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TELECOMMUNICATIONS SERVICES IN DEVELOPING COUNTRIES: TAX, TRADE, AND MOBILE MONEY

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par

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Summary

Telecommunications is one of the most dynamic sectors in many developing countries. Telecommunication services improve both the productivity of economies and the well-being of individuals. There are significant advantages in promoting digital inclusion through broader mobile phone network coverage and affordable access and usage costs as well. However, since 2004, many countries have increased telecommunications' tax burden through special taxes on mobile network operators (MNOs) or consumers. For MNOs, such policies may hurt innovation and investment in the sector and widen the digital divide between industrialized and developing countries.
The purpose of this thesis is to explore several issues raised by the development of telecommunication services in developing countries by addressing the following questions: What is the tax burden on telecommunications companies? How does the demand for telecommunication services vary with prices? How could innovations in the telecommunications sector help governments promote the diffusion of positive externalities?

Chapter 1 measures the tax burden on MNOs through the Average Effective Tax Rate (AETR) in twenty-five African countries. This tax burden encompasses general and special taxes under the Ministry of Finance's (MoF) control and fees raised by the national telecommunication Regulatory Agency (RA). For instance, the AETR varies significantly across countries, ranging from 33 percent in Ethiopia to 118 percent in Niger. Also, special taxes and fees represent a large share of the AETR, illustrating some taxation by regulation and a potential tax competition (a race to the top) between the MoF and the RA.

Chapter 2 estimates the demand price elasticity of mobile voice communication in developed and developing countries using quarterly operator data from 2000 to 2017. It finds that for developed countries, the demand is more price elastic, and voice communication is a substitute for internet data usage. Another important finding of that chapter is that, for operators in developing countries, the price

elasticity decreases with the market development level as opposed to those in developed countries. Demand for mobile voice communication is thus more sensitive to price changes in the less penetrated markets in developing countries and the mature markets in developed countries. Furthermore, price elasticity has decreased over time across operators in developing countries. The results also highlight that estimated price elasticities are high, suggesting that operators do not have an obvious interest in engaging in collusive behavior that would hinder competition.

Chapter 3 studies the causal effect of mobile money (MM) services adoption on intra-African goods trade considering data from 48 African countries from 1994 to 2018. It finds that countries that adopted MM services register a higher goods trade as a share of GDP compared to non-adopters, with a higher effect on food items trade.

Chapter 4 assesses the causal effect of person-to-government (P2G) mobile payment services adoption on direct tax revenue considering data from 96 developing countries from 1994 to 2018. According to the matching estimates, countries that adopt P2G services experience a 1.2–1.3 percentage point boost in direct tax revenue as a share of GDP. P2G adoption increases revenue from corporate and personal income taxes, with a more important effect on the latter. Moreover, the average treatment on the treated is higher among lower-middle-income countries and countries characterized by limited tax compliance and corruption control and low levels of urbanization and domestic credit to the private sector.

Keywords: Taxation; Tax revenue; Telecommunications sector; Project analysis; Econometric demand model; Comparative analysis; Mobile money; P2G; Goods trade; Impact analysis; Africa; Developing countries.

JEL classifications: C23; F10; H25; L96; O1; O22; O23; O33; O55; O57.

Résumé

Les télécommunications représentent de nos jours l'un des secteurs les plus dynamiques dans de nombreux pays en développement. Les services de télécommunication améliorent à la fois la productivité des économies et le bien-être des individus. Il y aurait donc des avantages à promouvoir l'inclusion numérique en élargissant la couverture des réseaux de téléphonie mobile et en proposant des coûts d'accès et d'utilisation abordables. Cependant, depuis 2004, de nombreux pays ont augmenté la charge fiscale du secteur des télécommunications par le biais de taxes spéciales sur les opérateurs de réseaux mobiles (ORM) ou les consommateurs. Pour les ORM, de telles politiques peuvent nuire à l'innovation et à l'investissement dans le secteur et élargir la fracture numérique entre les pays industrialisés et les pays en développement.
L'objectif de cette thèse est d'explorer plusieurs problématiques soulevées par le développement des services de télécommunication dans les pays en développement en répondant aux questions suivantes : Quelle est la charge fiscale pesant sur les entreprises de télécommunications ? Comment la demande de services de télécommunication varie-t-elle en fonction des prix ? Comment les innovations dans le secteur des télécommunications pourraient-elles aider les gouvernements à promouvoir la diffusion d'externalités positives ?

Le chapitre 1 mesure la pression fiscale sur les ORM à travers le taux effectif moyen d'imposition (TEMI) dans vingt-cinq pays africains. Cette charge fiscale englobe les taxes de droit commun et celles spéciales sous le contrôle du ministère des Finances (MoF) et les redevances perçues par l'agence nationale de régulation des télécommunications (RA). Par exemple, le TEMI varie considérablement d'un pays à l'autre, allant de 33 % en Éthiopie à 118 % au Niger. En outre, les taxes et redevances spéciales représentent une part importante du TEMI, ce qui illustre une certaine taxation par la réglementation et une concurrence fiscale potentielle (une course vers le haut) entre le ministère des Finances et l'AR.

Le chapitre 2 estime l'élasticité prix de la demande de communication vocale mobile dans les pays développés et en développement en utilisant les données trimestrielles des opérateurs de 2000 à 2017. Il montre que, dans les pays développés, la demande est plus élastique par rapport au prix et que la communication vocale est un substitut à l'utilisation des données Internet. Une autre conclusion importante de ce chapitre est que, pour les opérateurs des pays en développement, l'élasticité-prix diminue avec le niveau de développement du marché, contrairement à ceux des pays développés. La demande de communications vocales mobiles est donc plus sensible aux variations de prix sur les marchés moins pénétrés des pays en développement et sur les marchés matures des pays développés. En outre, l'élasticité des prix a diminué au fil du temps chez les opérateurs des pays en développement. Les résultats soulignent également que les élasticités-prix estimées sont élevées, ce qui suggère que les opérateurs n'ont pas un intérêt évident à adopter un comportement collusif qui entraverait la concurrence.

Le chapitre 3 étudie l'effet causal de l'adoption des services de Mobile Money (MM) sur le commerce intra-africain de marchandises en considérant les données de 48 pays africains de 1994 à 2018. Il révèle que les pays qui ont adopté les services MM enregistrent un commerce de biens (exprimé en fonction du PIB) plus élevé par rapport aux non-adoptants, avec un effet plus important sur le commerce des produits alimentaires.

Le chapitre 4 évalue l'effet causal de l'adoption des services de paiement mobile de personnes à gouvernement (P2G) sur les recettes fiscales directes en considérant les données de 96 pays en développement de 1994 à 2018. Selon les estimations, les pays qui adoptent les services P2G connaissent une augmentation de 1,2 à 1,3 point de pourcentage des recettes fiscales directes en pourcentage du PIB. L'adoption du P2G augmente les recettes de l'impôt sur les sociétés et de l'impôt sur le revenu des particuliers, avec un effet plus important sur ce dernier. En outre, le traitement moyen sur les traités est plus élevé parmi les pays à revenu moyen inférieur et les pays caractérisés par une conformité fiscale et un contrôle de la corruption

limités, ainsi que par de faibles niveaux d'urbanisation et de crédit domestique au secteur privé.

Mots-clés : Fiscalité ; Recettes fiscales ; Secteur des télécommunications ; Analyse de projet ; Modèle économétrique de la demande ; Analyse comparative ; Argent mobile ; P2G ; Commerce de marchandises ; Analyse d'impact ; Afrique ; Pays en développement.

Classifications JEL : C23 ; F10 ; H25 ; L96 ; O1 ; O22 ; O23 ; O33 ; O55 ; O57.

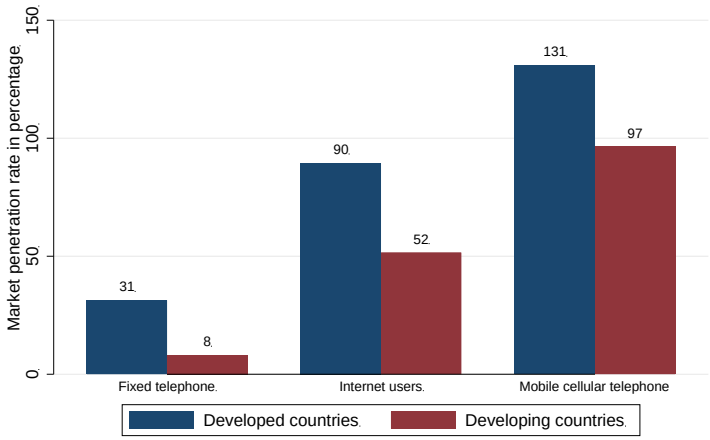
General Introduction

1. Context and stylized facts

1.1. Overview of the telecommunications sector in developing and developed countries

Since the 2000s, the telecommunications sector has experienced unprecedented development with the diffusion of telecommunications tools such as fixed and cell phones. However, disparities exist in the level of adoption according to the level of development of countries. Indeed, these tools have spread from developed to developing countries. That explains the significant differences in their penetration rates (Figure 1). In 2020, for example, while the percentage of fixed-line subscriptions was 31% in developed countries, it was 8% in developing countries. These low percentages are explained by the fact that cell phones have replaced fixed phones over the years.

Figure 1: Comparative graph of average services by development level in 2020 (mobile-internet-fixed)



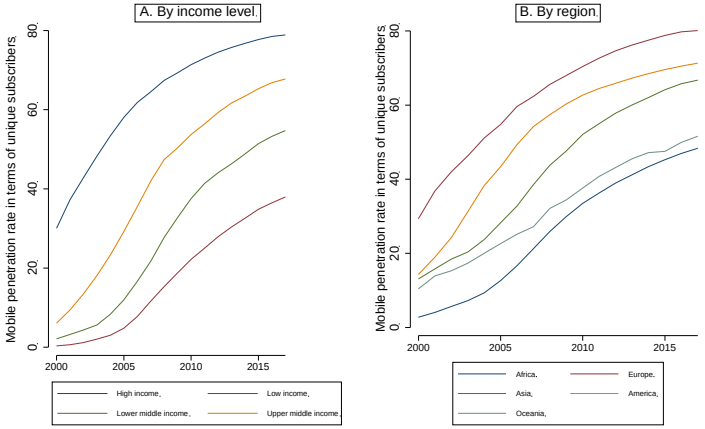
Source: Authors construction using data from International Telecommunication Union (ITU).

In 2020, the mobile phone market penetration rate was 131% and 97% in developed and developing countries, respectively. Another innovation in the sector is the Internet, which has contributed to

improving people's living and working conditions worldwide. The Internet users' population was 90% in developed countries and 52% in developing countries. Of all these innovations, the cell phone is the most widespread. That explains the choice of the thesis to focus on this tool.

Rogers (1976) establishes that the diffusion process of innovation, such as the mobile phone, follows an S-shaped curve in developed countries. He bases himself on the model of Bass (1969), who asserts that the diffusion of innovation in a population is mainly done through two influences. The first one, i.e., the external influence, includes factors such as advertising and encourages first customers to adopt the product. The second, which is the internal influence intervenes through imitation and results from the phenomenon of contagion between adopters and non-adopters until the saturation of the market. James (2016) shows that Rogers' innovation diffusion theory is also valid in developing countries for the mobile phone. Its adoption diffusion curves in figure 2 confirm this theory. Moreover, it is important to note that the diffusion of mobile phones is a factor that increases with the development level of countries (Figure 2, panel A). Furthermore, Africa (48%) and Oceania (51%) remain the regions with the lowest proportions of individuals with a cell phone. This shows the significant potential that exists in these.

Figure 2: *Graph of cell phone penetration by income level and region in 2017.*



Source: Authors construction using data from GSMA Intelligence. .

1.2. The telecommunication sector and economic growth

The relationship between telecommunications infrastructure and economic growth has been extensively discussed in the economic literature.[1] At the macro level, most studies conclude that telecommunications infrastructure has a positive and significant impact on economic growth (Röller and Waverman, 2001; Waverman et al., 2005; Sridhar and Sridhar, 2004; Datta and Agarwal, 2004; Lewin and Sweet, 2005; and Lee et al., 2012). Results from Röller and Waverman (2001), Waverman et al. (2005), and Andrianaivo and Kpodar (2012) show that this effect is larger for mobile phones in low-income countries. The effect of information and communication technologies on growth can be

[1] One of the biggest challenges in assessing this effect is endogeneity due to the inverse causality between telecom infrastructure development and economic growth. Some authors have tried to address this problem by adopting approaches that reduce bias in the estimates (Röller and Waverman, 2001; Waverman et al., 2005; Sridhar and Sridhar, 2004; Datta and Agarwal, 2004; Lewin and Sweet, 2005; Lee et al., 2012; and Andrianaivo and Kpodar, 2012).

direct[2] through demand (Datta and Agarwal, 2004) and supply (Datta and Agarwal, 2004, and Lewin and Sweet, 2005). It can also be indirect through all the social benefits of developing the telecommunications sector (Datta and Agarwal, 2004).[3] Tcheng et al. (2007) explain that the particularity of mobile phone subscriptions in Africa is the high demand for prepaid services. That leads to the development of retail services for phone cards, creating jobs for some individuals and facilitating access to telecommunication services, even though these businesses are often informal. Nonetheless, it remains important to note that the effect of telecommunications infrastructure on economic growth increases with the level of development of the telecommunications market (Grace et al., 2003; Roller and Waverman, 2001; Andrianavo and Kpodar, 2012; and Lee et al., 2012). That explains why in the early 2000s, only developed countries benefited more from ICT development.

At the micro level, Donner (2008), Aker and Mbiti (2010), and Duncombe (2016) review the benefits of mobile phone diffusion in developing countries. These benefits include access to and use of information, efficiency in business productivity, reduced household exposure to shocks, job creation, and the provision of services (e.g., financial, educational, health). From all these analyses, it appears that the diffusion of communication tools, particularly mobile phones, would promote economic growth through the diffusion of positive externalities (Economides, 1996, Arezki et al., 2021).

[2] The direct effect comes from the creation of jobs, the increase in GDP, the mobilization of more tax revenues for governments, and the positive effect on investments, affecting the balance of payments.

[3] Datta and Agarwal (2004) explain that ICT development can lead to the development of rural economies, the reduction of financial exclusion, the development of business productivity, and other factors related to market development.

1.3. The demand for telecommunication services

Price is an important factor in the demand for goods and services, including telecommunications. The increase in access to and use of telecommunications services could be explained by the downward price trend observed over the years. This downward trend can be explained by many factors, such as market competition, regulatory authorities providing a framework for setting prices, reducing operators' costs, and technological progress (innovation).[4] An immediate question arising from this observation is how demand for telecommunications services responds to price changes. The answer depends on the estimation of the demand price elasticity, which is essential in terms of policy implications.

Many authors discussed price elasticity in the economic literature about telecommunication services demand. Roller and Waverman (2001), using data on 21 OECD countries from 1979 to 1990, analyze the effect of telecommunication infrastructures on economic development. They use a simultaneous model integrating an equation for the demand for telecommunications investments. They found a demand price elasticity of -1.13. Hausman and Ros (2013) estimated the demand price elasticity to be approximately -0.5 considering a sample of 17 countries. Garbacz and Thompson (2007) used data on 53 developing countries from 1996 to 2003, disaggregating prices into two components, and found a connection charges elasticity of -1.2 and a monthly charge elasticity of -0.03. Koutroumpis et al. (2011), with quarterly data going from 2005 to 2010 on three operators, found a price elasticity (income elasticity) of -1.645 (1.213). Waverman et al. (2005) evaluate the price elasticity of telecommunication services in 92 countries from 1980 to2003. They used the average revenue per user (ARPU) as a proxy for

[4] However, Jeanjean (2015), studying 20 countries over the period 2006-2012, argues that continued investment in successive generations of technology (1G, 2G, 3G, and 4G) explains this price decline as operators' traffic increases much more than their revenues (turnover).

prices and found a price elasticity of -1.5. Madden et al. (2004), using data on 56 countries from 1995 to 2000, estimated a dynamic demand model and found the price elasticity to be -0.55 for the global sample and -0.53 for high-income countries. Hakim and Neaime (2014) found that the price elasticity of telecommunication services is between -1,241 and -1,008 in the middle east and north African countries.

Kathuria et al. (2009) used data on 19 Indian states from 1999 to 2008 and found a price elasticity of -2.12. Using the median market penetration value as a reference, they conclude that low penetrated States have a price elasticity of -1.92, whereas it is -1.87 for high penetrated States. They also estimate the income elasticity to 2.45 (respectively 2.34, 2.83) for the global sample (respectively low penetrated states, high penetrated states). Karacuka et al. (2011) used monthly data on five Turkish telecommunication operators to estimate a dynamic demand for telecommunication services. They found a short-run price elasticity of -0.28 and a long-run price elasticity of -0.45 for the entire market. In addition, they estimate the income elasticity to 0.16. Their study also considers the difference in price elasticity between prepaid and postpaid markets. Dewenter and Haucap (2008) also used a dynamic panel model to estimate price elasticities for the Austrian telecommunication market depending on the type of usage (business or private), the type of subscription (prepaid or postpaid), and operators. They found a short-run (long-run) elasticity ranging between -0.08 and -0.40 (-0.20 and -1.10). Caves (2011) used a discrete choice model for 38 US States from 2001 to 2007 to analyze the demand for wireless. They found a price elasticity between -1.77 and -1.63 (depending on whether Marshallian or Hicksian demand function is used and whether restricted or unrestricted it is). For Korea, Lee and Lee (2006) estimated the price elasticity of telecommunication services (differentiating between access and usage prices) during the pre and post-competition period. They found that access price is likely invalid in determining usage demand. Therefore, they estimate the

price elasticity to -0.9 in the pre-competition period and -0.609 in the post-competition period. Das and Srinivasan (1999), using data on 19 Indian States, estimated the price elasticity of telecommunication services using time series and panel data. For time series, they found a price elasticity of -0.58, and with panel data, the price elasticity is estimated to -0.55 using a random effects specification.

However, most of these studies were based on data at the national level or operator level data at a country level and did not allow comparisons between different markets following the same approach. Furthermore, they used pre-2012 data, whereas the sector had undergone significant development in recent years. That has motivated Chapter 2 of the thesis.

