**
Total revenue	**1,878**	**1,717**	**1,131**	**–**	**(12)**	**4,714**
Segment results: underlying EBITDA	**1,037**	**848**	**464**	**(38)**	**(0)**	**2,311**
Less:						
Depreciation and amortisation	**268**	**240**	**203**	**33**	**0**	**744**
Finance costs						**441**
Finance income						**(19)**
Other non-operating income (net)						**(111)**
Share of profit of associate						**(0)**
Exceptional items pertaining to operating profit	**–**	**32**	**–**	**–**	**–**	**32**
Profit before tax						**1,224**
Other segment items						
Capital expenditure	**251**	**271**	**125**	**9**	**–**	**656**
As of 31 March 2022						
Segment assets	**2,254**	**2,394**	**1,720**	**27,422**	**(23,426)**	**10,364**
Segment liabilities	**1,437**	**2,869**	**2,495**	**14,491**	**(14,577)**	**6,715**
Investment in associate (included in segment assets above)	**–**	**–**	**6**	**–**	**–**	**6**

1 Intra-segment elimination of $129m adjusted with mobile money revenue. It includes $85m pertaining to East Africa and a balance of $44m pertaining to Francophone Africa

2 It includes messaging, value added services, enterprise, site sharing and handset sale revenue

Notes: Year ended 31 March 2022

Figure E.5: MTN's Financial Statements - Fiscal Year 2020-2021

Group income statement

for the year ended 31 December 2021

	Note	2021 Rm	2020 Rm
Revenue	2.1, 2.2	**181 646**	179 361
Other income	9.4.2.4, 9.4.2.5	**677**	99
Direct network and technology operating costs		**(27 649)**	(28 208)
Costs of handsets and other accessories		**(10 584)**	(11 093)
Interconnect and roaming costs		**(9 622)**	(10 992)
Staff costs	2.3	**(11 716)**	(12 741)
Selling, distribution and marketing expenses		**(22 452)**	(21 158)
Government and regulatory costs		**(6 895)**	(6 823)
Impairment and write-down of trade receivables and contract assets	2.3	**(1 116)**	(2 169)
Other operating expenses		**(12 570)**	(9 584)
Depreciation of property, plant and equipment	5.1	**(21 181)**	(22 704)
Depreciation of right-of-use assets	6.5.3	**(7 216)**	(7 204)
Amortisation of intangible assets	5.2	**(6 243)**	(5 743)
Impairment of goodwill and investment in joint ventures	5.2, 9.2	**(583)**	(1 065)
Gain on disposal of investment in associates	9.4.1; 9.4.2.1	**1 212**	6 129
Loss on deconsolidation of subsidiary	9.4.2.3	**(4 720)**	–
Impairment loss on remeasurement of non-current assets held for sale	9.4.2.1; 9.4.2.3	**(53)**	(1 510)
Finance income	2.4	**1 198**	1 493
Finance costs	2.4	**(15 646)**	(19 726)
Net monetary gain		**275**	1 582
Share of results of associates and joint ventures after tax	9.2	**2 054**	1 142
Profit before tax		**28 816**	29 086
Income tax expense	3.1	**(11 822)**	(9 439)
Profit after tax		**16 994**	19 647
Attributable to:			
Equity holders of the Company		**13 750**	17 022
Non-controlling interests		**3 244**	2 625
		16 994	19 647
Basic earnings per share (cents)	2.5	**763**	946
Diluted earnings per share (cents)	2.5	**744**	936

Notes: Year ended 31 March 2021

Figure E.6: MTN's Revenue Breakdown - Fiscal Year 2020-2021

2 **RESULTS OF OPERATIONS** (continued)

2.1 **Operating segments** (continued)

These exclusions have remained unchanged from the prior year, apart from the fair value gain on acquisition of subsidiary, loss on deconsolidation of subsidiary, gain on exit in Yemen, gain on disposal of subsidiary and impairment loss on Yemen property, plant and equipment and intangible assets. Impairment losses on property, plant and equipment and intangible assets are generally included in the CODM EBITDA as they are operational in nature. As the impairment of Yemen's property, plant and equipment and intangible assets arises from the MENA exit strategy, it is not considered reflective of Yemen's performance for the period.

Irancell proportionate results are included in the segment analysis as reviewed by the CODM and excluded from reported proportionate results for revenue, CODM EBITDA and capital expenditure (capex) due to equity accounting for joint ventures. The results of Irancell in the segments analysis exclude the impact of hyperinflation accounting.