1.4. Evolution of taxation in the telecommunications sector

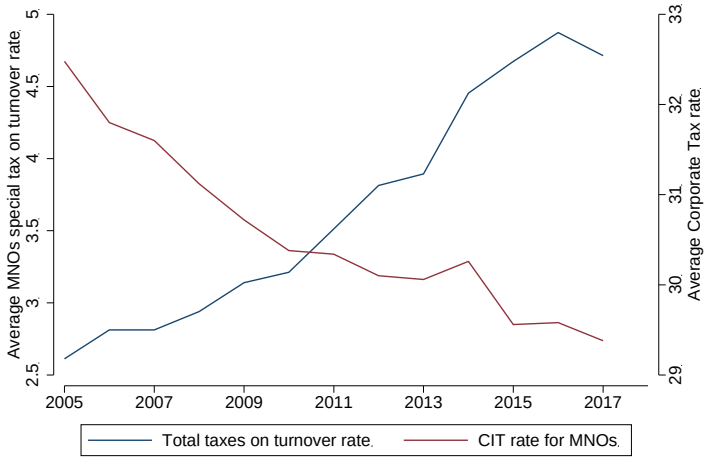
In addition to general taxes, the telecommunications sector is subject to several special taxes on users' consumption and the operators' activities. Special indirect taxes include excise duties and taxes on access and use of services such as those on SIM card subscriptions or voice communication traffic (national or international). Taxes borne by telecommunication operators include the tax on telecommunications companies, contributions to universal service, research and development, the financing of regulation, and other annual ad valorem taxes set as a percentage of MNOs' revenues. Other contributions to which telecommunications companies are subject include spectrum, license, and numbering fees.[5]

Since the early 2000s, special taxes rates in the sector have been on an upward trend. Figure 3 shows that in the considered 25 African countries, while the corporate income tax rate for telecom

[5] For a detailed review of tax systems related to the telecommunications sector, see Chapter 1 and Matheson and Petit (2021).

companies[6] has, on average, trended downward, dropping from an average rate of 32.5% to 29.2%, the special tax rate on MNOs' turnover has increased by over 80% from 2.6% in 2005 to 4.7% in 2018, on average.

Figure 3: *Average evolution of CIT and total turnover taxes in 25 African countries*



Source : Authors' elaboration.

In addition, the GSMA (2015) report on digital inclusion and taxation of the mobile sector shows that in 2013, the share of tax contributions from the[7] sector in total mobile sector revenues varies from 10.6% in Nigeria to 58.3% in Turkey, with an average value of 31.9%. Special taxation accounts for a significant share of total tax revenues from the telecommunications sector (GSMA, 2007, 2011, and 2015). Moreover, according to GSMA's reports,

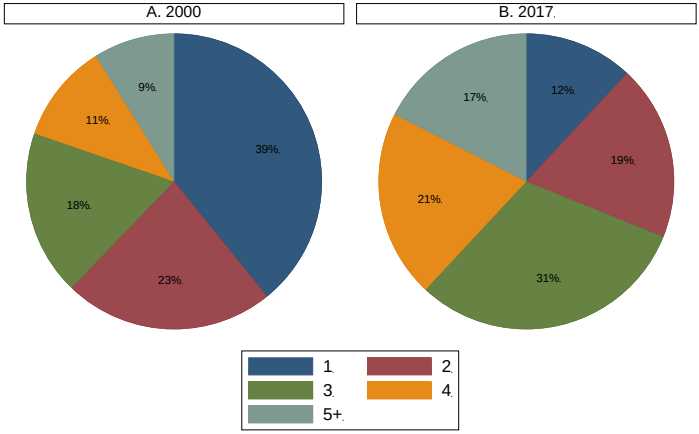
[6] In some countries, there is a differentiated corporate income tax rate for telecommunications companies.
[7] Including taxes on operators and consumers.

the ratio of taxes to the total cost of owning a mobile phone[8] has increased over time, from 17.4% in 2007 to 18.2% in 2011 and 20.1% in 2014.

For Matheson and Petit (2021), that is mainly due to three reasons. First, the dynamism of the sector and the growth of revenues generated by the high demand for telecommunication services is often put forward as the main reason. Second, there is the idea that mobile operators generate economic benefits because of the market structure, which is characterized by a high concentration. Finally, there is the weakness of tax administrations, which leads governments in developing countries to focus on large formal enterprises (such as telecom operators or banks) and indirect consumption taxes. That raises three main points. First, high revenues do not necessarily mean financial returns, given the operational and capital expenditures of the sector. Chapter 1 incorporates this discussion by considering pre-tax cash flows as a profitability measure. Second, the structure of the telecommunications market has changed significantly (figure 4). In 2000, for example, the sector had two or fewer operators in 62% of countries. In 2017, only 31% of countries maintained this market structure. Third, telecommunication services themselves could help improve government capacity and the cost of tax compliance (Wandaogo et al., 2022). This issue is discussed in Chapter 4.

[8] Includes all costs associated with owning a mobile phone, i.e., handset prices, connection fees, and usage costs.

Figure 4: Comparison of the market structure between 2000 and 2017.



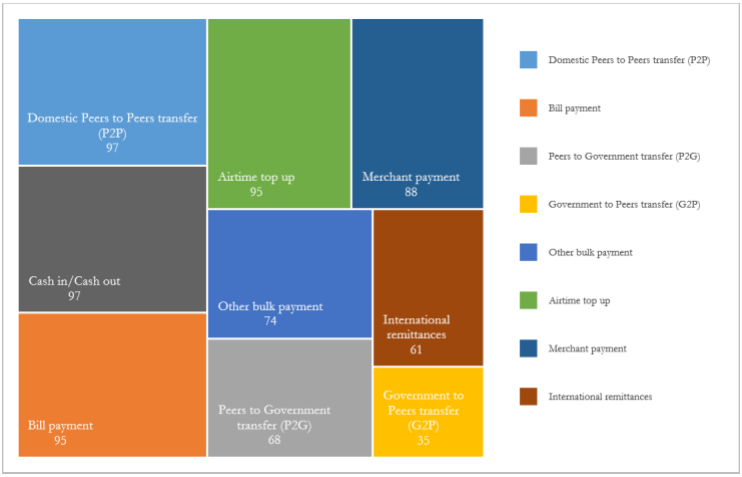
Source: Author construction using data from GSMA Intelligence.

1.5. Mobile money as a revolution in the telecommunications sector

First introduced in Russia between 2001-2002, mobile money (MM) transaction services have gradually spread within developing countries, particularly in sub-Saharan Africa. Indeed, in 2020 there were 1.2 billion MM accounts worldwide, with 46% in Sub-Saharan Africa (GSMA, 2021). The volume of MM transactions in the same year was $767 billion, with sub-Saharan Africa accounting for 64% of these transactions. MM is a mobile payment system linked to a phone number and allows its holders to perform most of the transactions offered by traditional banks. MM has thus enabled the financial inclusion of a large part of the population rationed by the traditional banking system in countries that have adopted it while providing them with a simple, efficient, and accessible means of payment for their commercial interactions. Chapter 3, therefore, analyzes the impact of MM services adoption on intra-African trade.

Today, MM offers a wide range of possibilities, from person-to-person money transfers and cash in/cash out (in 97 countries) to government-to-peers transfer services (in 35 countries) (figure 5).

Figure 5: *TreeMap of Mobile Money Service Adoption Worldwide.*



Source: Author construction using data from the GSMA Mobile Money deployment tracker.

For several years, it has thus become the payment method of choice for many economic agents in several African markets. In addition, the introduction of MM services such as P2G allows tax authorities to easily identify a taxpayer and simplify the reporting and payment procedures. That could encourage taxpayers to exercise tax discipline, especially since the MM service is available to all without income requirements. Chapter 4 provides a detailed analysis of this aspect.

2. Outline and contributions of the thesis

2.1. The tax burden on mobile network operators in Africa

This chapter estimates the tax burden on the mobile telecommunication sector in twenty-five African countries. Our approach complements previous studies on the taxation of the telecommunication sector, particularly those provided by GSMA (Katz et al., 2010, Rogers & Pedros, 2017; Pedros & Sivakumaran, 2019) and the International Telecommunication Union (ITU, 2013). These works study the affordability of cell phone services, especially in developing countries. Consequently, they focus mainly on indirect taxation such as Value Added Tax (VAT), excise taxes, and special mobile networks taxes, such as fees or surtax on SMS, Sim cards, and incoming international calls. In contrast, we consider all taxes a firm must pay to operate its mobile network license. The tax burden thus encompasses general and special taxes under the Ministry of Finance's (MoF) control and fees raised by the national telecommunication Regulatory Agency (RA). Given the lack of financial data at the country level, a representative mobile network operator, TELCO, is built using the GSMA Intelligence database. In this chapter, the Average Effective Tax Rate (AETR) is computed for this firm considering general, and special taxes and fees levied only on the telecommunication sector. The AETR varies significantly across countries, ranging from 33 percent in Ethiopia to 118 percent in Niger. Special taxes and fees represent a large share of the AETR, illustrating some taxation by regulation and a potential tax competition (a race to the top) between the MoF and the RA. The analysis includes a comparison of TELCO's AETR with that of a representative gold mining plant and a standard company with a similar gross return. The tax burden of the telecommunications sector is higher than that of the mining sector in 15 of the 19 countries for which data on the gold mining sector exist. Chapter 1 also includes a web application (https://data.cerdi.uca.fr/telecom/) that has been developed to

allow the reader to replicate our analysis or modify TELCO and tax parameters.

2.2. Demand price elasticity of mobile voice communication: A comparative firm-level data analysis

Chapter 2 estimates the price elasticity of mobile voice communication in developed and developing countries using quarterly operator data from 2000 to 2017. A novelty of this chapter is that the data allow considering the two types of data previously mentioned, i.e., data at the operator level and data covering many countries, including developing and developed countries; this allows comparisons based on operator and market characteristics. Although Dewenter and Haucap (2008), Karacuka et al. (2011), and Hausman and Ros (2013) use a difference-GMM as an estimation strategy, it considers a system-GMM, which produces more efficient and consistent estimates than the difference-GMM and is more suitable for unbalanced panel datasets. Unlike Kathuria et al. (2009), who use the median penetration rate to define the level of market development, it uses Rogers's (1976) innovation diffusion theory to identify three levels of market development, i.e., low penetrated, growing, and mature markets. In addition, to complete Hausman and Ros's (2013) analysis, it investigates the potential difference in price elasticities based on operators' positions or market shares. Furthermore, in the studies enumerated in this section, Hausman and Ros's (2013) 2011 data are the most recent; since 2011, the sector has undergone significant changes. Therefore, that study is an update of the literature on mobile voice communication demand. The results show that the demand price elasticity is higher for operators in developed countries. Controlling for cross-price elasticity with internet data prices reveals that voice communication is a substitute for internet data usage in developed countries. Another important finding is that, for operators in

developing countries, the price elasticity decreases with market development level, whereas it increases for those in developed countries. Demand for mobile voice communication is thus more sensitive to price changes in the less penetrated markets in developing countries and the mature markets in developed countries. Furthermore, over time, price elasticity has decreased across operators in developing countries, highlighting the need to update the telecommunications sector's regulatory frameworks to reflect the sector's various developments. In addition, when formulating regulatory and tax policies, some important economic factors, such as income level and domestic market characteristics, should be considered to avoid losses in consumer welfare. The high estimated price elasticities suggest that operators do not have an obvious interest in engaging in collusive behavior that would hinder competition. Moreover, since there is no differential effect due to operators' positions or market shares, asymmetric regulation of the dominant operators should be avoided.

2.3. Mobile money services adoption and intra-African goods trade

Since its introduction in Kenya in 2007, Mobile Money (MM) has gradually spread across the continent. From money transfer to bill payment and commerce, MM has become the favorite payment means for economic agents in many African markets. Furthermore, its flexibility and availability have made it transcend national borders with possibilities for inter-operator and international transactions with enterprises from micro to medium-sized and individuals. MM enables an intensification of intra-African trade as it promotes financial inclusion and financial development (Burns, 2015, Asongu, 2013, Donovan, 2012), which in turn increase international trade (Hajilee and Niroomand, 2019, Demir and Dahi, 2011, Hur et al., 2006). However, no empirical studies have so far addressed the role of MM in increasing intra-African trade. Therefore, chapter 3 studies the causal effect of

mobile money (MM) services adoption on intra-African goods trade considering data from 48 African countries from 1994 to 2018. It finds that countries that adopted MM services register a higher goods trade as a share of GDP than non-adopters, with a higher effect on food items trade.

2.4. Peer-to-government mobile payment services adoption and tax revenue mobilization in developing countries

Developing countries need to raise sufficient tax revenue to finance development. Revenue mobilization is often hampered by limited tax compliance, weak institutions, and technical problems with tax collection. One solution to these challenges is person-to-government (P2G) cell phone payments, adopted in several developing countries since the early 2000s. Despite the opportunities offered by P2G payment services, there are no studies, to our knowledge, that assess the impact of their adoption on tax revenue. This paper addresses this gap by estimating the effect of P2G adoption on direct tax revenue, relying on a sample of 96 developing countries. The choice of direct (instead of indirect or overall) tax revenue as the main outcome is based on the notion that taxpayers typically use P2G payments to settle tax obligations imposed on them directly by the tax administration. In addition to providing the first empirical estimates on the impact on tax revenue of adopting P2G services, the work highlights how structural factors that differ across countries mediate the impact, demonstrating which types of countries are most likely to benefit from the technology. This study assesses the causal effect of P2G adoption on tax revenue using propensity score matching. The main hypothesis is that P2G adoption improves direct tax revenues in developing countries by providing a new, convenient mechanism for settling tax obligations, hence improving compliance, reducing corruption, and improving administrative efficiency. According to the matching estimates, countries that

adopt P2G services experience a 1.2-1.3 percentage point boost in direct tax revenue as a share of GDP. P2G adoption increases revenue from both corporate and personal income taxes, with larger effects on the latter. The results remain robust to matching quality tests and alternative estimation methods, including function control, two-stage least squares, and system generalized method of moments. The average treatment effects are largest among lower-middle-income countries and countries characterized by limited tax compliance and corruption control, and low levels of urbanization and domestic credit to the private sector. Improvements in tax discipline, domestic revenue mobilization efficiency by the tax administration, and reduction in the size of the informal sector are the potential transmission channels through which P2G services adoption affects direct tax revenues in developing countries. The findings suggest that developing countries, particularly those with poor institutions and low levels of financial inclusion, should promote the adoption and use of mobile money services for tax transactions.

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Chapter 1: The tax burden on mobile network operators in Africa

This chapter is joint work with Grégoire ROTA-GRAZIOSI. A slightly different version of this chapter is published in *Telecommunications Policy*

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This chapter includes a web application (https://data.cerdi.uca.fr/telecom/) developed using the "R-shiny" package. It allows the reader to replicate our analysis or modify our assumptions, TELCO data, and tax parameters.

1. Introduction

The tax on internet voice calls such as WhatsApp, Skype, and Viber had triggered massive protests in Lebanon, which brought down the government. Several other countries, especially in Sub Saharan Africa (Uganda, Zambia, Kenya) raised or tried to raise (Benin[9]) similar taxes. These experiments illustrate governments' efforts to tax new bases and the political sensitivity of some bases, and the poor design of these taxes, which often take the form of a specific excise.[10] Such taxes add up to a lot of others, which are particular to the telecommunication sector. This sector is nevertheless one of the most dynamic economic sectors in sub-Saharan African countries. It participates in the region's economic development by improving market efficiency (Aker and Mbiti, 2010). However, it still has a substantial capacity to grow further as unique subscribers market penetration remains low. It is around 45 percent on average in Africa compared to more than 60 percent in other developing countries in 2017 (GSMA intelligence, 2018).

Despite the globalization process, the telecommunication markets remain highly fragmented with heterogeneous national regulations and tax systems. Several studies (e.g., Noll, 2000; Li and Xu, 2004; Howard and Mazaheri, 2009; Faccio and Zingales, 2017) focus on the role of privatization, competition, and regulation of the telecommunication sector in developing countries. Particularly, Howard and Mazaheri (2009) consider internet usage and mobile phone adoption in 154 countries over the period 1990-2007.[11] The

[9] Decree 218-34 of July 25, 2018, raised a tax on the use of social media at a rate of 5 FCFA or equivalently USD 0.009 per megabyte. However, Online and street protests push the government to cancel this tax a few months later.

[10] The tax is specific when its base is a quantity (e.g., minutes, megabytes, etc.).

[11] In line with Henisz et al. (2005), they consider four policy reforms of the telecommunication sectors: the privatization of the national telecommunication provider, the market liberalization allowing some competition among Mobile Network Operators (MNOs), the creation of an independent Regulatory Agency, and the depoliticization of

authors conclude that the independence of the Regulatory Agency (RA) reduces the "digital divide", but its full depoliticization has a negative effect by reducing the RA's capacity to effectively regulate and develop information infrastructure. Beyond the studied regulation reforms (privatization, market liberalization, the independence of RA and its depoliticization), we stress here the central role of the taxation of this sector, which is particularly complex given the variety of special taxes and regulatory fees raised not only by the Ministry of Finance (MoF) but also by the telecommunications RA. These two institutions may even compete in taxing the same base: the activity of Mobile Network Operators (MNOs). Such a tax competition can trigger a race to the top (excessive taxation) as described by Berkowitz and Wei (2000) in the context of Russia and China or Keen and Kostiogiannis (2002) in federal States.

Our analysis participates in the debate regarding the adequate level of taxation that should apply to the sector. On the one hand, some authors such as Matheson and Petit (2020) consider that MNOs extract rents from operating their exclusive licenses. Therefore, the tax regime applied to the telecommunication sector should follow a similar logic as for the extractive industries. On the other hand, other authors advocate the merits of telecommunication firms to bridge the digital divide. They justify potential tax incentives, such as exemptions or reduced rates, to enhance mobile phone devices and services affordability (Mistry, 2005; GSMA, 2017). According to Henry (2019) and West (2015), taxation increases the cost of access and use of mobile services. This impacts negatively MNOs' revenues and discourages their

the latter. These authors build an annual index of technology adoption for each country around several dimensions: Internet bandwidth, hosts and users, personal computers, and mobile phones.

investments. For Katz et al. (2010), the telecommunication sector's taxation models generate some economic distortions. This debate is not particular to the telecommunication sector. It reflects a well-known trade-off, prominent in developing countries, between fostering an economic activity through tax incentives and collecting tax revenues for public funding purposes.

Our approach complements previous studies on the taxation of the telecommunication sector, particularly those provided by GSMA (Katz et al., 2010, Rogers and Pedros, 2017 or Pedros and Sivakumaran, 2019) and the International Telecommunication Union (ITU, 2013). These works study the affordability of mobile phone services, especially in developing countries. Consequently, they focus mainly on indirect taxation such as Value Added Tax (VAT), excise taxes, and special mobile networks taxes, such as fees or surtax on SMS, Sim cards, and incoming international calls. In contrast, we consider all taxes a firm must pay to operate its mobile network license. These include direct taxation such as Corporate Income Tax (CIT) and some indirect taxes, which increase the production cost of mobile phone services unambiguously. Consequently, we do not consider VAT and some excises collected by the firm but borne by the final consumer. However, our choice remains subjective given the potential incidence of any tax on the consumer price.[12]

We estimate the tax burden borne by mobile phone companies in some African countries. We, therefore, compute the Average

[12] Weyl and Fabinger (2013) develop a theory of pass-through. They show how the tax burden's sharing between producers and consumers differs significantly depending on the market structure, demand characteristics, and the level of taxation. More recently, Baker et al. (2020) study CIT's incidence on consumer prices, estimating a price elasticity to net corporate tax rates of 0.17.

Effective Tax Rate (AETR), which summarizes the main taxes and fees paid by an MNO over the length of a telecommunication license (15 years by assumption). Our methodology follows the standard approach of forward-looking AETR through a representative firm (see Devereux and Griffith, 1998; Djankov *et al.*, 2010; Steinmüller *et al.*, 2019 for general economic activity; Daniel *et al.*, 2010 for the extractive industry). Given the lack of public firms' financial data, we build TELCO, a representative mobile phone company, using the GSMA Intelligence database. TELCO's financial data and economic activities are expressed in terms of percentage of final consumption or subscribers for each country. Next, we consider the tax regime relevant in 2018 over the length of a typical license period (15 years by assumption). An important assumption concerns the evolution of final consumption and mobile subscribers in each country over the 15 years license length. Multiple factors impact the development of this market: technological innovations, the number of license owners, demand elasticity, and any tax or fee, which would have an incidence on prices, etc. Given the induced complexity of the final effect on the market, we use observed data rather than projected estimates. Thus, we consider 2018's tax regime and apply it to a representative firm, which operates its license from 2003 to 2018.[13] We determine the AETR given the actual development of the 25 national mobile phone markets since 2003. Given the buoyancy of the telecommunication sector in Africa,

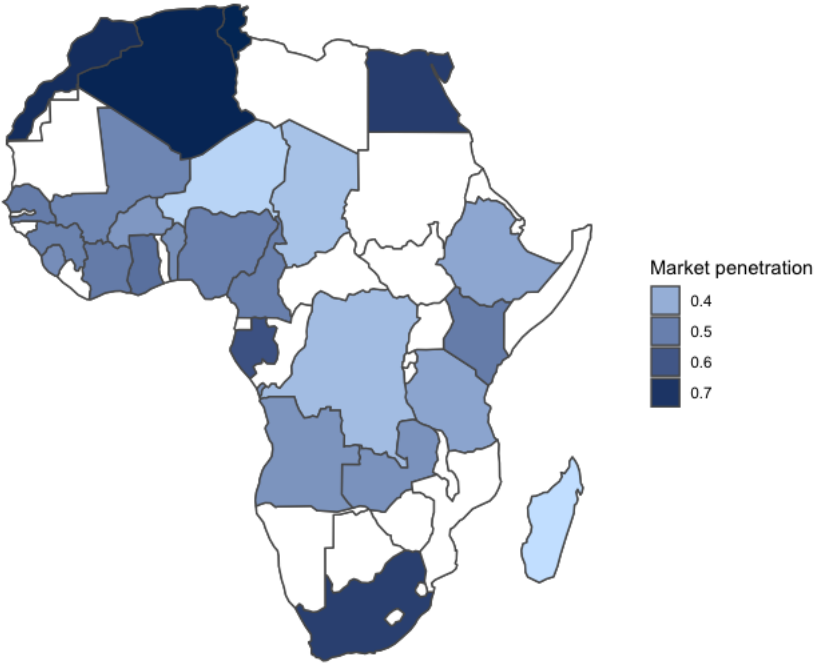
[13] An implicit assumption is that we do not consider any tax change over the period. There is no best solution to profile the future revenue or turnover. For instance, the Doing Business model (TaxpayerCo) assumes a constant activity expressed in terms of Gross National Income (GNI) per capita over five years. The Fiscal Analysis of Resource Industries (FARI) model of the International Monetary Fund (IMF) considers a production plan resulting from actual feasibility studies or an average estimation of the extraction process. However, the main weakness of this approach is the predicted commodity prices over a very long period (20 to 40 years), which are assumed to be constant or increasing at a given rate.

many countries have modified their tax regime every year since 2018: Some countries raised the rate of the studied taxes (for instance, Burkina Faso increased the rate of the telecommunications network access tax from 5 percent to 7 percent in 2020); Others introduced additional new taxes especially excises on Over-The-Top (OTT) services (Tanzania, Uganda, and Zambia), which we do not consider in our study. The associated web application (https://data.cerdi.uca.fr/telecom/) allows the reader to replicate our analysis, update national tax systems, and modify any parameter of the firm TELCO.

We study 25 African countries: Algeria, Angola, Benin, Burkina Faso, Cameroon, Chad, Cote d'Ivoire, DRC, Egypt, Ethiopia, Kenya, Gabon, Ghana, Guinea, Madagascar, Mali, Morocco, Niger, Nigeria, Senegal, Sierra Leone, South Africa, Tanzania, Tunisia, and Zambia. These countries represent 60 percent of Africa's total GDP, 79 percent of the total population, and 81 percent of unique African subscribers in 2018. However, they differ in the development of their respective telecommunication sector.[14] For instance, the 3G network coverage in 2018 varies from 31.6 percent in Mali to 99.2 percent in South Africa, and the market penetration of mobile phones from 30.9 percent in Madagascar to 75.4 percent in Tunisia (see Figure 1).

[14] Appendix A displays some characteristics of these countries.

Figure 6: Market penetration (unique subscribers in 2018) of the studied countries.



Source: Authors.

The AETR varies significantly across these countries. It goes from 33 percent in Ethiopia or 35 percent in Morocco to 97 percent in DRC and even 118 percent in Niger, with a mean of 64 percent. Ethiopia is an outlier in our sample since the liberalization of its telecommunication sector is still ongoing (see Table A in Appendix).[15] We can expect significant changes in the Ethiopian

[15] Our analysis remains hypothetical in the case of Ethiopia since we consider a private MNO, which did not exist in this country in 2018. Indeed, the Ethiopian government has

tax regime of the telecommunication sector in the coming years. With an AETR superior to 100 percent, TELCO would lose money in Niger. This country has the highest tax on international calls at 0.13 Euro per minute and significant cumulated turnover fees of 5 percent. The recent leaving of Niger by Orange SA results partly from this excessive tax burden.

We break down the AETR into two components: the Average Special Tax Rate (AESTR), which summarizes all special taxes and fees raised on MNOs; and the Average General Tax Rate (AEGTR), which captures "standard" taxes, and which applies to all firms in the country. We observe that special taxation represents the largest share of the final tax burden in 14 countries: The AEGTR is on average 26 percent, while the AESTR is 38 percent over our sample. We also compute the AETR of CIT only for a standard firm and an MNO. Our results are close to Steinmüller et al. (2019) with an average CIT AETR of 27.9 percent. We also observe that TELCO's CIT AETR is lower than the CIT AETR of the standard firm since several special telecommunication taxes and fees are deductible from the CIT base. As in previous studies adopting the AETR approach, we do not address profit shifting through mispricing or thin capitalization. That involves an overestimation of paid CIT and consequently of the AETR computation. We estimate in appendix O.IV the impact of an increase in the debt-to-equity ratio from 60 percent to 90 percent or even 100 percent. As a result, the AETR decreases on average only by 2 to 3 percentage points. For each country, we compare the AETR of TELCO to the AETR of a

engaged very recently in the liberalization of the telecommunication sector. In 2021, it privatized Ethio Telecom (the State-Owned Company) partly by selling a 45 percent stake. It has also offered two new telecom licenses. However, only one license has been awarded to an international consortium.

standard firm and a representative gold mining plant, which both have the same gross return of 60 percent. Indeed, the standard firm only supports general taxation. In contrast, the mining firm pays specific sectoral taxes such as mining royalties, surface taxes, and other fees.[16] Unambiguously, the AETR of TELCO is higher than that of the other two sectors in all countries except Angola, Chad, Kenya, and South Africa. Telecommunication is more taxed than mining.

The rest of the paper is organized as follows: Section 2 presents our AETR computation methodology, results, and some comparisons with the mining and the standard sector; Section 3 presents the results; and Section 4 concludes and presents some correlations between the computed AETRs and market penetrations or GNI per capita in 2018.

2. The AETR approach

We consider a representative MNO named TELCO. This firm operates a 15-year telecommunications license. It generates cash flows (revenue minus expenses) shared between the investor (the owner of TELCO), the government, and other regulatory authorities, which tax TELCO. The AETR captures this distribution of cash flows by measuring the effective tax burden on the telecommunication sector. We consider the general taxation system such as the Corporate Income Tax (CIT), professional taxes or payroll taxes, customs duties, and the special telecommunication taxation, including taxes on international or national traffic. Our analysis also integrates quasi-tax levies[17] such as the pre-shipment inspection fees and contributions to the RA. However, we do not consider indirect taxation such as VAT,

[16] We use the FERDI online database and its mining industries simulation tool (https://fiscalite-miniere.ferdi.fr/en).
[17] Quasi-taxes are not raised by the tax administration nor the customs.

excises, and Personal Income Tax (PIT), which are collected by the firm but are due either by customers or firm's employees.

Our approach follows previous analyses computing AETR for a general economic sector or a specific one such as the extractive industry. For instance, Djankov et al. (2010) study the effect of corporate taxes on investment and entrepreneurship. The authors build a five-year business plan for a representative firm named TaxpayerCo, producing and selling ceramic pots. The World Bank Doing Business survey uses this fictitious firm to rank countries every year. Blake and Roberts (2006), Daniel et al. (2010), Luca and Mesa Puyo (2016), and Diouf and Laporte (2017) apply the AETR approach to the extractive industry (mining and petroleum). Daniel et al. (2010) and Luca and Mesa Puyo (2016) present the Fiscal Analysis of Resources Industries (FARI) model, which the International Monetary Fund (IMF) used extensively to simulate tax policy reform in the mining and upstream petroleum sectors.

The cash flows sharing model is based on Net Present Values (NPV). The AETR is given by:

$$AETR = \frac{\sum_{t=1}^{15} \frac{T_t}{(1+d)^t}}{\sum_{t=1}^{15} \frac{R_t - C_t - K_t}{(1+d)^t}}, \qquad (eq.1)$$

where T_t denotes tax revenues in year *t*, R_t turnover, C_t OPEX, K_t CAPEX, and *d* is the discount rate. A rate of 50 percent would mean that tax payment is 50 percent of before-tax cash flows over the license life length.

2.1. TELCO's accounting data

Given data availability and the diversity of market structures, we build TELCO, a standard representative MNO, which obtains its exploitation license in 2018 for 15 years. We model TELCO's financial statements during its license exploitation period using the GSMA Intelligence database, covering 237 countries and

territories. This database encompasses market data (e.g., market shares, numbers of subscribers, market penetration, etc.), financial data (e.g., turnover, OPEX, CAPEX, and their decompositions, etc.), and communications volumes (e.g., outbound and inbound national and international minutes, SMS and data volumes).

To design the profile of TELCO, we consider all firms that were granted a mobile operating license in Africa over the period 2000-2017. We assume that the turnover and other data for each firm depend on its market penetration rate. We first define TELCO's turnover in each country as a share of the final national consumption. We consider national final consumption instead of Gross Domestic Product (GDP) since the former approximates better national demand for goods and services. That will allow us to consider market diversity by building different cash flow profiles depending on national demands. Final consumption data come from the World Development Indicators (WDI) of the World Bank. We express total OPEX and CAPEX as a proportion of turnover. We also consider the ratio of personnel and equipment costs over total OPEX. We determine national and international voice traffic in terms of inbound and outbound minutes per unique subscriber.[18] We then compute the weighted average of each variable for each year over the length of the license to obtain TELCO's data. The weight is the individual market penetration rate. Each variable, denoted by $\bar{x}_t$, is then given by the following formula:

$$\overline{x_t} = \sum_{i=1}^{n} \frac{MP_{it} * x_{it}}{\sum_{i=1}^{n} MP_{it}}, \qquad \text{(eq. 2)}$$

where MP_{it} and x_{it} represent respectively firm i's market penetration rate at time t and its considered financial variable at

[18] The use of the number of subscribers allows us to consider the market size, which may vary across countries. Since our initial year is 2018, we would need data on final consumption and the number of subscribers from 2018 to 2032. However, such data is not available. We thus prefer to use observed data over the last 15 years and deduce TELCO's financial profile.

time *t*.[19] TELCO's pre-tax Internal Rate of Return (IRR) is on average 60 percent across studied countries. Our web application allows users to modify TELCO's profile and apply the profile of actual MNOs.

2.2. Assumptions

We make several assumptions regarding TELCO's accounting and financial data (see the online appendix OI). First, we assume a straight-line depreciation rule, which determines CAPEX depreciation charges.[20] Second, we assume that TELCO finances its activity by combining debt and equity. We consider a debt-to-capital ratio of 60 percent with a repayment period of 5 years. These borrowings are subject to an interest rate of 10 percent. We consider a discount rate of 10 percent.[21] We also make a sensitivity analysis by considering a lower interest rate of 6 percent.

We consider that the upfront license cost is part of tax revenue since it is paid by the investor to the government.[22] An alternative approach would be considering the license cost as a market entry cost, a necessary investment to operate a mobile phone network.[23] To define employer costs such as payroll taxes, we assume that wages and salaries represent 70 percent of labor costs. For professional or business licensing taxes, we consider that the rental value of business property corresponds to 5 percent of the total OPEX, excluding the cost of personnel and equipment.

[19] Indeed, for each operator in the sample, we determine a variable t that takes the values 1, 2, ..., and 15 for the first, second, ..., and the fifteenth year of operation, respectively. Aggregation of the data is performed for each period using a market penetration weighted average. TELCO's data for each operating period would therefore represent the mean profile of firms.

[20] We consider that tangible CAPEX represents 95 percent of total CAPEX.

[21] These parameters are chosen according to Ferdi's gold mining representative firm's borrowing parameters for comparison purposes.

[22] We consider a one-off license payment at the beginning of the exploitation.

[23] The cost of the license would then be integrated into the denominator in deduction of the gross cash flows.

While our approach is close to this developed by the IMF for the extractive sector's rent sharing,[24] it differs significantly in its price structure assumptions. Indeed, oil and most mineral resources have a well-established world price, depending on global demand and supply variations. Commodity prices are thus an exogenous parameter for any individual mining or petroleum project, independent of its size. In other words, the extractive firm is a price taker, and its production has no impact on the global price.[25] The definition of prices is more complex in the telecommunication sector since markets are national and oligopolistic (see Faccio and Zingales, 2017). Telecommunications firms set their prices depending on the demand and the behavior of their competitors at the national level. On the supply side, interactions may take the form of a pure price or price-quality competition, which can significantly reduce firms' profits.[26] Many developments in industrial economics aim to study the competition structure of a market and its impact on prices and consumer surplus.

We use historical data to determine the profile of turnover of TELCO during the exploitation of its license. We express this turnover in terms of final national consumption (see the online appendix).[27] We focus only on the initial MNO core business in Africa: Selling prepaid access to voice and data services. Despite their recent rise, especially in East Africa, we do not regard complementary markets such as mobile phone banking or insurance. Considering these services would complexify our analysis significantly and involve additional fragile assumptions given the lack of sufficient hindsight over these activities.[28] The

[24] Fiscal Analysis of Resource industries: www.imf.org/external/np/fad/fari/.

[25] This hypothesis can be discussed for minerals such as uranium or mining deposits such as Simandou's in Guinea for iron. The production capacity of the latter would represent a significant volume of worldwide production.

[26] A classical result in the economic literature is the equivalence between Bertrand's duopoly equilibrium and pure and perfect competition. In both equilibria, prices are equal to marginal cost, and profits are zero.

[27] Available on https://www.dropbox.com/s/j69ohyskd1yr8hg/Online%20Appendix.docx?dl=0.

[28] Consequently, we do not consider special taxes levied on mobile banking.

discount rate captures the opportunity cost of invested capital in TELCO on the investor side. However, the discount rate also represents the government's preference for the present. That may explain the difference between the investor discount rate and the State discount rate. They can then vary across countries depending on risks and stakeholders' preferences. For example, we can expect higher discount rates for developing countries, given the short-term liquidity preference of their governments. However, choosing the appropriate discount rate is not easy given the preference divergence between governments and investors. Several analyses discuss factors such as the level of uncertainty, capital expenditures valuation, and other risk factors in the discount rate determination (Boadway and Bruce, 1984; Fane, 1987; Bonds and Devereux, 1995). For simplicity, we consider the same 10% discount rate for the investor and the government.[29] We propose a sensitivity analysis by setting the discount rate to 0, 5, and 12 percent in the online appendix O.IV.

Following Chennells and Griffith (1997), we consider exchange rates and inflation in the AETR computation. We convert all tax variables in Euro, which is the currency of the GSMA database. Using data in nominal or real terms will not affect the AETR results, as the conversion rate will be the same for the numerator and the denominator of the AETR expression. In addition, the potentially substantial upfront license payment takes place on Year 0 and is not impacted by inflationary concerns. We then choose to keep the data in a nominal term as expressed in the GSMA database.

2.3. Tax data

The study considers the tax regimes applicable in 2018 to MNOs in 25 African countries. General taxation applies to all firms

[29] Chennells and Griffith (1997), Djankov et al. (2010), Luca and Mesa Puyo (2016), and Diouf and Laporte (2017) consider a discount rate of 10 percent. However, Luca and Mesa Puyo (2016) differentiate their discount rate for the government (10 percent) and the contractor (12.5 percent).

operating in the country. Tax and Customs Codes, Laws, and Acts define the standard tax regime. In addition, some special sources such as Investment Codes and other legal sources (act, decree, ministerial ruling, etc.) may provide tax incentives by reducing tax rates or the taxable base (see Appendix B). The taxation of the telecommunication sector is buoyant, and the current tax regimes may differ from these presented here. For instance, Burkina Faso increases the telecommunications network access tax rate from 5 percent to 7 percent (Article 28 of 2020's Finance Act).

General taxation includes direct and indirect taxation, as well as tariff duties collected at the borders. Direct taxation includes CIT, a minimum tax usually based on turnover, employer contributions on wages, and professional taxes based on rental or fixed asset value (see Table 1). CIT rates vary from 20 percent in Madagascar to 40 percent in Zambia. Three counties: Cote d'Ivoire, Tunisia, and Zambia, raise a higher CIT rate on MNOs than the standard rate. Moreover, Algeria, Ghana, Nigeria, and Tunisia also have an additional ad valorem tax applying to profits. Many African countries have an alternative mechanism for CIT purposes, which taxes turnover. This mechanism is called Minimum Income Tax and has a rate varying from 0.2 percent in Tunisia to 3 percent in Kenya. The employer contribution raised on wages ranges from 0.5 percent in Gabon to 20 percent in Chad. Cote d'Ivoire and Niger, for example, distinguish between the rate applied to local workers and foreigners. The professional tax has two components in Burkina Faso, Guinea, and Niger: a fixed lump sum from 279 Euro in Guinea to at least 4,573 Euro in Niger;[30] and a proportional one based on the rental value of the business property from 8 percent in Burkina Faso to 15 percent in Guinea. In the other countries, it is expressed as a percentage of turnover (Algeria and Senegal, for example) or assets value. Niger also has a commercial tax based on the number and types of billboards and advertising activities. Finally, Cote d'Ivoire, Gabon, Nigeria, and

[30] In Niger, the fixed lump sum is determined depending on the turnover value going from 4,573 Euro to 45,734 Euro.