Revenue 2021	Network services Rm	Mobile devices Rm	Interconnect and roaming Rm	Digital and fintech Rm	Other Rm	Revenue from contracts with customers Rm	Interest revenue Rm	Total revenue Rm
South Africa	31 030	9 271	4 070	2 429	1 521	48 321	395	48 716
Nigeria	50 241	107	5 594	3 216	892	60 050	–	60 050
SEA	11 830	211	759	3 598	557	16 955	–	16 955
Uganda	5 728	84	378	2 199	160	8 549	–	8 549
Zambia	1 606	77	108	596	42	2 429	–	2 429
Other SEA	4 496	50	273	803	355	5 977	–	5 977
WECA	34 371	223	2 499	9 750	1 162	48 005	–	48 005
Ghana	13 046	56	642	5 151	292	19 187	–	19 187
Côte d'Ivoire	6 022	47	879	1 456	499	8 903	–	8 903
Cameroon	5 475	38	385	1 262	84	7 244	–	7 244
Other WECA	9 828	82	593	1 881	287	12 671	–	12 671
MENA	5 209	13	1 055	200	73	6 550	–	6 550
Sudan	1 619	6	548	43	10	2 226	–	2 226
Afghanistan	1 670	7	341	57	17	2 092	–	2 092
Other MENA[1]	1 920	–	166	100	46	2 232	–	2 232
Major joint venture – Irancell[2]	5 831	128	289	324	138	6 710	15	6 725
Head office companies[3]	1 515	–	5 076	188	12 183	18 962	134	19 096
Eliminations	(438)	(1)	(5 303)	(206)	(11 635)	(17 583)	(130)	(17 713)
Hyperinflation impact	(229)	1	226	(5)	(6)	(13)	–	(13)
Irancell revenue exclusion	(5 831)	(128)	(289)	(324)	(138)	(6 710)	(15)	(6 725)
Consolidated revenue	133 529	9 825	13 976	19 170	4 747	181 247	399	181 646

[1] Syria and Yemen segment analysis has been included until the Group lost control of MTN Syria on 25 February 2021 and the Group exited Yemen on 17 November 2021. Refer to note 9.4.2.3 and note 9.4.2.4.

[2] Irancell proportionate results are included in the segment analysis as reviewed by the CODM. This is, however, excluded from IFRS reported results due to equity accounting for joint ventures.

[3] Head office companies consist mainly of revenue from GlobalConnect Solutions Limited (GlobalConnect), the Group's central financing activities and management fees from segments.

Notes: Year ended 31 March 2021

Figure E.7: MTN's Financial Statements - Fiscal Year 2021-2022

Group income statement

for the year ended 31 December 2022

	Note	2022 Rm	2021 Rm
Revenue	2.1; 2.2	**207 003**	181 646
Other income	6.5.5	**410**	677
Direct network and technology operating costs		**(32 854)**	(27 649)
Costs of handsets and other accessories		**(12 055)**	(10 584)
Interconnect and roaming costs		**(11 288)**	(9 622)
Staff costs	2.3	**(12 675)**	(11 716)
Selling, distribution and marketing expenses		**(24 819)**	(22 452)
Government and regulatory costs		**(7 610)**	(6 895)
Impairment and write-down of trade receivables and contract assets	2.3	**(1 579)**	(1 116)
Other operating expenses		**(13 431)**	(12 570)
Depreciation of property, plant and equipment	5.1	**(20 812)**	(21 181)
Depreciation of right-of-use assets	6.5.3	**(7 840)**	(7 216)
Amortisation of intangible assets	5.2	**(5 999)**	(6 243)
Impairment of goodwill and investment in joint ventures	5.2; 9.2	**(625)**	(583)
Gain on disposal of investment in associates	9.4.1.1	**–**	1 212
Loss on deconsolidation of subsidiary	9.4.1.3	**–**	(4 720)
Impairment loss on remeasurement of non-current assets held for sale	9.4.2.4	**(1 263)**	(53)
Finance income	2.4	**2 042**	1 198
Finance costs	2.4	**(19 728)**	(15 646)
Net monetary gain		**1 251**	275
Share of results of associates and joint ventures after tax	9.2	**3 369**	2 054
Profit before tax		**41 497**	28 816
Income tax expense	3.1	**(17 236)**	(11 822)
Profit after tax		**24 261**	16 994
Attributable to:			
Equity holders of the Company		**19 337**	13 750
Non-controlling interests		**4 924**	3 244
		24 261	16 994
Basic earnings per share (cents)	2.5	**1 071**	763
Diluted earnings per share (cents)	2.5	**1 044**	744

Notes: Year ended 31 March 2022

Figure E.8: MTN's Revenue Breakdown - Fiscal Year 2021-2022

Notes to the Group financial statements (continued)

for the year ended 31 December 2022

2 RESULTS OF OPERATIONS (continued)

2.1 **Operating segments** (continued)