Tanzania have ad valorem taxes based on the turnover of MNOs, which aim to finance some activities such as arts, education, and local services.

Appendix B presents tax incentives, which apply to MNOs operating in the studied countries. Several countries such as Egypt, Ethiopia, Ghana, Senegal, and South Africa apply standard CIT rates. On the opposite, Tunisia displays a very generous mechanism by providing ten years CIT exemption and a reduced rate by half for the next ten years. Losses carry-forward significantly increase the effective length of CIT exemptions. Almost all countries have reduced or zero rates of customs duties for equipment and capital goods.

We only consider certain indirect taxes, which increase TELCO's production cost (see Table 2).[31] These taxes are customs duties, non-deductible VAT on oil products, and the different levies associated with imports. We do not consider VAT in general and several excises, i.e., those raised on mobile handsets or OTT mobile communication applications.[32] These taxes are assumed to be transferred immediately to consumers. VAT is a tax on consumption as long as its mechanism of debit and credit is respected. VAT becomes a cost for the firms when it is not deductible (e.g. petroleum goods).[33] The taxation of OTT services aims at taxing the apps providers and not the MNO operating the telecommunication license. By contrast, customs duties directly increase the cost of production since networks equipment is imported. They range from zero to 30 percent. They are some specific fees or levies collected at the border.[34] For instance, customs unions such as the Eastern African Community (EAC) or the Western African Economic and Monetary Union

[31] The AETR computation does not consider VAT, sales tax, and excise duties on telecommunication services.

[32] Uganda raised such tax in 2018. The latter corresponds to a daily payment of 200 shillings (0.053 USD) to use any one of 58 applications such as Facebook, Twitter, Instagram, LinkedIn, WhatsApp, Snapchat, Skype, Tinder, Grindr, etc...

[33] VAT rates vary from 5 percent in Nigeria to 20 percent in Madagascar and Morocco.

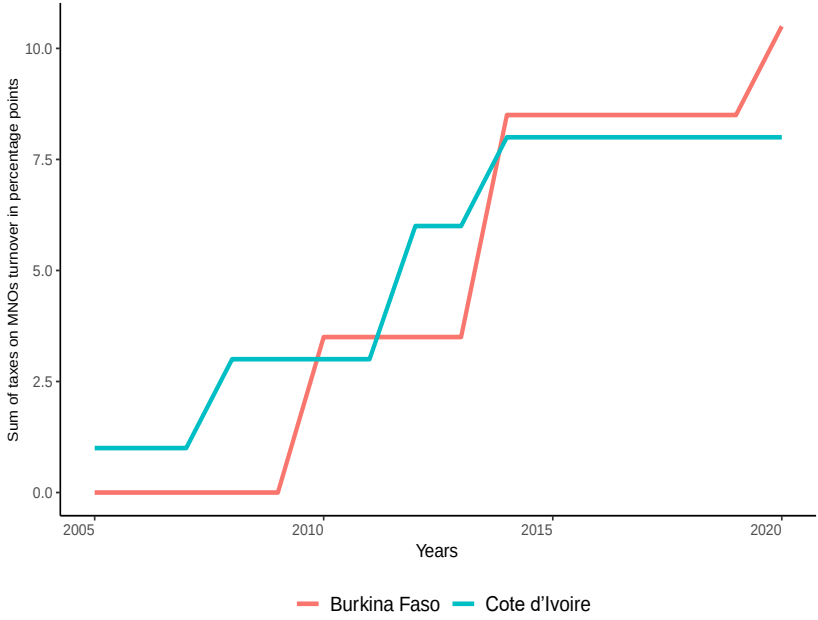
[34] Those are collected on network equipment and mobile device imports for TELCO.

(WAEMU) raise fees or quasi-tax for the budget of their respective Commissions. In addition, several African countries also use private firms to assist their own customs administration through Pre-Shipment Inspection (PSI) programs. These firms provide additional information on the value of imported goods. The importers must pay this service through a fee equivalent to a quasi-tariff on importations (see Dequiedt et al., 2012).

Special taxation on the telecommunication sector results from specific laws and decrees, which regulate this sector (see Table 3). We consider the following taxes and fees: taxes on national and international traffic, telecommunication network access tax, numbering fees, Universal Service Fund, research and development fund, and RA levy and particular fees.[35] These taxes may be ad valorem (based on turnover) or specific (nominal amount based on some activity measures such as minutes, data, and SMS). This special taxation is similar to excise duties collected by firms but legally due by consumers. However, given the incidence of this mobile-specific taxation and the demand elasticity of the sector, we assume that this special taxation is due by MNOs themselves. The sum of special ad valorem taxes and fees raised on turnover varies from 0.55 percent in South Africa to 8.5 percent in Burkina Faso. We express specific taxes in Euro. Taxes on MNOs have increased significantly over time. Figure 2 illustrates the case of Burkina Faso and Côte d'Ivoire. For the former, the sum of tax rates on MNOs turnover increased from 0% in 2005 to 10.5% in 2020, while it increased from 1% in 2005 to 8% in 2014 for the latter.

[35] We have used GSMA reports on telecommunications sector taxation to ensure that we have captured most of the taxes applied to telecommunications companies. Indeed, GSMA conducts studies on telecommunications taxation at the country level and regional or global levels. These reports present all taxes paid by MNOs in the countries we study. In addition, we compared studied taxes with those mentioned in Matheson and Petit (2021). Finally, we had several interviews with the CFOs of some MNOs, who provided us with the details on some contributions.

Figure 7: Evolution of special taxes on MNOs' turnover in Burkina Faso and Cameroon



Source: Authors.

Spectrum fees are the main component of regulatory fees. Table 3 displays an estimation of these fees in terms of turnover, which is based on the average relevant payment reported in the GSMA database. However, spectrum fees vary significantly in their form across countries and from one year to another. For example, DRC raises a specific tax of 53,500 USD/MHz for GSMs, 6,000 USD/MHz for microwaves, and 3,000 USD/MHz for the internet. The Guinean spectrum fees have the following structure: 5,525 Euro/MHz for WiMAX networks, 110 Euro for ARMC's, 7,735 Euro for GSM 900's and DCS 1800's, 5,525 Euro for VSAT's and from 1,547 to 9,282 Euro paid annually for digital terrestrial networks depending on the size of beams.

Table 1: Direct taxes in 2018

	Corporate Income Tax (CIT)	CIT minimum perception	Apprenticeship tax	Other direct taxes			Other taxes
				Professional tax	Property tax	Commercial publicity tax	
Taxable base	Profits	Turnover	Wages	Turnover, lump sum, rental value of property or turnover	Fixed assets value inclusive of all taxes	Number or area of advertising mediums days or operations	Turnover
Algeria	0.26	-	-	0.02	-	-	-
Angola	0.3	-	0.08	-	-	-	-
Benin	0.3	0.0075	0.04	-	-	-	-
Burkina Faso	0.275	0.005	0.03	Fixed duty: 610 Euro Proportional duty: 0.08	-	-	-
Cameroon	0.33	0.022	-	0.00156 [1]	-	-	-
Chad	0.35	0.015	0.20 [2]	-	-	-	-
Cote d'Ivoire	0.30	0.005	Nationals: 0.035 Foreigners: 0.155 [3]	0.007 [1]	-	-	0.003 [4]
DRC	0.35	0.01	0.02	-	-	-	-
Egypt	0.225	-	-	-	-	-	-
Ethiopia	0.3	-	0.11	-	-	-	-
Gabon	0.30	0.01	0.005 [2]	-	-	-	0.01 [5]
Ghana	0.25	-	-	-	-	-	0.05 [6]
Guinea	0.35	0.015	0.075 [3]	Fixed duty: 279 Euros Proportional duty: 0.15 [1]	-	-	-
Kenya	0.3	0.03	0.05 [7]				
Madagascar	0.2	0.005	0.13	-	-	-	-
Mali	0.30	0.01	0.085 [8]	Fixed duty: 1,524 Euro Proportional duty: 0.10	-	-	-
Morocco	0.31	0.005	-	0.10	-	-	-
Niger	0.30	0.015	Nationals: 0.03 Foreigners: 0.05	Fixed duty: 4,573 to 45,734 Euro Proportional duty: 0.10	0.01	0.3 to 7,6 Euro/day, M2, or operation	-
Nigeria	0.3	0.0025	0.01 [9]	-	-	-	0.03 [10]
Senegal	0.30	0.005	0.03	0.003 of the before tax turnover [11]	-	-	-
Sierra Leone	0.3	-	0.1	-	-	-	-
South Africa	0.28	-	0.01 [12]	-	-	-	-
Tanzania	0.3	0.005	0.06 [12]	-	-	-	0.003 [13]
Tunisia	0.35	0.002	0.1857 [14]	-	-	-	0.002 on turnover + 0.01 on CIT base [16]
Zambia	0.4	-	0.055 [17]	-	-	-	-

Source: Countries' General tax codes and finances acts.

[1] Business licence tax.

[2] It includes the lump-sum tax on salaries at a rate of 7.5 percent, the tax on salaries at a rate of 11.5 percent, and the apprenticeship tax at a rate of 1.2 percent.

[3] Including the national levy for economic, cultural and social development of the nation at the rate of 1.5 percent, the apprenticeship tax at the rate of 0.5 percent; and additional taxes for continuing professional training at the rate of 1.5 percent. For foreigners, the employer levy at the rate of 11.5 percent is included.

[4] Including artisitic creation tax at the rate of 0.2 percent and equipment special tax at the rate of 0.1 percent.

[5] Special solidarity levy.

[6] National fiscal stabilisation levy which applies on the CIT base. It is expected to apply from 2018 to 2025.

[7] Employer contribution.

[8] Including the employer lump sum contribution at the rate of 3.5 percent, professional training tax at the rate of 2 percent, young people employment tax at the rate of 2 percent, and housing tax at the rate of 1

[9] Industrial training cost.

[10] Including the tertiary education tax of 0.02 and the international technology tax of 0.01.

[11] It is about local economy levy which replace the busing licensing tax in 2018.

[12] Skill development levy.

[13] Local service tax.

[14] Including the professional training tax at a rate of 0.02 and the social security levy at a rate of 0.1657.

[15] Tax on establishments of an industrial, commercial or professional nature for the benefit of local authorities.

[16] Social solidarity levy.

[17] Including the skill development levy at a rate of 0.5 percent and the national pension scheme at a rate of 5 percent.

Table 2: Indirect taxes, customs duties, and fees in 2018

Indirect taxes	Custom duties	Non deductible VAT	Community Solidarity levy	Statistical import charge	Community levies [1]	OHADA levy [2]	Pre-shipment inspection tax
Taxable base	CIF imports value	Before tax Goods and services value	CIF imports value				
Algeria	0.3	0.19	0.01	-	-	-	-
Angola	0.1	0.14	-	-	-	-	-
Benin	0.05; 0.1; 0.2; 0.35	0.18	0.008	0.01	0.005	-	0.01
Burkina Faso	0.05; 0.1; 0.2; 0.35	0.18	0.008	0.01	0.005		0.01
Cameroon	0.05; 0.1; 0.2; 0.30	0.1925	0,01	0.01	0,004	0.0005	0,002
Chad	0.05; 0.1; 0.2; 0.30	0.16	0,01	0.01	0,004	0.0005	0,002
Cote d'Ivoire	0.05; 0.1; 0.2; 0.35	0.09	0.008	0.01	0.005		0.01
DRC	0.05; 0.1; 0.2; 0.30	0.16	0,01	0.01	0,004	0.0005	0,002
Egypt	0.05-0.4	0.1	-	-	-		-
Ethiopia	0-0.35	0.15	-	-	-	-	-
Ghana	0 - 0.2	0.15	0.035 [3]	0.01	0.005	-	-
Gabon	0.05; 0.1; 0.2; 0.30	0.18	0,01	0.01	0,004	0.0005	0,002
Guinea	0.05; 0.1; 0.2; 0.35	0.18	0.008	0.01	0.005	-	0.01
Kenya	0 - 0.25	0.16	0.015 [3]	0.02			
Madagascar	0.05 - 0.2	0.2	-	-	-	-	-
Mali	0.05; 0.1; 0.2; 0.35	0.18	0.008	0.01	0.005	-	0.01
Morocco	0-0.25	0.20					
Niger	0.05; 0.1; 0.2; 0.35	0.19	0.008	0.01	0.005	-	0.01
Nigeria	0 - 0.24	0.05	0.005	0.01			
Senegal	0.05; 0.1; 0.2; 0.35	0.18	0.008	0.01	0.005	-	0.01
Sierra Leone	0.05; 0.1; 0.2; 0.35	0.15	-	0.01	0.005	-	-
South Africa	0 - 0.4	0.14	-	-			
Tanzania	0 - 0.25	0.18	0.015 [4]	0.02			
Tunisia	0.3	0.19	-	-	-	-	-
Zambia	0 - 0.25	0.16	-	-	-		-

Source: Countries' General tax codes and finances acts.

[1] Community integration levy: Communauté des Etats d'Afrique Centrale (CEMAC), Eastern Africa Community (EAC), Economic Community of West African States (ECOWAS), South Africa Custom Union (SACU), Western African Economic and Monetary Union (WAEMU).

[2] Organisation pour l'Harmonisation en Afrique du Droit des Affaires.

[3] Including the special import levy at a rate of 0.01 in place from 2018 to 2025 and the national insurance levy at a rate of 0.025.

[4] Railway development levy.

Table 3: Special taxation in 2018

Special taxes	Tax on national traffic	Tax on international inbound traffic	Numbering fees	Telecommunication network access tax	Universal service fund	Research and development fund	Regulatory agency financing levy	Annual fees on turnover [5]	Spectrum fees
Taxable base	Number of interconnected national minutes (Euro/minute)	Number of international inbound minutes (Euro/minute)	Number of assigned/booked phone numbers (Euro/number)			Gross turnover			Turnover (Computed)
Algeria	-	-	-	0.01	0.03	0.003	0.005	0.01	0.0074
Angola	-	-	0.20598	-	0.01	-	-	-	0.0074
Benin	-	*0.1 [1]	0.2286	0.02	0.01	0.005	0.01	-	0.0074
Burkina Faso	-	-	0.61	0.05 [2]	0.02	0.005	0.01	-	0.015
Cameroon	-	-	0.23	0.03 [3]	-	-	0.015	-	0.016
Chad	-	0.0762	0.2515	-	0.025	0.01	0.035 [4]	-	0.0074
Cote d'Ivoire	-	-	0.15	0.05	0.02 [5]	0.005	0.005	-	0.017
DRC	0.00367 [6]	0.0678 [7]	0.38	-	-	-	-	0.03 [8]	0.025
Egypt	-	-	-	0.03	0.005	-	-	-	0.02
Ethiopia	-	-	-	-	-	-	-	-	0.0074
Gabon	-	0.0716 [9]	0.686	-	0.01	0.02	-	-	0.016
Ghana	-	0.0508 [10]	0.42379	-	0.01	-	-	0.01	0.0061
Guinea	0.00279 [11]	0.1	0.07	0.03	0.015	0.01	-	-	0.03
Kenya	-	-	-	-	0.005	-	-	0.004	0.0185
Madagascar	-	-	-	0.02	0.02 [12]	-	-	-	0.03
Mali	-	-	0.3	0.05	0.01	-	-	-	0.011
Morocco	-	-	-	0.01	0.02	-	-	-	0.016
Niger	-	0.1311 [13]	0.15	-	0.02	0.01	0.02	-	0.013
Nigeria	-	-	0.02348	-	0.025	-	-	-	0.0017
Senegal	-		0.3	0.05 [14]	-	-	-	-	0.02
Sierra Leone	-	-	0.1926	0.005	-	-	-	0.01	0.035
South Africa	-	-	-	-	0.002	-	-	0.0035	0.0074
Tanzania	-	0.0419 [15]	0.1695	-	0.003	-	-	0.01	0.0047
Tunisia	-	-	0.1614	0.05	-	-	-	-	0.0074
Zambia	-	-	0.0244	-	-	-	-	0.03	0.0074

Source: National legislations.

[1] Turnover relating to international incoming calls.
[2] Specific tax on telecommunication companies.
[3] Telecommunication special fund levy.
[4] ARCEP administration fee.
[5] In addition to the 3 percent annual fees on turnover DRC raises also some managment fees on interconnection activities at the rate of 15 percent of the cost of interconnected minutes.
[6] Local interconnection tax.
[7] Telecommunication regulation tax.
[8] Telecommunication special fund levy.
[9] The tax on international incoming trafic rate is 0.2086 Euro/Minute, of which 65.7 percent is refunded to MNOs.
[10] Applicable to telecommunication operators and internet providers.
[11] National interconnection fees.
[12] Contribution to the development of telecommunication fund.
[13] This tax was repealed in FY 2018 and restaured by the 2019 Finance Law.
[14] Special levy on telecommunications.
[15] It represents the share returned to the government.

3. Results

Table 4 displays the AETR results. The tax burden on TELCO exceeds 50 percent in several countries and even 100 percent in some of them, meaning that TELCO's investors would lose money.[36] The AETR varies from 33 percent of generated cash flows in Ethiopia to 118 percent in Niger, with an average value of 64 percent across the sample (column 1 of Table 3). We previously emphasized the fictitious case of a private MNO in Ethiopia since the telecommunication sector was still State-owned in 2018. The market liberalization process began in this country only in June 2019. The AETR in Niger is above 100 percent (118 percent), meaning that our representative MNO will lose money by operating its license in this country. Special taxation explains 65 percent of this excessive tax burden. Among the studied countries, Niger levies the heaviest tax on international calls at 0.13 Euro per minute and significant cumulated turnover fees (5 percent)[37], while it provides one of the most generous incentives regimes with a total CIT exemption for seven years. The tax on international calls was cancelled in 2018 and restored in 2019. This tax regime appears particularly distortionary, burdensome, and uncertain. It may explain why Orange SA, the French MNO, which operates in 18 African countries, decided to leave Niger by selling its subsidiary Orange Niger in 2019.[38] Some countries such as Guinea and DRC also apply specific taxes on traffics and experience high tax burdens. For others (e.g., Mali and Senegal), the high cost of the exploitation license represents a large share of the AETR.

We compute the AETR considering only CIT (column 3 in Table 3). It ranges from 8.5 percent in Tunisia to 37.6 percent in Zambia, with an average value of 27.9 percent. This average is close to the estimation of the AETR for the information media and telecommunication sector, equal to 24.3 percent in Steinmüller et al. (2019). These authors calculate the average firm-industry-level ETR for 142 countries over the period 2004 to 2014.

[36] In such a case, MNOs may obtain additional and particular tax advantages, which may not be publicly disclosed.

[37] These fees finance the Universal Service fund (2 percent of the turnover), the Research and Development fund (1 percent), and the Regulatory Agency (2 percent).

[38] Orange Niger disputed a tax claim of 33 million euros and was ordered to close offices in 2018.

Columns 4 and 6 provide a breakdown of the AETR in terms of general (AEGTR) and special taxation (AESTR). The former expresses the burden of general taxation in each country, as the national Tax and Customs Codes (or Acts) define it. At the same time, the AESTR summarizes special taxation applied to the telecommunication sector. The high level of AETRs results mainly from mobile-special taxation. The AESTR ranges from 2 percent of the pre-tax cash flows in Ethiopia to 106 percent in Niger, with an average value of 38 percent. The AESTR is significantly higher than the AEGTR in 14 countries. The online appendix O.IV displays a sensitivity analysis of our results depending on the discount rate and the interest rate. Our results remain robust to these variations.

Some special taxes are deductible from CIT. Table 4 displays a striking result in several countries (Benin, Chad, DRC, Gabon, Niger, Senegal, Tanzania, Tunisia), where the AEGTR is below the CIT AETR. It may appear surprising since the computation of the AEGTR encompasses the CIT and other direct taxes. However, the taxable base of the AEGTR is smaller since special taxes are deductible for CIT purposes and are not considered in the computation of the CIT AETR. For instance, DRC displays a gap of 21 percent: its CIT AETR is equal to 37.2 percent, while its AEGTR amounts to 16.4 percent. DRC raises numerous and significant special taxes on MNOs, its AESTR reaching 81.1 percent.

Figure 3 depicts the AETR by type of tax. We distinguish special telecommunication taxes from standard general taxes. We notice that license fees represent more than 50 percent of the AESTR (57 percent of the AESTR in Benin, 67 percent in Mali, 63 percent in Senegal, and 60 percent in Sierra Leone). In the other countries, the other special mobile phone companies' taxes explain more than 50 percent of the AESTR. Their share in TELCO's pre-tax cash flows varies from 2 percent in Ethiopia to 76 percent in Niger. We complete our analysis by breaking down the AETR within all beneficiary institutions, namely States and local governments, RAs, and other stakeholders such as Customs Unions[39] or other institutions as the pre-shipment inspection firms (see Figure 4). State and local governments are the main beneficiaries of tax revenues, with an AETR ranging from 20 percent of TELCO's pre-tax cash flows in Morocco to 98 percent in Niger. Indeed,

[39] WAEMU, CEMAC, and ECOWAS, for example.

they receive direct taxes, non-deductible VAT on petroleum products, customs duties, and a share of special telecommunication taxes.

Table 4: AETR (percentage)[40]

	AETR	Statutory rate (CIT)	AETR (CIT)	AEGTR [2]	% AETR	AESTR [1]	% AETR
Algeria	48.77	26.0	26.75	28.84	*59.1%*	19.92	*40.8%*
Angola	43.25	30.0	30.43	32.76	*75.7%*	10.49	*24.3%*
Benin	78.84	30.0	29.46	28.19	*35.8%*	50.66	*64.3%*
Burkina Faso	87.29	27.5	31.67	23.53	*27.0%*	63.75	*73.0%*
Cameroon	66.38	33.0	25.41	25.41	*38.3%*	40.97	*61.7%*
Chad	70.54	35.0	32.3	23.61	*33.5%*	46.93	*66.5%*
Cote d'Ivoire	81.38	25.0 ; 30.0 [3]	22.0 ; 26.4	23.67	*29.1%*	57.71	*70.9%*
Congo, DR	97.49	35.0	37.22	16.36	*16.8%*	81.13	*83.2%*
Egypt	41.17	22.5	23.92	21.4	*52.0%*	19.77	*48.0%*
Ethiopia	33.08	30.0	28.79	31.2	*94.3%*	1.88	*5.7%*
Gabon	64.84	30.0	34.78	31.08	*47.9%*	33.76	*52.1%*
Ghana	54.23	25.0	25.7	29.23	*53.9%*	25.00	*46.1%*
Guinea	93.69	35.0	34.26	17.93	*19.1%*	75.76	*80.9%*
Kenya	43.16	30.0	31.67	34.37	*79.6%*	8.79	*20.4%*
Madagascar	46.71	20.0	21.85	22.39	*47.9%*	24.33	*52.1%*
Mali	93.83	30.0	20.69	20.8	*22.2%*	73.02	*77.8%*
Morocco	35.06	31.0	16.78	18.58	*53.0%*	16.48	*47.0%*
Niger	118.16	30.0	19.84	12.37	*10.5%*	105.79	*89.5%*
Nigeria	40.51	30.0	27.66	32.63	*80.5%*	7.88	*19.5%*
Senegal	92.53	30.0	34.79	32.23	*34.8%*	60.3	*65.2%*
Sierra Leone	70.05	30.0	28.46	28.14	*40.2%*	41.91	*59.8%*
South Africa	37.2	28.0	32.73	31.58	*84.9%*	5.62	*15.1%*
Tanzania	63.2	30.0	28.9	27.03	*42.8%*	36.16	*57.2%*
Tunisia	46.93	25.0 ; 35.0 [3]	6.2 ; 8.5	25.22	*53.7%*	21.71	*46.3%*
Zambia	50.55	25.0 ; 40.0 [3]	32.9 ; 37.6	37.8	*74.8%*	12.75	*25.2%*

Source: Authors computations.

[1]: Average Effective General Tax Rate.

[2]: Average Effective Special Tax Rate.

[3]: Côte d'Ivoire, Tunisia and Zambia apply a higher CIT rate for MNOs, respectively 30, 35 and 40 percent instead of 25 percent.

RAs are the second most important beneficiary as they receive the remaining part of special telecommunication taxes, including universal services fund, regulatory taxes and fees, and research and development contributions.

The autonomy or independence of the Telecommunication RA may trigger a race to the top with the Ministry of Finance, which means an excessive tax burden. Keen and Kotsogiannis (2002) formalize the

[40] Online Appendix O.II illustrates our approach for the case of Cameroon.

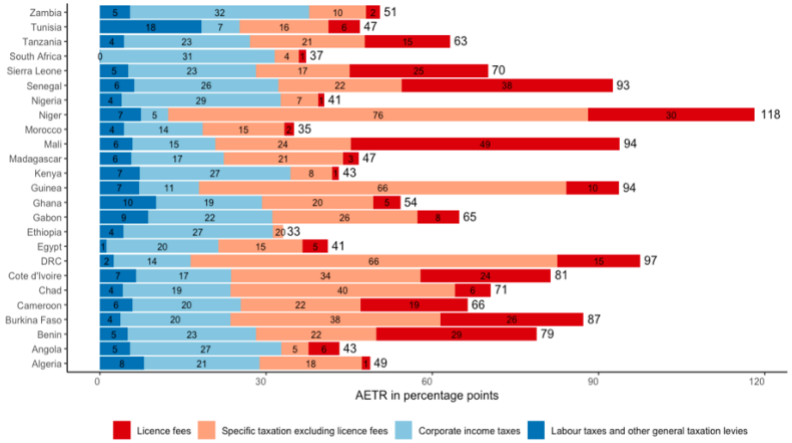
vertical tax competition between two levels of government in federal State. Both institutions tax the same base, and this competition, or equivalently the lack of cooperation among them, induces higher tax rates. Such interactions contrast with the standard view of horizontal tax competition (see Wilson, 1986, Zodrow and Mieszkowski, 1986, and Rota-Graziosi, 2018) and its race to the bottom. Beyond vertical tax competition, Berkowitz and Li (2000) develop the notion of tax rights that is the property rights that a government or an agency has on a particular tax base. Multiple tax agencies' over-exploitation of the same tax base involves an excessively high aggregated tax rate, low investments, inefficient public expenditures, and poor economic performance. The competition or cooperation between the Telecommunication RA and the Ministry of Finance can explain the level of the AETR of TELCO and its heterogeneity across countries.

We now compare the AETRs of three sectors in each country: telecommunications, gold mining,[41] and, a standard economic one.[42] An immediate result (see Figure 5) is that MNOs face a higher tax burden than the gold mining sector in fifteen (15) countries. The AETR in the gold mining sector varies from 31 percent in Nigeria to 72 percent in Chad. Its average value is around 46 percent against 68 percent for the mobile sector. In several countries, the special taxation on telecommunications alone is higher than the total tax burden applied to the mining sector. The mining sector remains, however, more taxed than the standard economic one except in Nigeria.

[41] The AETR computation for the gold mining sector comes from https://fiscalite-miniere.ferdi.fr/en consulted on June, 21th 2019. We retained simulations with a medium-grade open-pit mine (3g/t) and a price of 1,300 USD/oz. Details on the FERDI's representative mining firm are given in the online appendix O.III (for more details, see Laporte et al., 2019). The gold price is considered to be 1,300 USD regarding its observed value on June 17, 2019, at 10h30 (1,333.2 USD/oz on https://www.banque-france.fr/en/statistics/rates/gold-prices-0 consulted on June 17, 2019). Algeria, Egypt, Ethiopia, Morocco, Tunisia, and Zambia are not covered in the FERDI analysis of the gold mining sector.

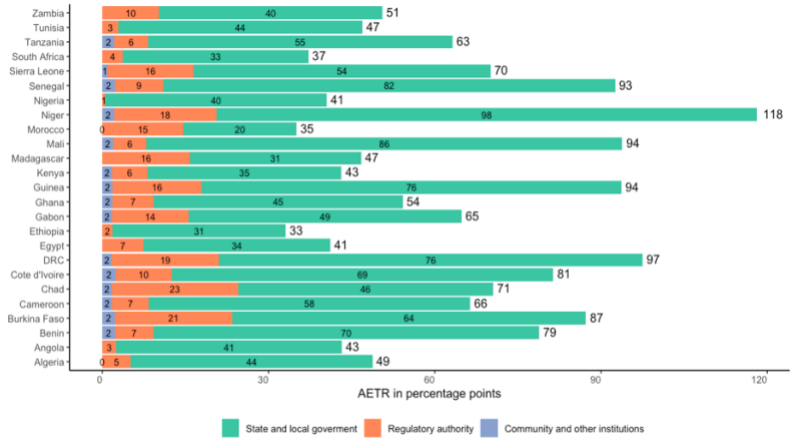
[42] We also compute the AETR of a firm operating in a standard economic sector under the general tax regime and with similar financial features (turnover, OPEX, CAPEX...) than TELCO.

Figure 8: AETR breakdown by taxation type.



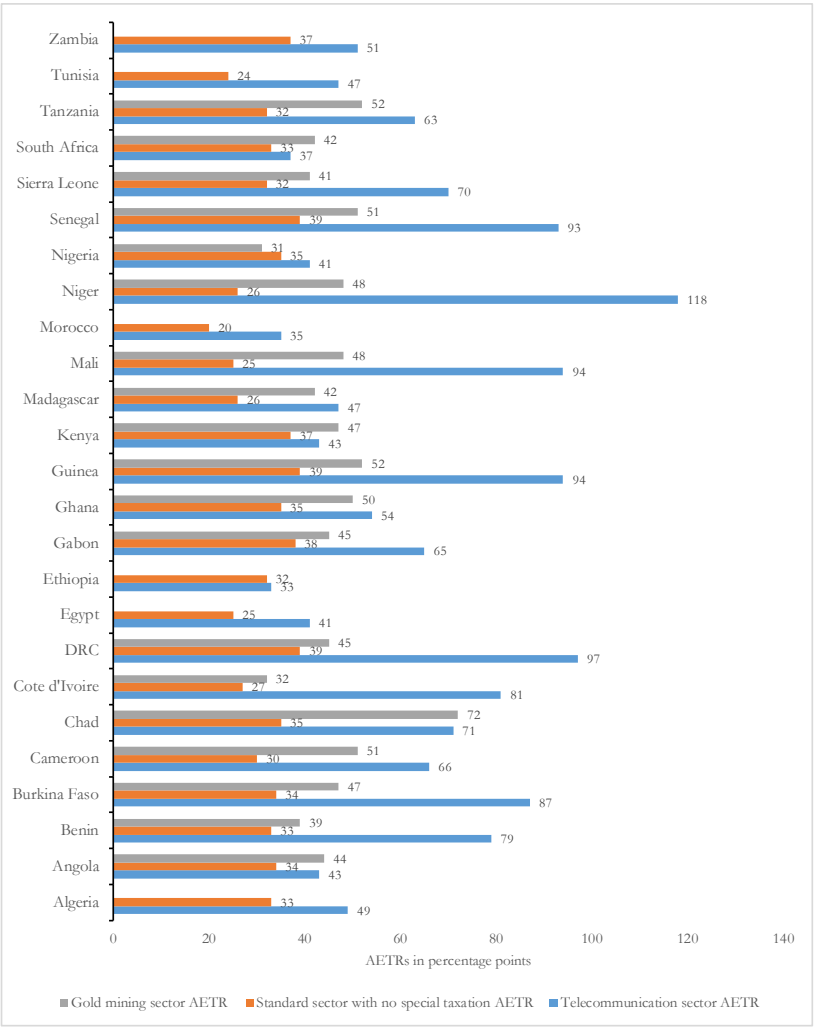
Source: Authors.

Figure 9: AETR breakdown by beneficiary institutions.



Source: Authors.

Figure 10: AETRs across sectors.



Source: Authors.

The difference in taxation between the mining and telecom sector results from the number and the rates of special taxes. It may appear surprising, even inconsistent, given the tax base: a non-renewable resource on one side and a limited resource with significant positive externalities on the

other side. This difference can reflect better coordination or lower tax competition between the MoF and the Minister in charge of the Mining and Petroleum sector than between the former and the Telecommunication RA. Another potential explanation is the more efficient lobbying activity from the extractive industries. For instance, the mining sector enjoys tax stability clauses, which protect investors against any modification of general and special tax rates. The main justification of these clauses is the risky nature of mining investments, given the profile of generated cash flows. Furthermore, extractive industries have to invest a significant level of capital at the beginning of the exploitation to build the mining plant. This investment is irreversible and linked to the deposit. These characteristics expose the sector to the risk of partial expropriation through increased taxation or even complete expropriation through nationalization. Nevertheless, initial investments in the telecommunication sector are also substantial, irreversible, and linked to a given territory. Moreover, they may represent a significant share of total capital expenditures (more than 50 percent for our representative firm). Finally, a last explanation of the higher tax burden for MNOs is the history of each sector, which shapes their respective tax regime: The extractive industry is in place for some time in almost all the studied countries, while the telecommunication sector is relatively new.

4. Conclusion

We estimate the AETR for a standard representative firm, TELCO, in twenty-five (25) African countries using a cash flow model over the length of a telecommunication license. The tax burden varies significantly from one country to another depending on the weight and the characteristics of special taxes applied to telecommunications companies. The AETR varies from 33 percent in Ethiopia to 118 percent in Niger. We distinguish general taxation from special telecommunications taxation highlighting the risk of tax competition between the MoF and the Telecommunication RA. The results show that the MNOs' special taxation component explains more than 50 percent of the AETR in many countries. States and RAs are the main beneficiaries of tax revenues. We also compute the AETR for CIT only. We observe that this measure is lower for TELCO than for a standard firm since several special telecommunication taxes and fees are deductible from the CIT base.

Telecommunication is generally more taxed than the mining sector. We compare the AETR of TELCO with a representative gold mining firm and a standard firm, which both display the same gross return of investment, around 60 percent. The tax burden of TELCO is higher in fifteen (15) countries out of the nineteen (19) countries for which we have information covering their mining tax regime. We mention some potential explanations such as a more efficient lobbying activity of the mining sector or a vertical tax competition between the MoF and Telecommunication RAs[43], which deserve more investigations.

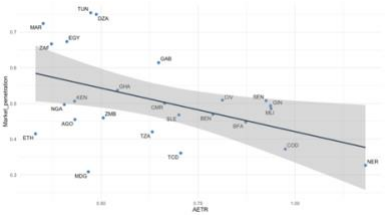
Our analysis is not sufficient to deduce the right level of an optimal tax burden. That is a delicate issue in general and for some specific economic sectors as the extractive industries. Moreover, beyond the level of taxation, the form of taxation (based on profit, turnover, or volume) matters too in terms of economic distortions, telecommunication development, and digital inclusion (see Ndung'u, 2017). Figure 6 displays a correlation analysis between computed AETRs and market penetration and Gross National Income (GNI) per capita.[44] We find a negative correlation between the AETR and these two variables. Countries with lower market penetration rates and GNI per capita experience higher AETRs. Special taxes and fees drive these results since the correlation between AESTRs and market penetration or GNI per capita is also negative. The correlation is by contrast positive between the standard taxes captured by the AEGTRs and the two variables. We stress that telecommunication RAs can raise very distortionary taxes or fees, as Hausman (1998) emphasized in the case of the US Telecommunication sector.[45] The deductibility of some special taxes from the CIT base may increase the economic inefficiencies of special taxation. Alternatively, these correlations may also illustrate that more advanced countries in terms of mobile phone market penetration rely less on special taxation. This relationship could result from more powerful lobbying of MNOs in these countries.

[43] However, it is worth noting that RAs may not be independent from the political influence in practice in some countries.
[44] The small number of countries limits our capacity to conduct rigorous empirical analysis.
[45] The author highlights the inefficiency of fees raised by the Federal Communications Commission to fund a program providing free internet access to schools and libraries. Despite all the technological innovations in the telecommunication sector over the past decades, several issues addressed in this paper remain highly relevant.

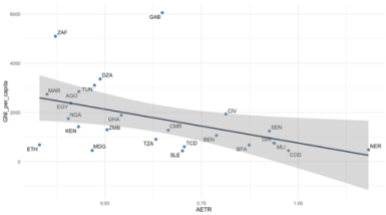
We restricted our analysis to the exploitation of the telecommunication license. However, multiple services may be related to this license, particularly mobile money services, which are booming in Africa and contribute to the financial inclusion of populations. The importance of these services differs across countries. On average, mobile money barely accounted for less than 10 percent of the telecommunication firm's turnover in 2018 (see GSMA database). However, several countries raise new taxes on firms' turnover or mobile money transactions. The analysis of the impact of these taxes on financial and digital inclusions is beyond the scope of this paper and could be addressed in further research.

Figure 11: Correlation analysis.