Revenue 2022	Network services Rm	Mobile devices Rm	Inter-connect and roaming Rm	Digital and fintech Rm	Other Rm	Revenue from contracts with customers Rm	Interest revenue Rm	Total revenue Rm
South Africa	32 018	9 792	4 359	2 417	1 573	50 159	481	50 640
Nigeria	65 721	237	6 518	4 087	697	77 260	–	77 260
SEA	12 732	240	872	5 019	479	19 342	–	19 342
Uganda	6 518	90	400	2 932	186	10 126	–	10 126
Zambia	2 096	104	184	869	63	3 316	–	3 316
Other SEA	4 118	46	288	1 218	230	5 900	–	5 900
WECA	35 510	204	2 294	8 920	1 351	48 279	–	48 279
Ghana	12 920	62	590	4 170	289	18 031	–	18 031
Côte d'Ivoire	6 446	46	663	1 116	647	8 918	–	8 918
Cameroon	5 829	28	354	1 422	94	7 727	–	7 727
Other WECA	10 315	68	687	2 212	321	13 603	–	13 603
MENA	5 005	27	1 007	146	27	6 212	–	6 212
Sudan	3 276	19	642	78	17	4 032	–	4 032
Afghanistan	1 729	8	365	68	10	2 180	–	2 180
Major joint venture – Irancell[1]	7 093	183	362	702	206	8 546	18	8 564
Head office companies[2]	1 856	–	6 180	–	15 100	23 136	255	23 391
Eliminations	(957)	(3)	(5 571)	(22)	(13 810)	(20 363)	(242)	(20 605)
Hyperinflation impact	1 988	13	419	49	15	2 484	–	2 484
Irancell revenue exclusion	(7 093)	(183)	(362)	(702)	(206)	(8 546)	(18)	(8 564)
Consolidated revenue	153 873	10 510	16 078	20 616	5 432	206 509	494	207 003

[1] Irancell proportionate results are included in the segment analysis as reviewed by the CODM. This is, however, excluded from IFRS reported results due to equity accounting for joint ventures.

[2] Head office companies consist mainly of revenue from GlobalConnect Solutions Limited (GlobalConnect), the Group's central financing activities and management fees from segments.

Notes: Year ended 31 March 2022

Figure E.9: Orange's Financial Statements - Fiscal Year 2021-2022

Consolidated income statement

(in millions of euros, except for per share data)	Note	2022	2021	2020
Revenue	4.1	**43,471**	**42,522**	**42,270**
External purchases	5.1	(18,732)	(17,973)	(17,691)
Other operating income	4.2	747	783	604
Other operating expenses	5.2	(413)	(700)	(789)
Labor expenses	6.1	(8,920)	(9,917)	(8,490)
Operating taxes and levies	10.1.1	(1,882)	(1,926)	(1,924)
Gains (losses) on disposal of fixed assets, investments and activities	3.1	233	2,507	228
Restructuring costs	5.3	(125)	(331)	(25)
Depreciation and amortization of fixed assets	8.2	(7,035)	(7,074)	(7,134)
Depreciation and amortization of financed assets	8.5	(107)	(84)	(55)
Depreciation and amortization of right-of-use assets	9.1	(1,507)	(1,481)	(1,384)
Impairment of goodwill	7.1	(817)	(3,702)	-
Impairment of fixed assets	8.3	(56)	(17)	(30)
Impairment of right-of-use assets	9.1	(54)	(91)	(57)
Share of profits (losses) of associates and joint ventures	11	(2)	3	(2)
Operating income		**4,801**	**2,521**	**5,521**
Cost of gross financial debt excluding financed assets		(775)	(829)	(1,099)
Interests on debts related to financed assets		(3)	(1)	(1)
Gains (losses) on assets contributing to net financial debt		48	(3)	(1)
Foreign exchange gain (loss)		(97)	65	(103)
Interests on lease liabilities		(145)	(120)	(120)
Other net financial expenses		52	106	11
Finance costs, net	13.2	**(920)**	**(782)**	**(1,314)**
Income taxes	10.2.1	(1,265)	(962)	848
Consolidated net income		**2,617**	**778**	**5,055**
Net income attributable to owners of the parent company		2,146	233	4,822
Non-controlling interests	15.6	471	545	233
Earnings per share (in euros) attributable to parent company	15.7			
Net income				
- basic		0.73	0.00	1.72
- diluted		0.73	0.00	1.71