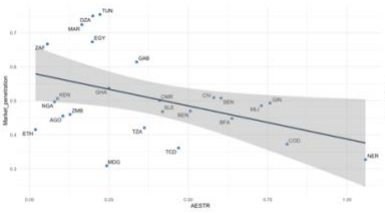
Panel A: AETR and market penetration



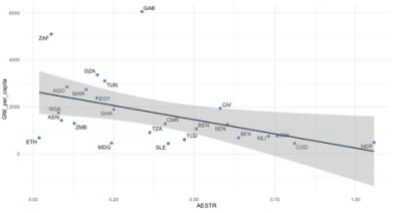
Panel B: AETR and GNI per capita



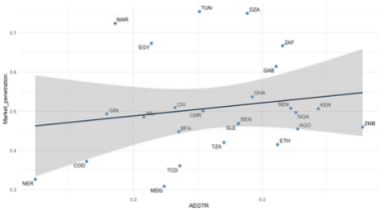
Panel C: AESTR and market penetration



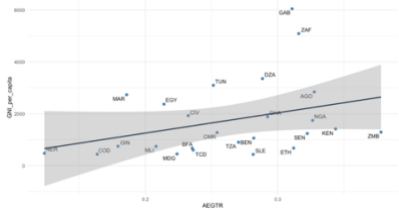
Panel D: AESTR and GNI per capita



Panel E: AEGTR and market penetration



Panel F: AEGTR and GNI per capita



Source: Authors.

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Appendices

Appendix A: Some characteristics of the studied countries in 2018

	Population	GDP/capita EUR (2018)	Unique subscribers Market penetration	Number of MNOs	Date of liberalization	ARPU by subscriber in EUR	3G network coverage by population	SIM cards per subscriber
Algeria	42 228 429	3487.6	74.97%	3	2002	5.19	90.00%	1.57
Angola	30 809 762	2913.9	45.50%	2	2001	14.12	61.00%	1.04
Benin	11 485 048	1099.1	46.94%	4	2000	6.07	63.36%	1.66
Burkina Faso	19 751 535	726.5	44.78%	3	2000	4.85	65.00%	2.15
Cameroon	25 216 237	1359.2	50.08%	4	1998	5.54	74.99%	1.51
Chad	15 477 751	643.2	36.09%	3	1998	5.5	36.89%	1.71
Congo, Dem. Rep.	84 068 091	493.4	37.22%	4	2001	2.42	53.10%	1.23
Cote d'Ivoire	25 069 229	2039.6	50.94%	4	1997	9.52	94.44%	2.48
Egypt	98 423 595	2160.6	67.33%	4	2003	2.2	99.00%	1.51
Ethiopia	109 224 559	653.9	41.50%	1	-	0.85	85.00%	1.38
Gabon	2 119 275	7047.7	61.43%	3	2000	19.15	63.64%	2.23
Ghana	29 767 108	1950.7	53.69%	6	1990	7.13	85.00%	2.29
Guinea	12 414 318	871.0	49.34%	4	2005	5.58	65.00%	1.75
Kenya	51 393 010	1512.9	50.64%	3	2000	6.41	88.00%	1.6
Madagascar	26 262 368	467.2	30.86%	4	1998	4.18	81.46%	1.21
Mali	19 077 690	797.3	48.54%	3	2003	7.59	31.63%	2.36
Morocco	36 029 138	2854.1	72.40%	3	2000	8.11	98.00%	1.7
Niger	22 442 948	506.2	32.66%	4	2002	5.37	62.76%	1.45
Nigeria	195 874 740	1800.5	49.69%	4	1999	5.75	70.00%	1.57
Senegal	15 854 360	1298.2	50.78%	3	1997	6.86	85.00%	2,00
Sierra Leone	7 650 154	473.0	46.79%	3	2003	6.33	40.02%	1.64
South Africa	57 779 622	5645.9	66.69%	4	1994	16.16	99.20%	2.36
Tanzania	56 318 348	939.8	42.03%	6	2005	3.38	48.96%	1.61
Tunisia	11 565 204	3046.0	75.41%	3	2002	3.93	97.00%	1.95
Zambia	17 351 822	1378.5	45.96%	3	1995	4.42	40.00%	1.77
Africa	1 303 404 680	2319.0	49.15%	2.76	-	5.7	69.99%	1.65
World	7591932906.5	9646.9	69.58%	3.08	-	17.55	89.85%	1.544

Sources: WDI, GSMA Intelligence, ITU Measuring the Information Society Report 2018 – Volume 2, and google search.

Note: 3G network coverage by population correponds to "3G mobile coverage, expressed as a percentage of the total market population, at the end of the period."

ARPU by subscriber is the average revenue per user and measures "total recurring (service) revenue generated per unique subscriber per month in the period."

Appendix B: Tax advantages (exemption and reduced rates) in 2018

	CIT			Custom duties on equipment			Other advantages
	Advantage	Number of years	Losses carry forward (Nb. Years)	Advantage	Number of years	Allowance for special taxes on turnover (% of turnover)	Other taxes
Algeria	Exempt.	3	4	Exempt.		0,15	Professional tax (exempt.), 3 years
Angola	Reduced rate: 20%	2	3			0,15	
Benin	Exempt.	5	3	Exempt.		0,15	
Burkina Faso	Exempt. CIT min. tax	1	4	Exempt.		0,15	Apprenticeship tax (exempt.), 7 years.
Cameroon	Reduced rate by 75% by 50%	5 Year 6 to 10	4	Reduced rate: 5%		-	Bussiness licensing fees (exempt.), 2 years.
Chad	Exempt.	5	3	Exempt.		0,15	
Egypt			5	Reduced rate: 2%		0,15	
Ethiopia			5	Exempt.	6	0,15	
Gabon	Exempt.	2	5	Reduced rate: 5%		-	
Cote d'Ivoire	Tax credit		5			0,05	Tax credit (25%) on Bussiness License fees and payroll charges for national employees.
DRC	Exempt.	1	Infinite			0,15	
Ghana			3			0,15	
Guinea	Exemption Reduced rate by 50% by 25%	Year 1 and 2 Year 3 and 4 Year 5 and 6	3			0,15	Lump-sum levy on salaries, Apprenticeship tax: Reduction by 100% for the first 2 years, 50% for year 3 and 4, 25% for year 5 to 8.
Kenya	Reduced rate at 27%	3	9			0,15	
Mali	Reduced rate at 25%	15	3	Exempt.	3	0,1	
Morocco	Exemption Reduced rate at 17.5%	5 Infinite	4			0,15	Local taxes (exempt.), 5 years
Niger	Exempt.	7	3	Exempt.	7	0,22	
Nigeria	Exempt.	5	Infinite			0,15	Apprenticeship tax reduced by 50%.
Senegal			3	Exempt.	3	0,2	Lump-sum levy (exempt.), 3 years.
Sierra Leone	Exempt.	5	10			0,15	
South Africa			Infinite			0,15	
Tanzania	Exempt.	5	Infinite	Exempt.		-	
Tunisia	Exemption Reduced rate by 50%	Year 1 to 10 Year 11 to 20	5			0,15	
Zambia	Exempt.	5	5	Exempt.	5	0,15	

Source: Discussions with financial services of some telecommunication companies, investment and general tax codes, and authors assumptions.

Chapter 2: Demand price elasticity of mobile voice communication: A comparative firm level data analysis

A slightly different version of this chapter is published in *Information Economics and Policy*

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1. Introduction

Since the 2000s, the mobile telecommunications sector has undergone unprecedented development in many developing countries, with a proliferation of "greenfield" operations and the opening up of the sector to competition. This has been accompanied by the creation of regulatory agencies that have become independent over time in most countries (ITU, 2018). All these factors have contributed to a significant decrease in communication tariffs in the sector, increasing consumer consumption, with concomitant welfare gains.

However, the OECD (2012), in a study on Mexico's telecommunications services, concludes that the high prices due to the sector's high concentration have led to losses in consumer welfare from 2005 to 2009. Hausman and Ros (2013), in response to the OECD study, contend that concentration and high market share are a necessary but not sufficient condition for a dominant position of power and higher prices; they show, through an estimation of the demand price elasticity, that the consumer surplus has been affected positively in the period. They argue that, in addition to competition, regulatory agencies should consider various more important factors, such as market share and the price elasticities of demand and supply. In addition, Jeanjean (2015) shows that investment in new technologies is more decisive in lowering prices than competition, which has a limited effect over time.

From another point of view, some authors, such as Matheson and Petit (2020), argue that mobile network operators (MNOs) extract a sort of rent through their exploitative behavior due to limited competition. This implies tacit collusive behavior among MNOs and some failures in regulatory processes. Carlton and Perloff (2004) and Dewenter and Haucap (2008) argue that the demand price elasticity in an industry is an important indicator of companies' decision to engage in collusive behavior. Indeed, low price elasticities are a motivation to engage in collusive behavior, as operators are afforded the choice to set higher prices without losing demand, thus increasing their mark ups. Conversely, higher price elasticities are not conducive to collusion due to the possible "cheating" problem that may result in a great loss to the cheated firm. From all these studies, it may be noted that demand price elasticity is an important factor in an analysis of the demand for

telecommunication services through regulatory processes, consumer welfare, and operators' behaviors.

Many studies on the telecommunications sector have addressed the question of the demand for telecommunications services in the economics literature (Roller and Waverman, 2001; Martins, 2003; Waverman et al., 2005; Madden et al., 2004; Garbacz and Thompson, 2007; Dewenter and Haucap, 2008; Hausman and Ros, 2013). Some have considered market or operator characteristics (Koutroumpis et al., 2011; Kathuria et al., 2009; Karacuka et al., 2011; Dewenter and Haucap, 2008). However, most of these studies were based on operator data at country level and did not allow comparisons between different markets following the same approach. Furthermore, they used pre-2012 data, whereas the sector had undergone significant development in recent years.

Therefore, using quarterly mobile operator data from 2000 to 2017, taken from the GSMA Intelligence database, the objective of my study is to analyze demand price elasticity dynamics for operators in both developing and developed countries, and the extent to which these estimates could vary, depending on such factors as the country of location income level, region, market penetration level, or some other operator characteristics. Moreover, I analyze the relationship between voice communication and internet data usage, filling an important gap in the literature on this issue. To determine short- and long-run price elasticities, I consider a dynamic panel model that I estimate using a system-GMM that produces more efficient and consistent estimates than the first difference GMM. I find that demand for mobile voice communication is more elastic in developed countries, due to their market characteristics. Furthermore, my results show that mobile voice communication is a substitute for internet data usage only in these countries. An important finding is that the demand price elasticity has decreased over the years in developing countries, and that it decreases with market development level. In developed countries, it has remained constant over the years, and increases with market development level. Concerning debates on collusion behaviors or dominant market position power abuse, my results show that there is no differential price elasticity due to operators' market shares or positions, suggesting that asymmetric regulation should be avoided, as proposed by Hausman and Ros (2013). Considering the first period of estimation (2000–2008), my results

confirm the findings of previous studies (Martins, 2003; Lee and Lee, 2006; Kathuria et al., 2009; Koutroumps et al., 2011; Hakim and Neaime, 2014).

The remainder of the paper is organized as follows: Section 2 summarizes some stylized facts and presents a brief literature review. Section 3 presents the empirical strategy and the data used, while Section 4 is devoted to the results. Finally, Section 5 concludes with a discussion of the findings.

2. Stylized facts and literature review

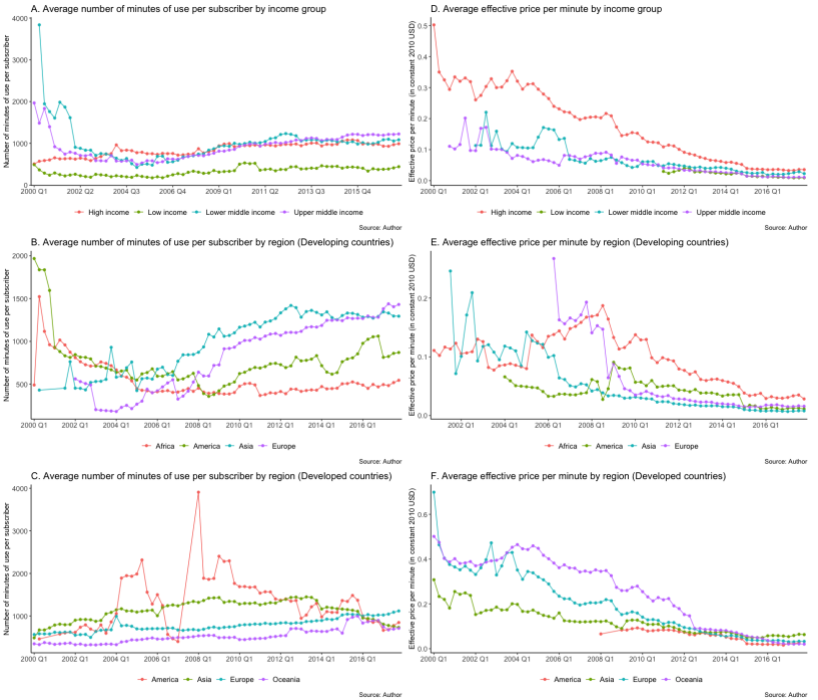
2.1. Stylized facts

Over the years, the number of minutes of use per subscriber has increased in all countries, depending on their income level (figure 1.A). This individual demand has been lower for operators in low-income countries. I observe that operators in developing African countries have faced lower minutes of use per subscriber since 2009 (figure 1.B). The decreasing trend is due to the important growth of subscribers that has occurred since 2001. For operators in developed countries (figure 1.C), the individual demand for minutes of use is lower for those located in Oceania. The peaks observed in America between 2006 and 2010 are due to the unavailability of data for several operators. For 2007, for example, I only have data for one operator, with minutes of use per subscriber of less than 1000; for 2008, I have data for 3 operators, with minutes of use per subscriber of, respectively, approximately 2000, 4000, and 6000.

Figure 1 presents the evolution of the average operator's minutes of use per subscriber and price of a minute of communication, depending on country of location level of income and region. Figure 1.D shows the evolution of the price of a minute of call, depending on countries' income level. Prior to 2009, the price evolution trend was not entirely stable, and the average price of a minute remained above USD 0.05, with high income countries' operators charging higher prices. In the period after 2009, prices generally followed a decreasing trend and were below USD 0.05 for operators in developing countries, with those in low and upper-middle income countries charging lower and similar prices. Operators in high income countries still charged higher effective prices. Considering regions in figure 1.E for operators in developing countries,

I note two periods, 2000–2008 and 2009–2017, with an ambiguous evolution for the first period. At the end of this period, operators in Africa and Europe charged higher prices for a minute of call. In the second period, prices decreased in all regions but remained higher for African operators. In addition, Asian and European operators for which prices had significantly decreased charged lower prices. For operators in developed countries, those located in Europe and Oceania had charged higher effective prices prior to 2012.

Figure 12: Average minutes of use and prices of a minute of call evolution



This decreasing trend can be explained by many factors, such as competition in the markets, the presence of regulatory authorities that provide a framework for price setting, reduced operator costs, and technological progress (innovation). However, Jeanjean (2015), studying

20 countries in the period 2006–2012, argues that the ongoing investments in successive generations of technology (1G, 2G, 3G, and 4G) explain this drop in prices, as operators' traffic increases much more than their revenues (turnover).

An immediate question from this observation is how demand for telecommunications services reacts to price changes. The answer depends on the estimation of the demand price elasticity, which is significant in terms of policy implications. Consider the example of a tax policy that led to a 20 percent increase in prices. With a demand price elasticity of -0.3, one could, ceteris paribus, assert that demand would decrease by 6 percent. Suppose that the elasticity was -1.1; then one would expect a decrease in demand of 22 percent, ceteris paribus. In this example, the first situation leads to a lower impact on consumers, while allowing the government to collect more revenues. It therefore serves as a reference, because it allows a prediction of the potential effects that a policy might have on the demand side. Furthermore, as previously explained, for Carlton and Perloff (2004) and Dewenter and Haucap (2008), the demand price elasticity is an important indicator of companies' decision to engage in collusive behavior.

2.2. Literature review

Many studies have investigated the question of telecommunications services demand price elasticity in the economics literature and considered different markets. Some considered the fixed telephone market (Das and Srinivasan, 1999; Röller and Waverman, 2001; Martins, 2003), others the mobile telephony market (Madden et al., 2004; Lee and Lee, 2006; Dewenter and Haucap, 2008; Kathuria et al., 2009; Koutroumpis et al., 2011; Karacuka et al., 2011; Hausman and Ros, 2013; Hakim and Neaime, 2014), while others have looked into both markets (Waverman et al., 2005; Garbacz and Thompson, 2007; Caves, 2011). Concerning the type of data used, most studies considered panel or time series data at an aggregated country level to estimate price elasticities (Hausman and Ros, 2013; Garbacz and Thompson, 2007; Waverman et al., 2005). Some authors also used operator data at country level to analyze demand for telecommunications services (Koutroumpis et al., 2011; Dewenter and Haucap, 2008; Karacuka et al., 2011). Table A.5 in the appendix presents more detailed information on these studies.

Martins (2003), Madden et al. (2004), and Waverman et al. (2005) compared the price elasticity based on countries' income level and found that the demand was more elastic in developing countries. Lee and Lee (2006) incorporated competition in their analysis by comparing the demand price elasticity between pre-competition and post-competition periods and found that it decreased between the two periods. Kathuria et al. (2009) considered the market development level and compared the price elasticity between Indian states with low and high penetration. Their results showed that the states with low penetration faced higher demand price elasticity than those with high penetration. Dewenter and Haucap (2008) and Karacuka et al. (2011), considering operator data, compared the demand price elasticity between the mobile prepaid and postpaid markets in Austria and Turkey respectively: both studies concluded that the price elasticity was higher for the postpaid markets. Dewenter and Haucap (2008) also differentiate between the price elasticity in private and business usage. Hausman and Ros (2013) estimated the price elasticity to evaluate consumer welfare variation in Mexico and suggested that regulatory authorities should avoid asymmetric regulation. However, they did not explicitly include operators' position or market shares in their analysis.

A novelty of my study is that the data allow me to consider the two types of data previously mentioned, i.e., data at operator level and data covering many countries, including developing and developed countries; this allows comparisons based on operator and market characteristics. Although Dewenter and Haucap (2008), Karacuka et al. (2011), and Hausman and Ros (2013) use a difference-GMM as an estimation strategy, I consider a system-GMM, which produces more efficient and consistent estimates than the difference-GMM and is more suitable for unbalanced panel datasets. Unlike Kathuria et al. (2009), who use the median penetration rate to define the level of market development, I use Rogers's (1976) innovation diffusion theory to identify three levels of market development.[46] In addition, to complete Hausman and Ros's (2013) analysis, I investigate the potential difference in price elasticities

[46] Indeed, innovation diffusion theory holds that the evolution of the penetration rate of an innovation in a given population follows an S-curve. Initially, the adoption rate of the innovation is low, particularly by innovators. Over time, the phenomenon of imitation leads to increasingly more people adopting the innovation, until the market reaches maturity.

based on operators' positions or market shares. Furthermore, in the studies enumerated in this section, Hausman and Ros's (2013) 2011 data are the most recent; since 2011, the sector has undergone significant changes. Therefore, my study constitutes an update of the existing literature on mobile voice communication demand.