Notes: Year ended 31 March 2022

Figure E.10: Orange's Revenue Breakdown - Fiscal Year 2021-2022

1.2 Segment revenue

(in millions of euros)	France(1)	Europe: Spain(1)	Europe: Other European countries(3)	Europe: Eliminations Europe	Europe: Total	Africa & Middle-East	Enterprise(5)	Totem(1)(2)	International Carriers & Shared Services(1)(6)	Eliminations	Total telecom activities	Mobile Financial Services	Eliminations telecom activities / mobile financial services	Orange consolidated financial statements
December 31, 2022														
Revenue(4)	**17,983**	**4,647**	**6,329**	**(14)**	**10,962**	**6,918**	**7,930**	**685**	**1,540**	**(2,538)**	**43,480**	**-**	**(9)**	**43,471**
Convergence services	4,857	1,870	959	-	2,830	-	-	-	-	-	7,687	-	-	7,687
Mobile-only services	2,332	790	2,079	-	2,869	5,272	659	-	-	(38)	11,093	-	(0)	11,093
Fixed-only services	3,787(7)	436	783	-	1,219	800	3,466(8)	-	-	(150)	9,121	-	(1)	9,120
IT & integration services	-	41	430	-	471	40	3,489	-	-	(184)	3,817	-	(6)	3,811
Wholesale	4,938	878	964	(14)	1,828	663	41	685	1,060	(1,859)	7,356	-	-	7,356
Equipment sales	1,323	632	927	-	1,559	104	275	-	-	(7)	3,255	-	(0)	3,254
Other revenue	746	1	185	-	187	39	-	-	480	(299)	1,152	-	(2)	1,150
External	*17,238*	*4,586*	*6,219*	-	*10,805*	*6,750*	*7,548*	*113*	*1,017*	-	*43,471*	-	-	*43,471*
Inter-operating segments	*745*	*61*	*109*	*(14)*	*157*	*168*	*383*	*572*	*523*	*(2,538)*	*9*	-	*(9)*	-
December 31, 2021														
Revenue(4)	**18,092**	**4,720**	**5,870**	**(11)**	**10,579**	**6,381**	**7,757**	**n/a**	**1,515**	**(1,795)**	**42,530**	**-**	**(7)**	**42,522**
Convergence services	4,697	1,870	850	-	2,720	-	-	n/a	-	-	7,417	-	-	7,417
Mobile-only services	2,276	880	2,007	-	2,887	4,884	636	n/a	-	(31)	10,652	-	(0)	10,652
Fixed-only services	3,872(7)	435	652	-	1,087	664	3,633(8)	n/a	-	(168)	9,089	-	(1)	9,088
IT & integration services	-	14	338	-	352	31	3,195	n/a	-	(167)	3,411	-	(4)	3,407
Wholesale	5,313	900	998	(11)	1,886	654	42	n/a	1,056	(1,249)	7,702	-	-	7,702
Equipment sales	1,226	621	869	-	1,490	112	250	n/a	-	(8)	3,070	-	(0)	3,070
Other revenue	708	1	155	0	157	36	-	n/a	460	(172)	1,188	-	(2)	1,186
External	*17,489*	*4,672*	*5,776*	-	*10,449*	*6,216*	*7,371*	*n/a*	*998*	-	*42,522*	-	-	*42,522*
Inter-operating segments	*603*	*48*	*94*	*(11)*	*131*	*165*	*386*	*n/a*	*517*	*(1,795)*	*7*	-	*(7)*	-
December 31, 2020														
Revenue(4)	**18,461**	**4,951**	**5,638**	**(9)**	**10,580**	**5,834**	**7,807**	**n/a**	**1,450**	**(1,855)**	**42,277**	**-**	**(7)**	**42,270**
Convergence services	4,559	1,984	733	-	2,717	-	-	n/a	-	-	7,276	-	-	7,276
Mobile services only	2,245	1,012	2,026	-	3,038	4,420	649	n/a	-	(35)	10,317	-	(0)	10,317
Fixed services only	3,959(7)	471	611	-	1,083	562	3,851(8)	n/a	-	(177)	9,278	-	(0)	9,277
IT & integration services	-	8	301	-	310	25	3,086	n/a	-	(164)	3,256	-	(4)	3,252
Wholesale	5,866	916	1,017	(9)	1,924	695	45	n/a	1,038	(1,313)	8,255	-	-	8,255
Equipment sales	1,187	547	828	-	1,375	89	175	n/a	-	(5)	2,821	-	(0)	2,821
Other revenue	644	12	122	-	134	43	-	n/a	412	(160)	1,073	-	(2)	1,072
External	*17,794*	*4,908*	*5,559*	-	*10,467*	*5,660*	*7,405*	*n/a*	*944*	-	*42,270*	-	-	*42,270*
Inter-operating segments	*667*	*43*	*79*	*(9)*	*113*	*175*	*402*	*n/a*	*506*	*(1,855)*	*7*	-	*(7)*	-