3. Empirical strategy

To estimate mobile voice communication demand price elasticity, I draw on Houthakker and Taylor's (1970) model[47], which has been used in several studies, including Swamy (1968), Phlips (1971), and Sexauer (1977). The model is defined as follows:

$$ln(y_{ijt}) = \beta ln(y_{ijt-1}) + \delta ln(p_{ijt}) + \gamma X_{ijt} + \alpha_i + \eta_j + \theta_{ij} + \epsilon_{ijt} \quad (1)$$

where $ln(y_{ijt})$ is the logarithm of the total number of minutes of use per subscriber at a country-operator level over quarter t and represents the individual demand of a subscriber of operator i in country j during quarter t. $ln(p_{ijt})$ is the logarithm of the effective price of a minute of call, X_{ijt} is a vector of control variables, including the logarithm of the GDP per capita, the number of SIM cards per unique subscriber, and a time trend.[48] α_i, η_j, and θ_{ij} represent fixed effects, respectively, at the operator, country, and country-operator levels. ϵ_{ijt} is the error term. δ, which is the variable of interest, represents the short-run price elasticity, while the long-run price elasticity, ρ, is determined by the formula

$$\rho = \frac{\delta}{1-\beta} \quad (2)$$

I use an unbalanced panel of firm level quarterly data from Q1 2000 to Q4 2017. The data come from the GSMA Intelligence database (GSMA, 2018), which covers 237 countries and territories and comprises market

[47] The Houthakker-Taylor model allows consideration of the relation between past and current consumptions and determines both short- and long-run elasticities. Indeed, the model postulates that current demand is not only determined by changes in price, income, or other variables, but also by consumers' habits (Houthakker and Taylor, 1970).

[48] In figure 1, there is an apparent trend in the individual demand; I therefore add a time trend to account for the autonomous structural changes in the demand. Houthakker and Taylor (1970) argue that there are two types of structural changes: autonomous change, which is not caused by preferences in demand and arises externally, and endogenous change, which is due to real time demand.

data (e.g., market shares, numbers of subscribers, market penetration, etc.), financial data (e.g., turnover, OPEX, CAPEX, and their decompositions, etc.), and communication volumes (e.g., outbound and inbound national and international minutes, SMSs, and data volumes).

As I have data on total minutes of use and the number of subscribers by operator in each country, I estimate the number of minutes of use by subscriber to obtain each operator's individual demand relative to their market share. To determine prices, I use total voice revenue data in constant 2010 USD and compute, for each operator, the average revenue per minute of use (this also applies to MB of data used).[49] Data on GDP per capita come from World Development Indicators. As the main variables are in quarterly frequency and GDP per capita in yearly format, I extrapolate quarterly GDP per capita linearly. An important issue in the telecommunications sector is the role of promotional offers, which affect demand structure significantly. In developing countries, a subscriber can have many SIM cards to benefit from these promotions.[50] Following Karacuka et al. (2011), I therefore consider the number of SIM cards per subscriber from GSMA Intelligence as a proxy for promotional offers. Since my interest is in elasticities, I use the logarithmic form of the number of minutes of use per subscriber, the price of a minute of use, and the GDP per capita, for the purpose of interpreting coefficients. Tables A.1–A.3 and A.4 in the appendix present the descriptive statistics and the data description, respectively.

To estimate price elasticity in the telecommunications sector, many authors have used panel fixed effects models. However, their models do not include a lagged dependent variable, as it leads to inconsistent estimates because of its correlation with the error term (Nickell, 1981). Therefore, a dynamic panel model is appropriate. In addition,

[49] Voice revenues include both revenues from incoming, outgoing, and roaming minutes. Koutroumpis et al. (2011), Hausman and Ros (2013), Hakim and Neaime (2014), and Dewenter and Haucap (2008) also used this method to determine the price of a unit of communication. This, additionally, explains the use of total minutes of use rather than outbound minutes of use, for which I do not have data by operator. Furthermore, a subscriber's welfare is affected when he receives calls, which justifies the use of total voice traffic.

[50] These promotions generally involve the purchase of communications top-ups. Indeed, for a given top-up amount, a bonus of x percent, which can even go up to 200 percent or 400 percent, can be applied. However, in general, this credit bonus can only be used for on-net calls, which are also less expensive. This means that subscribers prefer a SIM card for each operator or several operators, to have more communication time with their contacts, who may be subscribers of different operators.

endogeneity is an important issue when estimating a demand model, as price and demand are directly related.[51] Hausman and Ros (2013) and Dewenter and Haucap (2008) used a difference-GMM to estimate their dynamic panel model. The difference-GMM method overcomes these issues by eliminating the heterogeneity bias and mitigating endogeneity concerns. However, Blundell and Bond (1998) and Blundell et al. (2001) argue that it produces less efficient and consistent estimates than the system-GMM in the presence of time persistent variables; however, the stationarity condition must be verified. Nonetheless, Hauk and Wacziarg (2009) argue that the system-GMM produces reduced bias compared to the difference-GMM, even when the stationarity condition is not verified. Moreover, Roodman (2009) argues that, with unbalanced panel data, such as mine, the system-GMM is preferable because the difference-GMM has the shortcoming of amplifying gaps. The system-GMM entails estimating a system of equations with a levels-equation and a difference-equation in which the treatment of the endogenous variables is as follows: In the levels-equation, lagged first differences are used as instruments and, in the difference-equation, the lagged levels are considered as instruments, thus overcoming the issue of endogeneity. I therefore employ a two-step[52] system-GMM estimator (Blundell and Bond, 1998).

4. Results

The results of the estimations are presented in Tables 1 to 6. To avoid a proliferation of instruments, I restrict and collapse the instruments matrix (Roodman, 2009). The Hansen J-test confirms the validity of the instruments. Additionally, I correct the finite sample bias by using Windmeijer (2005) standard errors. The AR(2) test p-value reveals an

[51] Prices are considered endogenous because of the simultaneity problem that may occur with the demand for voice communication. Indeed, there are unobserved factors, such as regulation or supply forces in the telecommunications market, which affect both subscribers' demand and operators' pricing strategies; these factors are known to both groups (Hausman and Taylor, 1981; Hausman et al., 1994; Hausman and Leonard, 2002; Garbacz and Thompson, 2007; Dewenter and Haucap, 2008; and Hausman and Ros, 2013). Following Hausman and Ros (2013), I consider GDP per capita as an exogenous variable.

[52] A two-step estimator is considered to produce estimates that are more robust to heteroscedasticity and other disturbances (see, e.g., Tsionas (2019)) than a one-step estimator. Dewenter and Haucap (2008) used a one-step difference GMM.

absence of second order correlation in the dependent variable. The coefficient of the lagged dependent variable is positive and statistically significant, and its high value supports the appropriateness of the system-GMM.

4.1. Main results

Column 1 of table 1 presents the main results for the global sample. The coefficient of lp, which represents the short-term price elasticity of voice communication demand, is -0.16 and significant at the 1 percent level. Notably, in the short-run, subscribers are less sensitive to price changes. The long-run price elasticity is estimated to be -0.85 and is significant at the 1 percent level.[53] A 10 percent increase in the effective price per minute would result in a decrease in the number of minutes of use per subscriber of 8.5 percent. The lgdp coefficient is equal to 0.46 in the long-run, and significant at the 1 percent level. The individual demand for voice communication increases by 4.6 percent for a GDP per capita increase of 10 percent. Promotional offers, measured by the number of SIM cards per unique subscriber, positively and significantly affect demand for voice communication.

As explained by Houthakker and Taylor (1970) and Dewenter and Haucap (2008), cross-price elasticities of other telecommunications services can play an important role in the demand estimation, as, for example, complementarity or substitutability can occur between internet data usage and voice communication. I therefore investigate the relation between voice communication and internet data usage by including the logarithm of the price of a megabyte (MB) of mobile internet data usage (lpd) to determine the cross-price elasticity.[54] A positive (negative) coefficient of the cross-price elasticity reveals a substitutability (complementarity) relation between voice communication and internet usage. Column 2 of table 1 presents the results. The coefficient of lpd is positive but not significant; therefore, the substitution effect for internet data usage and mobile voice communication is inconclusive. The long-term own price elasticity of voice communication remains significant at

[53] I used the delta method to compute the standard errors (Greene, 2003).

[54] I consider lpd only in this part of the results. Including it in the other regressions leads to a significant drop in the number of observations, since there are many missing data for the variable.

the 1 percent level and is equal to -0.79, which is comparable to the one estimated in column 1.

Due to differences in the terms of fixed line or other information and communication technology (ICT) infrastructure availability and regulation between developed and developing countries, I include in the estimations the proportion of households with a fixed line telephone (in column 3), the proportion with a computer (column 4), and the overall ICT regulatory environment score (column 5). The results remain robust to the control for these factors.

To explore the heterogeneity of the price elasticity between developed and developing countries, I consider the same specifications as in table 1 for each country group. Table 2 presents the results. The results for operators in developing countries are presented in columns 1 to 8. The short-run usage price elasticity is -0.19 and the long-run price elasticity is -0.82, statistically significant at the 5 percent and 1 percent levels, respectively. The lgdp coefficient, which represents the short-run (long-run) income elasticity of voice communication demand, is positive and significant at the 5 percent level, and equal to 0.07 (0.32). Additionally, promotional offers positively and significantly affect subscribers' demand for voice communication. The coefficient of lpd is positive, reflecting a substitution of internet data usage with voice communication; however, the coefficient is not significant. The long-run price elasticity remains stable in terms of coefficient (-0.77) and significance level. It remains robust to the control for fixed line and computers infrastructures, and regulation. Furthermore, in columns 6 to 8, I investigate the differences in price elasticities based on the income level of country of location. I therefore generate, for each country group, a dummy variable, lic, which takes on the value 1 for low-income countries, and 0 otherwise. I repeat the process for low middle-income and upper middle-income countries, whose dummy variables are, respectively, lmi and umi. I then include, for each group, its dummy variable and its interaction with lp. A significant effect of the interaction term means that the concerned country group exhibits a different price elasticity compared to the other groups. The net effect is then obtained by adding the lp and interaction term coefficients. Clearly, none of the interaction terms is significant, suggesting no evidence of differential price elasticity due to the income level of country of location.

Columns 9 to 13 of table 2 present the results for operators in developed countries. In column 9, the short-run price elasticity is significant at the 1 percent level and is equal to -0.37. In the long-run, the price elasticity increases to -1.12, and this coefficient is significant at the 1 percent level. The short-run (long-run) income elasticity of demand is positive, significant at the 1 percent level, and equal to 0.16 (0.48). Furthermore, promotional offers positively affect subscribers' demand for voice communication; however, unlike the developing countries group, its coefficient is not significant. Notably, the price elasticity estimates for developed countries are higher than those for developing countries. This result contradicts, at this stage, the finding by Martins (2003).[55] Figure 2 presents some evidence that could justify this finding. Indeed, this could be due to an important substitute for mobile phones in terms of usage, which is the fixed line telephone in developed countries. Indeed, Waverman et al. (2005) argue that mobile phones tend to be substitutes for fixed lines in developing countries, but complements in developed countries in terms of access. Figure 2.C explains this assertion; as there are as many fixed line subscriptions as there are mobile phone subscriptions in developed countries, one can expect that, if the effective price of a mobile minute of call increases, subscribers should prefer using their fixed lines to using their mobile phones. In developing countries, this option is not available for a large proportion of mobile subscribers. Furthermore, one notes, in figure 2.A, that prepaid subscriptions outnumber contracts in both developed and developing countries. However, contract subscription is more advanced in developed countries than in developing countries (figure 2.D). Lambrecht and Skiera (2006) found that, with changes in prices, prepaid consumers were more likely to churn, and contract consumers were more likely to stay with the same operator but switch to another tariff. I argue that churning does not significantly affect the minutes of use per subscriber, as consumers churn to continue benefiting from the same services and demand, while switching to a lower tariff reduces the average individual demand. This may therefore explain the observation that operators in developed countries have higher demand price elasticity than those in developing

[55] However, Martins et al. (2003) executed their study on data before 2000. In sub-section 3 of the results section, I divide my sample into two sub-samples to see the evolution of the price elasticity, and thus compare my findings to those of other studies.

countries. Furthermore, Dewenter and Haucap (2008) and Karacuka et al. (2011) found that demand was more elastic in postpaid markets. It is worth noting that the development of internet services in developed countries could also explain the higher substitution effect with voice communication. In column 10, the coefficient of lpd is positive and statistically significant at the 5 percent level, suggesting that voice communication is a substitute for internet data usage in developed countries. The short-run price elasticity increases to -0.56, while the long-run price elasticity decreases to -0.82, and becomes comparable to the estimates for the global and developing countries sample. In columns 11 to 13, I control for fixed line and computers infrastructures, and regulation.[56] The estimates remain robust to these factors.

In the next subsection, I analyze the price elasticity of demand with respect to country of location market penetration level.

[56] In column 13, the results show that regulation negatively affects the demand for mobile voice communication. That could be explained by the fact that developed countries generally have strict regulatory policies, which tend to limit competition (Hausman et al., 1997; Vogelsang, 2017).

Table 1: Main results for the global sample

	(1)	(2)	(3)	(4)	(5)
L.lmns	0.810***	0.618***	0.812***	0.791***	0.838***
	(0.0528)	(0.1581)	(0.0801)	(0.0546)	(0.0539)
lp	-0.161***	-0.302**	-0.164*	-0.184***	-0.127**
	(0.0548)	(0.1357)	(0.0975)	(0.0536)	(0.0515)
lgdp	0.087***	0.156**	0.109	0.084***	0.071**
	(0.0307)	(0.0698)	(0.0726)	(0.0270)	(0.0289)
SIMpsubs	0.099**	0.035	0.109	0.122***	0.061*
	(0.0416)	(0.0602)	(0.0830)	(0.0447)	(0.0333)
time trend	-0.006***	-0.010**	-0.007	-0.008***	-0.005**
	(0.0023)	(0.0049)	(0.0050)	(0.0025)	(0.0023)
lpd		0.051			
		(0.0364)			
fixed			9.62e-5		
			(0.0007)		
computers				0.001	
				(0.0006)	
regulation					8.93e-5
					(0.0004)
Constant	1.108***	2.328**	0.968*	1.428***	0.962***
	(0.3202)	(1.1873)	(0.5577)	(0.4168)	(0.3363)
Observations	4339	966	1129	4236	3837
Groups	174	73	100	173	170
Instruments	27	28	30	30	30
AR1-pvalue	0.00	0.00	0.01	0.00	0.00
AR2-pvalue	0.82	0.57	0.30	0.80	0.82
Hansen-pvalue	0.13	0.51	0.28	0.23	0.15
LR price elasticity	-0.851***	-0.791***	-0.876***	-0.880***	-0.785***
Standard error	(0.1002)	(0.1210)	(0.2198)	(0.0856)	(0.1154)

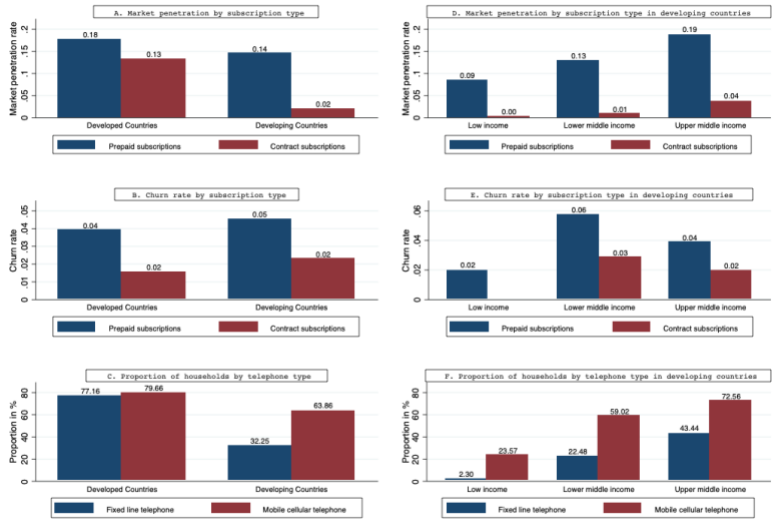
Robust standard errors in brackets. *p<0.10, **p<0.05, and ***p<0.01. The lp is considered endogenous, while the other variables are considered exogenous.

Table 2: Main results for developing and developed countries

	Developing countries								Developed countries				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
L.lmns	0.768***	0.663***	0.712***	0.758***	0.820***	0.752***	0.781***	0.789***	0.667***	0.316*	0.890***	0.666***	0.662***
	(0.0864)	(0.1542)	(0.1367)	(0.0911)	(0.0719)	(0.0900)	(0.0879)	(0.0826)	(0.0703)	(0.1682)	(0.0329)	(0.0722)	(0.0757)
lp	-0.189**	-0.260*	-0.248*	-0.199**	-0.129*	-0.204**	-0.182**	-0.152**	-0.374***	-0.557***	-0.121**	-0.375***	-0.373***
	(0.0855)	(0.1363)	(0.1432)	(0.0896)	(0.0696)	(0.0857)	(0.0865)	(0.0734)	(0.0774)	(0.1325)	(0.0515)	(0.0788)	(0.0740)
lgdp	0.075**	0.106**	0.145	0.077**	0.053**	0.083**	0.053	0.036	0.161***	0.178**	-0.026	0.162***	0.156***
	(0.0330)	(0.0514)	(0.0887)	(0.0390)	(0.0263)	(0.0338)	(0.0334)	(0.0399)	(0.0540)	(0.0693)	(0.0432)	(0.0568)	(0.0448)
SIMpsubs	0.155*	0.031	0.174	0.165*	0.092	0.172*	0.131*	0.132*	0.106	0.510*	-0.049	0.102	0.038
	(0.0839)	(0.0669)	(0.1197)	(0.0882)	(0.0646)	(0.0880)	(0.0788)	(0.0792)	(0.0730)	(0.2685)	(0.0451)	(0.0796)	(0.0502)
time trend	-0.008**	-0.011**	-0.012	-0.009**	-0.006*	-0.009**	-0.007**	-0.007**	-0.012***	0.004	-0.001	-0.012***	-0.011***
	(0.0038)	(0.0054)	(0.0074)	(0.0039)	(0.0034)	(0.0037)	(0.0032)	(0.0030)	(0.0029)	(0.0101)	(0.0029)	(0.0030)	(0.0023)
lpd		0.037								0.207**			
		(0.0376)								(0.0857)			
fixed			-0.001								0.002		
			(0.0013)								(0.0012)		
computers				2.523e-4								-1.169e-4	
				(0.0007)								(0.0017)	
regulation					0.001								-0.003***
					(0.0007)								(0.0011)
lp.lic						-0.070							
						(0.0553)							
lic						-0.286							
						(0.2331)							
lp.lmi							0.028						
							(0.0364)						
lmi							0.074						
							(0.1390)						
lp.umi								-0.021					
								(0.0346)					
umi								-0.013					
								(0.1333)					
Constant	1.671***	2.759**	1.927*	1.826***	1.296**	1.783***	1.702**	1.761**	1.992***	0.305	0.802	2.008***	2.268***
	(0.6275)	(1.3667)	(1.0323)	(0.6736)	(0.5582)	(0.6402)	(0.6673)	(0.7107)	(0.4825)	(2.8887)	(0.5541)	(0.5275)	(0.4919)
Observations	2182	722	760	2103	2059	2182	2182	2182	2157	244	369	2133	1778
Groups	92	51	57	91	91	92	92	92	82	22	43	82	79
Instruments	27	28	28	28	28	51	51	51	33	20	34	34	34
AR1-pvalue	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.00
AR2-pvalue	0.20	0.51	0.17	0.20	0.30	0.18	0.23	0.23	0.10	0.42	0.12	0.10	0.15
Hansen-pvalue	0.30	0.57	0.15	0.30	0.44	0.99	0.16	0.23	0.18	0.78	0.18	0.17	0.13
LR price elasticity	-0.817***	-0.769***	-0.859***	-0.820***	-0.717***	-0.821***	-0.831***	-0.724***	-1.122***	-0.815***	-1.099***	-1.123***	-1.104***
Standard error	(0.1153)	(0.1412)	(0.2111)	(0.1170)	(0.1419)	(0.1098)	(0.1799)	(0.1446)	(0.1440)	(0.1150)	(0.3149)	(0.1464)	(0.1105)

Robust standard errors in brackets. *p<0.10, **p<0.05, and ***p<0.01. The lp and interactions terms are considered endogenous, while the other variables are considered exogenous.