Notes: Year ended 31 March 2022

Figure E.11: Vodacom's Financial Statements - Fiscal Year 2020-2021

Condensed consolidated income statement

for the year ended 31 March

Rm	Notes	2021 Reviewed	2020 Audited
Revenue	3	**98 302**	90 746
Direct expenses[1]		**(36 269)**	(32 075)
Staff expenses		**(6 990)**	(6 421)
Publicity expenses		**(1 718)**	(1 907)
Net credit losses on financial assets[1]		**(1 078)**	(802)
Other operating expenses		**(12 973)**	(12 024)
Depreciation and amortisation		**(15 117)**	(13 955)
Impairment losses		**(6)**	–
Net profit from associate and joint ventures		**3 501**	4 149
Operating profit		**27 652**	27 711
Net loss on disposal of subsidiaries	4.4	**(70)**	(819)
Finance income		**767**	884
Finance costs		**(4 190)**	(4 702)
Net loss on remeasurement and disposal of financial instruments		**(378)**	(16)
Profit before tax		**23 781**	23 058
Taxation		**(6 710)**	(6 414)
Net profit		**17 071**	16 644
Attributable to:			
Equity shareholders		**16 581**	15 944
Non-controlling interests		**490**	700
		17 071	16 644

1. Net credit losses on financial assets were included in direct expenditure in prior periods. The reclassification had no impact on any reported totals, headline earnings per share or on any amounts presented in the statement of financial position.

Cents	Notes	2021 Reviewed	2020 Audited
Basic earnings per share	4	**978**	939
Diluted earnings per share	4	**956**	923

Notes: Year ended 31 March 2021

Figure E.12: Vodacom's Revenue Breakdown - Fiscal Year 2020-2021

Revenue is further disaggregated into product type below.

Rm	South Africa	International	Corporate and elimination	Total	Safaricom[1]
31 March 2021 – reviewed					
Mobile contract revenue	20 829	1 469	(6)	22 292	3 420
Mobile prepaid revenue	25 359	18 009	(2)	43 366	30 153
Customer service revenue	46 188	19 478	(8)	65 658	33 573
Mobile interconnect	1 742	1 330	(544)	2 528	1 426
Fixed service revenue	3 556	1 233	(390)	4 399	1 429
Other service revenue	4 919	105	(35)	4 989	1 172
Service revenue	56 405	22 146	(977)	77 574	37 600
Equipment revenue	14 672	285	(21)	14 936	1 527
Non-service revenue	5 299	303	(183)	5 419	500
Revenue from contracts with customers	76 376	22 734	(1 181)	97 929	*
Interest income recognised as revenue	296	12	–	308	*
Other[2]	65	–	–	65	*
Revenue	76 737	22 746	(1 181)	98 302	39 627

1. The Group has a 34.94% effective interest in Safaricom Plc (Safaricom) through its subsidiary Vodafone Kenya Limited, which the Group equity accounts for as an investment in an associate at 39.93%. Due to the significance of this investment, and the information available for review by the chief operating decision maker, Safaricom is presented as a separate segment. The above results represent 100% of the results of Safaricom.
2. Other revenue largely represents lease revenues recognised under IFRS 16 "Leases".

* Not reviewed by the chief operating decision maker.

Notes: Year ended 31 March 2021

Figure E.13: Vodacom's Financial Statements - Fiscal Year 2021-2022

Condensed consolidated income statement

for the year ended 31 March

Rm	Note	2022 Reviewed	2021 Audited
Revenue	3	**102 736**	98 302
Direct expenses		**(38 624)**	(36 269)
Staff expenses		**(7 266)**	(6 990)
Publicity expenses		**(1 886)**	(1 718)
Net credit losses on financial assets		**(704)**	(1 078)
Other operating expenses		**(14 419)**	(12 973)
Depreciation and amortisation		**(14 657)**	(15 117)
Impairment losses		**–**	(6)
Net profit from associates and joint ventures		**3 056**	3 501
Operating profit		**28 236**	27 652
Net loss on disposal of subsidiaries		**–**	(70)
Finance income		**554**	767
Finance costs		**(4 229)**	(4 190)
Net gain/(loss) on remeasurement and disposal of financial instruments		**2**	(378)
Profit before tax		**24 563**	23 781
Taxation		**(6 829)**	(6 710)
Net profit		**17 734**	17 071
Attributable to:			
Equity shareholders		**17 163**	16 581
Non-controlling interests		**571**	490
		17 734	17 071

Cents	Note	2022 Reviewed	2021 Audited
Basic earnings per share	4	**1 013**	978
Diluted earnings per share	4	**984**	956

Notes: Year ended 31 March 2022

Figure E.14: Vodacom's Revenue Breakdown - Fiscal Year 2021-2022

Revenue is further disaggregated into product type below.

Rm	South Africa	International	Corporate and elimination	Total	Safaricom[1]
31 March 2022 – reviewed					
Mobile contract revenue	21 985	1 615	(8)	23 592	4 673
Mobile prepaid revenue	25 171	18 294	–	43 465	28 899
Customer service revenue	47 156	19 909	(8)	67 057	33 572
Mobile interconnect	1 703	1 175	(440)	2 438	1 321
Fixed service revenue	3 847	1 011	(325)	4 533	1 508
Other service revenue	5 820	118	(30)	5 908	1 314
Service revenue[2]	58 526	22 213	(803)	79 936	37 715
Equipment revenue	15 838	373	(7)	16 204	1 925
Non-service revenue	5 990	291	(170)	6 111	346
Revenue from contracts with customers	80 354	22 877	(980)	102 251	*
Interest income recognised as revenue	410	11	–	421	*
Other[3]	64	–	–	64	*
Revenue	80 828	22 888	(980)	102 736	39 985

1. The Group has a 34.94% effective interest in Safaricom Plc (Safaricom) through its subsidiary Vodafone Kenya Limited, which the Group equity accounts for as an investment in an associate at 39.93%. Due to the significance of this investment, and the information available for review by the chief operating decision maker, Safaricom is presented as a separate segment. The above results represent 100% of the results of Safaricom.
2. Includes financial services revenue of R2 665 million for South Africa; R4 961 million for International and R14 452 million for Safaricom.
3. Other revenue largely represents lease revenues recognised under IFRS 16 "Leases".

* Not reviewed by the chief operating decision maker.

Notes: Year ended 31 March 2022

Figure E.15: Safaricom's Financial Statements - Fiscal Year 2020-2021

FINANCIAL STATEMENTS FOR THE YEAR ENDED 31 MARCH 2021

STATEMENT OF PROFIT OR LOSS
AND OTHER COMPREHENSIVE INCOME

		GROUP		COMPANY	
	Notes	2021 KShs'm	2020 KShs'm	2021 KShs'm	2020 KShs'm
Revenue from contracts with customers	5(a)	261,462.3	260,463.8	259,296.3	259,078.7
Revenue from other sources	5(b)	2,564.2	2,091.9	3,153.4	2,326.8
Total revenue		264,026.5	262,555.7	262,449.7	261,405.5
Direct costs	6(a)	(80,852.8)	(75,284.9)	(80,334.1)	(75,468.7)
Expected credit losses on financial assets	6(b)	(3,009.7)	(1,669.6)	(3,863.7)	(1,418.7)
Other expenses	7	(46,034.8)	(47,559.7)	(45,168.6)	(47,023.1)
Earnings before interest, taxes, depreciation and amortisation (EBITDA)		134,129.2	138,041.5	133,083.3	137,495.0
Depreciation of property and equipment	18	(32,624.5)	(31,964.8)	(32,570.4)	(31,925.3)
amortisation – Indefeasible Rights of Use (IRUs)	19	(406.5)	(301.0)	(406.5)	(301.0)
amortisation – intangible assets	21	(1,628.5)	(1,359.1)	(1,628.1)	(1,358.0)
amortisation – Right of Use (ROU) assets	22(a)	(3,304.8)	(2,922.8)	(3,304.8)	(2,922.8)
Operating profit		96,164.9	101,493.8	95,173.5	100,987.9
Finance income	8	2,198.4	3,518.8	2,177.0	3,494.5
Finance cost	9	(4,220.8)	(2,596.6)	(4,405.5)	(2,585.5)
Share of (loss)/profit of associates	23(b)	(192.9)	60.9	(192.9)	60.9
Share of (loss)/profit of joint venture	23(b)	(314.1)	3,296.1	(314.1)	3,296.1
Profit before income tax		93,635.5	105,773.0	92,438.0	105,253.9
Income tax expense	12(a)	(24,959.3)	(32,115.1)	(24,481.4)	(31,969.7)
Profit for the year attributable to the owners of the Company		68,676.2	73,657.9	67,956.6	73,284.2
Other comprehensive income		–	–	–	–
Total comprehensive income for the year attributable to the owners of the Company		68,676.2	73,657.9	67,956.6	73,284.2
Basic and diluted earnings per share (KShs per share)	13	1.71	1.84	1.70	1.83

Notes: Year ended 31 March 2021

Figure E.16: Safaricom Company's Revenue Breakdown - Fiscal Year 2020-2021

5 Revenue continued

(a) Revenue from contracts with customers continued

Company	31 MARCH 2021 KShs'm At a point in time	KShs'm Over time	KShs'm Total	31 MARCH 2020 KShs'm At a point in time	KShs'm Over time	KShs'm Total
Voice revenue	–	82,552.0	82,552.0	–	86,529.9	86,529.9
Interconnect revenue from local partners	–	6,175.2	6,175.2	–	5,039.3	5,039.3
Messaging revenue	–	13,602.4	13,602.4	–	15,403.5	15,403.5
Mobile data revenue	–	44,793.2	44,793.2	–	40,157.5	40,157.5
Fixed data revenue	–	9,507.2	9,507.2	–	8,966.8	8,966.8
M-PESA revenue	80,635.8	–	80,635.8	83,135.6	–	83,135.6
Other Services Revenues*	–	7,624.8	7,624.8	–	7,153.9	7,153.9
Mobile Incoming	–	3,295.2	3,295.2	–	3,442.5	3,442.5
Service revenue	80,635.8	167,550.0	248,185.8	83,135.6	166,693.4	249,829.0
Handset revenue	8,511.7	–	8,511.7	6,631.0	–	6,631.0
Connection revenue	–	1,761.1	1,761.1	–	2,034.8	2,034.8
Construction revenue	–	837.7	837.7	–	583.9	583.9
Total revenue	89,147.5	170,148.8	259,296.3	89,766.6	169,312.1	259,078.7

Service revenue streams have been reclassified to align to new Group reporting needs. Appendix 2 shows the comparative based on old revenues classification.

* Other Services Revenues includes Okoa Jahazi fees, roaming revenues, bulk SMS, digital agriculture revenues.

Notes: Year ended 31 March 2021

Figure E.17: Safaricom Group's Revenue Breakdown - Fiscal Year 2021-2022

5 Revenue

(a) Revenue from contracts with customers

The Group has one reportable operating segment whose revenue is presented below.

Group	31 MARCH 2021 KShs'm At a point in time	KShs'm Over time	KShs'm Total	31 MARCH 2020 KShs'm At a point in time	KShs'm Over time	KShs'm Total
Voice revenue	–	82,552.0	82,552.0	–	86,529.9	86,529.9
Interconnect revenue from local partners	–	6,175.2	6,175.2	–	5,039.3	5,039.3
Messaging revenue	–	13,602.4	13,602.4	–	15,403.5	15,403.5
Mobile data revenue	–	44,793.2	44,793.2	–	40,157.5	40,157.5
Fixed data revenue	–	9,507.2	9,507.2	–	8,966.9	8,966.9
M-PESA revenue	82,647.4	–	82,647.4	84,438.0	–	84,438.0
Other services revenues*	–	7,779.2	7,779.2	–	7,236.5	7,236.5
Mobile Incoming	–	3,295.2	3,295.2	–	3,442.5	3,442.5
Service revenue	82,647.4	167,704.4	250,351.8	84,438.0	166,776.1	251,214.1
Handset revenue	8,511.7	–	8,511.7	6,631.0	–	6,631.0
Connection revenue	–	1,761.1	1,761.1	–	2,034.8	2,034.8
Construction revenue	–	837.7	837.7	–	583.9	583.9
Total revenue	91,159.1	170,303.2	261,462.3	91,069.0	169,394.8	260,463.8

Service revenue streams have been reclassified to align to new Group reporting needs. Appendix 2 shows the comparative based on old revenues classification.

* Other Services Revenues includes Okoa Jahazi fees, roaming revenues, bulk SMS, digital agriculture revenues.

Notes: Year ended 31 March 2021

Figure E.18: Safaricom's Financial Statements - Fiscal Year 2021-2022

FINANCIAL STATEMENTS FOR THE YEAR ENDED 31 MARCH 2022

Statements of Profit or Loss and other Comprehensive Income

		GROUP		COMPANY	
	Notes	**2022 KShs'm**	2021 KShs'm	**2022 KShs'm**	2021 KShs'm
Revenue from contracts with customers	5(a)	**295,441.4**	261,462.3	**292,556.2**	259,296.3
Revenue from other sources	5(b)	**2,636.5**	2,564.2	**3,289.7**	3,153.4
Total revenue		**298,077.9**	**264,026.5**	**295,845.9**	**262,449.7**
Direct costs	6(a)	**(91,467.8)**	(80,852.8)	**(90,613.6)**	(80,334.1)
Expected credit losses on financial assets	6(b)	**(2,361.2)**	(3,009.7)	**(2,602.7)**	(3,863.7)
Other expenses	7	**(55,187.0)**	(46,034.8)	**(49,545.5)**	(45,168.6)
Earnings before interest, taxes, depreciation and amortisation (EBITDA)		**149,061.9**	**134,129.2**	**153,084.1**	**133,083.3**
Depreciation of property and equipment	18	**(34,145.2)**	(32,624.5)	**(33,922.2)**	(32,570.4)
Amortisation – Indefeasible rights of use (IRUs)	19	**(281.3)**	(406.5)	**(281.3)**	(406.5)
Amortisation – Intangible assets	21	**(1,850.0)**	(1,628.5)	**(1,850.0)**	(1,628.1)
Amortisation – Right-of-use (RoU) assets	22(a)	**(3,656.8)**	(3,304.8)	**(3,644.2)**	(3,304.8)
Operating profit		**109,128.6**	**96,164.9**	**113,386.4**	**95,173.5**
Finance income	8	**2,413.4**	2,198.4	**2,050.1**	2,177.0
Finance costs	9	**(8,852.6)**	(4,220.8)	**(8,895.2)**	(4,405.5)
Share of loss of associates	23(b)	**(279.8)**	(192.9)	**(279.8)**	(192.9)
Share of loss of joint venture	23(b)	**(196.2)**	(314.1)	**(196.2)**	(314.1)
Profit before income tax		**102,213.4**	**93,635.5**	**106,065.3**	**92,438.0**
Income tax expense	12(a)	**(34,717.3)**	(24,959.3)	**(34,276.0)**	(24,481.4)
Profit for the year		**67,496.1**	**68,676.2**	**71,789.3**	**67,956.6**
Attributable to:					
Equity holders of the parent		**69,648.1**	68,676.2	**71,789.3**	67,956.6
Non-controlling interests		**(2,152.0)**	–	**–**	–
Other comprehensive loss:					
Items that will subsequently be reclassified to profit or loss					
Exchange differences on translation of foreign operations		**(9,536.3)**	–	**–**	–
Total comprehensive income for year		**57,959.8**	**68,676.2**	**71,789.3**	**67,956.6**
Attributable to:					
Equity holders of the parent		**64,335.4**	68,676.2	**71,789.3**	67,956.6
Non-controlling interests		**(6,375.6)**	–	**–**	–
Total comprehensive income for year		**57,959.8**	**68,676.2**	**71,789.3**	**67,956.6**
Basic earnings per share (KShs per share)	13	**1.74**	**1.71**	**1.79**	**1.70**
Diluted earnings per share (KShs per share)	13	**1.74**	**1.71**	**1.79**	**1.70**

Notes: Year ended 31 March 2022

Figure E.19: Safaricom Company's Revenue Breakdown - Fiscal Year 2021-2022

5 Revenue continued

(a) Revenue from contracts with customers continued

The Group has one reportable operating segment whose revenue is presented below:

	31 MARCH 2022			31 MARCH 2021		
Company	KShs'm At a point in time	KShs'm Over time	KShs'm Total	KShs'm At a point in time	KShs'm Over time	KShs'm Total
Voice revenue	–	83,211.8	83,211.8	–	82,552.0	82,552.0
Interconnect revenue from local partners	–	6,840.6	6,840.6	–	6,175.2	6,175.2
Messaging revenue	–	10,876.7	10,876.7	–	13,602.4	13,602.4
Mobile data revenue	–	48,441.0	48,441.0	–	44,793.2	44,793.2
Fixed data revenue	–	11,242.5	11,242.5	–	9,507.2	9,507.2
M-PESA revenue	105,218.1	–	105,218.1	80,635.8	–	80,635.8
Other services revenues*	–	9,383.8	9,383.8	–	7,624.8	7,624.8
Mobile incoming	–	3,007.6	3,007.6	–	3,295.2	3,295.2
Service revenue	105,218.1	173,004.0	278,222.1	80,635.8	167,550.0	248,185.8
Handset revenue	12,334.7	–	12,334.7	8,511.7	–	8,511.7
Connection revenue	–	1,999.4	1,999.4	–	1,761.1	1,761.1
Construction revenue	–	–	–	–	837.7	837.7
Total revenue	117,552.8	175,003.4	292,556.2	89,147.5	170,148.8	259,296.3

* *Other services revenues include Okoa Jahazi fees, roaming revenues, bulk SMS, and digital agriculture revenues.*

Notes: Year ended 31 March 2022

Figure E.20: Safaricom Group's Revenue Breakdown - Fiscal Year 2021-2022

5 Revenue

(a) Revenue from contracts with customers

The Group has one reportable operating segment whose revenue is presented below:

	31 MARCH 2022			31 MARCH 2021		
Group	KShs'm At a point in time	KShs'm Over time	KShs'm Total	KShs'm At a point in time	KShs'm Over time	KShs'm Total
Voice revenue	–	83,211.8	83,211.8	–	82,552.0	82,552.0
Interconnect revenue from local partners	–	6,840.6	6,840.6	–	6,175.2	6,175.2
Messaging revenue	–	10,876.7	10,876.7	–	13,602.4	13,602.4
Mobile data revenue	–	48,441.0	48,441.0	–	44,793.2	44,793.2
Fixed data revenue	–	11,242.5	11,242.5	–	9,507.2	9,507.2
M-PESA revenue	107,691.8	–	107,691.8	82,647.4	–	82,647.4
Other services revenues*	–	9,795.3	9,795.3	–	7,779.2	7,779.2
Mobile incoming	–	3,007.6	3,007.6	–	3,295.2	3,295.2
Service revenue	107,691.8	173,415.5	281,107.3	82,647.4	167,704.4	250,351.8
Handset revenue	12,334.7	–	12,334.7	8,511.7	–	8,511.7
Connection revenue	–	1,999.4	1,999.4	–	1,761.1	1,761.1
Construction revenue	–	–	–	–	837.7	837.7
Total revenue	120,026.5	175,414.9	295,441.4	91,159.1	170,303.2	261,462.3

Notes: Year ended 31 March 2022