Figure 13: Comparison of some market characteristics by income level



Source: Author

4.2. Country of location market penetration level

In this section, I examine whether price elasticity depends on country market penetration level. I therefore divide the sample into 3 sub-samples, following the innovation diffusion theory. The first sub-sample, for countries with a market penetration lower than 35 percent, is classified as one of low penetration. The second group is for countries with a market penetration between 35 percent and 64 percent, which is classified as one of growth. The last group includes countries with a market penetration higher than 64 percent that I consider as mature. I then estimate the model for each sub-sample.

I first consider the whole sample, including both developing and developed countries (columns 1 and 2 of table 3).[57] The results for operators in the growing markets are presented in column 1. The short-

[57] I only consider the markets in the growth and mature classes, as there is no low penetration market in the developed countries group.

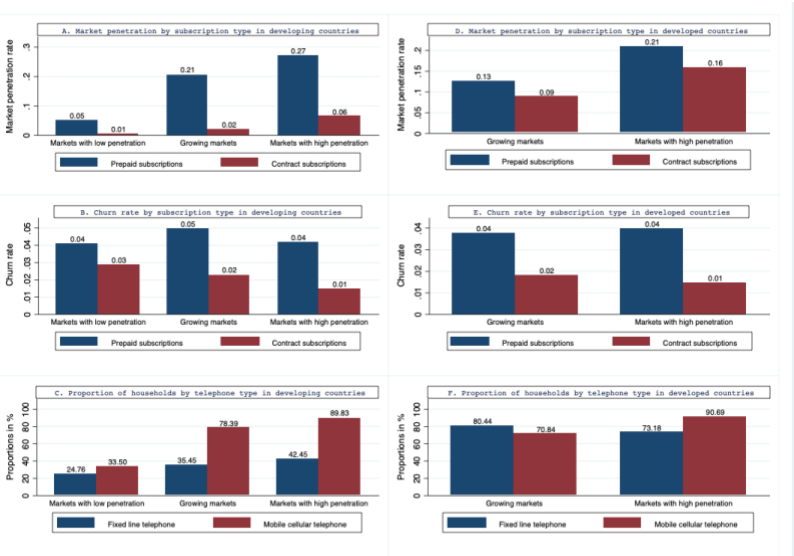
run price elasticity is -0.07 but not significant; the long-run price elasticity is -0.57 and significant at the 10 percent level. Regarding operators in the mature markets (column 2), the short-run price elasticity is -0.16 and significant at the 1 percent level, while the long-run price elasticity is significant at the 1 percent level and equal to -0.86.

Columns 5 to 7 of table 3 present the results for operators in the developing countries. For operators in the less penetrated countries group (column 5), I find a short-run price elasticity of -0.48 and a long-run price elasticity of -1.17, which are statistically significant at the 5 percent and 1 percent levels, respectively. For operators in the growing markets (column 6), the short-run price elasticity is -0.16, while the long-run price elasticity is -0.73; only the long-run price elasticity is statistically significant at the 1 percent level. For operators in the mature markets, the short-run price elasticity is -0.13, whereas the long-run price elasticity is -0.61, which is significant at the 1 percent level (column 7). I note that the short-run price elasticity is not significant, which suggests that price changes do not affect subscribers' demand for voice communication in the short-run in the growing and mature developing markets. Consistent with Martins (2003) and Kathuria et al. (2009), the results for the developing countries support the underlying assumptions in demand theory, i.e., that demand price elasticity is higher in smaller markets, where the diffusion process begins, and whose elasticity decreases with the development of the diffusion process. Figures 3.A, 3.B, and 3.C show some evidence of these findings. Indeed, as there are more prepaid subscriptions than contracts, one expects that, as previously explained, price changes will lead to more churn than switching, and this increases with the level of market development. Furthermore, the proportion of households with fixed line telephones increases with market penetration level, offering potential for substitution.

The results for the developed countries are presented in Columns 8 and 9 of table 3. For operators in the growing markets (column 8), the short-run price elasticity is -0.38 and the long-run price elasticity is -0.84, which are both statistically significant at the 1 percent level. For operators in the mature markets, the short-run price elasticity is -0.33, while the long-run price elasticity is -1.09; they are also both significant at the 1 percent level (column 9). I therefore conclude that, in the developed countries, price elasticity increases with market development level. In figure 3.D,

operators in the markets with high penetration have more contract subscriptions, which suggests that the subscribers in this market are more likely to switch than those in the growing markets. In addition, figure 3.F shows that, in the growing developed market, some fixed line telephone subscribers do not have mobile phones, while all fixed line telephone subscribers are mobile subscribers in the highly penetrated markets. This suggests that subscribers in the developed markets with high penetration may be more likely to substitute mobile voice communication with fixed lines than those in the growing markets.

Figure 14: Comparison of some market characteristics by market penetration level



Source: Author

To test these arguments for validity, I include, in the global sample model specification, the ratio of contract to prepaid subscriptions (cont_prep), the ratio of fixed to mobile lines (fixe_mobile), and their interactions with lp (lp.cont_prep and lp.fixe_mobile) in columns 3 and 4 of table 3,

respectively.[58] The results show that the lp.cont_prep and lp.fixe_mobile coefficients are negative and significant at the 10 percent and 1 percent levels, respectively, supporting the explanation that countries with more contract subscriptions and more fixed line infrastructures experience greater price elasticity.

Table 3: Results by market penetration level

	Global sample				Developing countries			Developed countries	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
L.lmns	0.870***	0.816***	0.834***	0.754***	0.586***	0.782***	0.789***	0.543***	0.697***
	(0.0654)	(0.0503)	(0.0465)	(0.1015)	(0.1618)	(0.1428)	(0.0964)	(0.1336)	(0.0681)
lp	-0.074	-0.158***	-0.126**	-0.161*	-0.483**	-0.159	-0.128	-0.383***	-0.330***
	(0.0736)	(0.0469)	(0.0496)	(0.0905)	(0.2149)	(0.1524)	(0.0795)	(0.1474)	(0.0747)
lgdp	0.034	0.090***	0.066**	0.221***	0.137	0.066	0.053	0.169	0.133***
	(0.0300)	(0.0322)	(0.0277)	(0.0778)	(0.1247)	(0.0508)	(0.0445)	(0.1051)	(0.0482)
SIMpsubs	0.039	0.032	0.078**	0.116	0.236	0.127	0.026	-0.112	0.046
	(0.0612)	(0.0312)	(0.0320)	(0.1105)	(0.2730)	(0.1521)	(0.0513)	(0.1270)	(0.0628)
time trend	-0.002	-0.007***	-0.005**	-0.021***	-0.026***	-0.006	-0.007	0.003	-0.011***
	(0.0033)	(0.0020)	(0.0020)	(0.0062)	(0.0099)	(0.0062)	(0.0040)	(0.0028)	(0.0028)
cont_prep			-1.98e-5						
			(1.69e-5)						
lp.cont_prep			-1.46e-5*						
			(7.85e-6)						
fixe_mobile				-0.941***					
				(0.3561)					
lp.fixe_mobile				-0.213**					
				(0.1041)					
Constant	0.684	1.216***	1.046***	3.333***	4.580***	1.306	1.862**	0.182	2.118***
	(0.5219)	(0.3248)	(0.2862)	(0.8931)	(1.7107)	(1.0151)	(0.9030)	(0.6987)	(0.5064)
Observations	1487	2593	4318	898	259	1194	729	293	1864
Groups	105	126	173	95	28	75	47	30	79
Instruments	27	27	51	42	27	27	27	29	33
AR1-pvalue	0.00	0.00	0.00	0.01	0.07	0.00	0.00	0.07	0.00
AR2-pvalue	0.05	0.12	0.91	0.06	0.72	0.04	0.43	0.43	0.03
Hansen-pvalue	0.19	0.02	0.11	1.00	0.62	0.23	0.28	0.97	0.35
LR price elasticity	-0.569*	-0.856***	-0.762***	-1.524***	-1.166***	-0.728***	-0.610***	-0.838***	-1.089***
Standard error	(0.3123)	(0.1218)	(0.1242)	(0.1982)	(0.1870)	(0.2521)	(0.1892)	(0.1234)	(0.1475)

Robust standard errors in brackets. *p<0.10, **p<0.05, and ***p<0.01. The lp and interaction terms are considered endogenous, whereas the other variables are considered exogenous.

4.3. Time period

As shown in figure 1, the price of a minute of voice communication decreased over the years and was relatively constant for the period 2008–2009. At the beginning of the 2000s, telecommunications goods, such as telephones, were considered to be luxury goods due to their high cost of ownership. Therefore, only certain classes of people could buy and own mobile phones and obtain subscription during this period. Public main

[58] I thank an anonymous referee for suggesting this investigation.

line telephones were the only way for less rich people to communicate, and prices were an important factor in the decision to call and the number of minutes of communication to use. Therefore, I expect that, in this time period, a change in price would result in a bigger change in consumers' choices. However, with time and the development of technologies, the cost of mobile phones has decreased, and the promotion of regulation in many countries contributes to more affordable telecommunications services, thus increasing the number of subscribers. The important role of telecommunications in people's lives and economic activities has led to a dependence on these services. I therefore consider the evolution of price elasticity over two periods, 2000–2008 and 2009–2017. Column 1 of table 4 presents the results for the first period for the global sample. The short-run price elasticity is significant at the 5 percent level and equal to -0.34. The long-run price elasticity is -1.21 and significant at the 1 percent level. Regarding the second period (column 2), the short-run price elasticity is significant at the 10 percent level and is estimated to be -0.07, while the long-run price elasticity is -0.59 and significant at the 1 percent level. Consistent with Lee and Lee (2006), I find that the price elasticity has decreased considerably over time.

For operators in the developing countries, the results are presented in columns 3 and 4 of table 4. Over the first period, the short-run price elasticity is -0.34, while the long-run price elasticity is -1.35. These estimates are significant at the levels of 10 percent and 1 percent, respectively (column 3). For the second period, the short-run price elasticity decreases to -0.06 but is not significant, whereas the long-run price elasticity is -0.50 and significant at the 5 percent level (column 4). Over time, in the developing countries, mobile services are assuming an important role in subscribers' lives' and decreasing their sensitivity to voice communication price changes.

The results for the developed countries are presented in columns 5 and 6 of table 4. Over the first period, the short-run price elasticity is -0.56 and the long-run price elasticity is -1.18. These estimates are both significant at the level of 1 percent (column 5). For the second period, the short-run price elasticity is -0.35 and the long-run price elasticity is -1.17 (column 6), both significant at the 1 percent level. Over the two

time periods, the voice communication price elasticity remained constant.

As most of the studies on telecommunications services price elasticity use pre-2009 data, I compare my findings on the first period to theirs. I find support for the conclusion by Martins (2003) and Madden et al. (2004) that demand is more elastic in developing countries. Furthermore, consistent with Röller and Waverman (2001), Martins (2003), Waverman et al. (2005), Kathuria et al. (2009), Koutroumpis et al. (2011), Caves (2011), and Hakim and Neaime (2014), I find that the demand price elasticity is lower than -1.

Table 4: Results by time period

	Global sample		Developing countries		Developed countries	
	(1)	(2)	(3)	(4)	(5)	(6)
L.lmns	0.723***	0.889***	0.746***	0.874***	0.527***	0.705***
	(0.1091)	(0.0431)	(0.1230)	(0.0705)	(0.1270)	(0.0520)
lp	-0.336**	-0.065*	-0.343*	-0.063	-0.560***	-0.345***
	(0.1374)	(0.0387)	(0.1806)	(0.0621)	(0.1540)	(0.0579)
lgdp	0.181**	0.034	0.103	0.026	0.217**	0.126***
	(0.0787)	(0.0216)	(0.0808)	(0.0234)	(0.0926)	(0.0367)
SIMpsubs	0.186	0.027	0.516	0.036	0.024	0.036
	(0.1550)	(0.0205)	(0.3408)	(0.0427)	(0.1346)	(0.0451)
time trend	-0.009	-0.003	-0.022	-0.002	-0.002	-0.013***
	(0.0057)	(0.0016)	(0.0133)	(0.0026)	(0.0033)	(0.0024)
Constant	0.781	0.731***	3.096	0.876*	0.272	2.514***
	(0.5962)	(0.2780)	(1.9960)	(0.5158)	(0.6207)	(0.4677)
Observations	877	3462	261	1921	616	1541
Groups	70	160	28	83	42	77
Instruments	27	27	27	27	33	33
AR1-pvalue	0.01	0.00	0.04	0.00	0.05	0.00
AR2-pvalue	0.66	0.29	0.85	0.05	0.71	0.12
Hansen-pvalue	0.13	0.14	0.89	0.26	0.17	0.20
LR price elasticity	-1.213***	-0.585***	-1.351***	-0.500**	-1.183***	-1.171***
Standard error	0.1472	0.1556	(0.2230)	(0.2369)	(0.1560)	(0.1098)

Robust standard errors in brackets. *p<0.10, **p<0.05, and ***p<0.01. The lp is considered endogenous, while the other variables are considered exogenous.

4.4. Operators position and market share

In columns 1 and 4 of table 5, I investigate whether price elasticity differs between incumbent operators and followers, in both the developing and developed countries. I therefore generate a dummy variable,

"incumbent", taking on a value of 1 for each quarter and country if the operator is an incumbent, and 0 otherwise. For operators in developing and developed countries, I find that the interaction term for lp and incumbent is negative but not significant, suggesting that price elasticity does not vary between incumbent operators and followers in both samples.[59] The long-run price elasticity estimates remain robust and equal to -0.82 for operators in the developing countries (column 1) and -1.13 for those in the developed countries (column 4), respectively. The two coefficients are significant at the 1 percent level. Furthermore, I examine whether operators' market shares are a factor in estimating the price elasticity. I divide the operators into two groups for the developing and developed countries. Using the market share of 0.27[60] as a reference, I distinguish between operators with low market shares and those with high market shares.

Columns 2 and 3 of table 5 present the results for the low and high market share groups, respectively, in developing countries. For the operators with low market shares (column 2), I find that the short-run price elasticity is -0.23 and statistically significant (at the 5 percent level), while the long-run price elasticity is -0.80 and statistically significant (at the 1 percent level). For the operators with high market shares (column 3), the short-run price elasticity is -0.24 and the long-run price elasticity is -0.85, which are statistically significant at the 5 percent and 1 percent levels, respectively.

Columns 5 and 6 of table 5 present the results for the low and high market share groups, respectively, in developed countries. For the operators with low market shares (column 5), the short-run price elasticity is -0.45 and significant at the 1 percent level, while the long-run price elasticity is estimated to be -1.24 and is statistically significant at the 1 percent level. For the operators with high market shares (column 6), the short-run price elasticity is -0.47 while the long-run price elasticity is -1.20, which are both statistically significant at the 1 percent level.

[59] However, Dewenter and Haucap (2008) find that price elasticity is higher for incumbent operators in Austria.
[60] I consider the median as the reference market share.

The results corroborate my previous finding that price elasticity does not vary with operators' market position in both developing and developed countries.

Table 5: Results by operators' characteristics

	Developing countries			Developed countries		
	(1)	(2)	(3)	(4)	(5)	(6)
L.lmns	0.761***	0.713***	0.719***	0.679***	0.635***	0.607***
	(0.0905)	(0.1217)	(0.0951)	(0.0671)	(0.1305)	(0.0757)
lp	-0.196**	-0.230**	-0.240**	-0.362***	-0.450***	-0.470***
	(0.0880)	(0.1136)	(0.1087)	(0.0769)	(0.1476)	(0.0898)
lgdp	0.078**	0.095**	0.092**	0.151***	0.269***	0.193***
	(0.0343)	(0.0372)	(0.0363)	(0.0515)	(0.0695)	(0.0665)
SIMpsubs	0.164*	0.166**	0.209*	0.101	0.100	0.125
	(0.0883)	(0.0747)	(0.1140)	(0.0693)	(0.0787)	(0.0882)
time trend	-0.008**	-0.011**	-0.009**	-0.012***	-0.017***	-0.015***
	(0.0038)	(0.0052)	(0.0048)	(0.0029)	(0.0044)	(0.0036)
lp.incumbent	-0.077			-1.138		
	(0.5070)			(3.5185)		
incumbent	-0.204			-1.719		
	(1.8510)			(5.9953)		
Constant	1.712***	2.211**	1.863**	1.954***	1.789**	2.330***
	(0.6424)	(1.0581)	(0.7494)	(0.4787)	(0.7891)	(0.5433)
Observations	2182	707	1475	2157	483	1674
Groups	92	39	60	82	34	63
Instruments	34	28	26	46	33	33
AR1-pvalue	0.00	0.00	0.00	0.00	0.08	0.00
AR2-pvalue	0.18	0.03	0.68	0.09	0.11	0.95
Hansen-pvalue	0.56	0.40	0.34	0.72	0.35	0.11
LR price elasticity	-0.819***	-0.802***	-0.852***	-1.126***	-1.235***	-1.196***
Standard error	(0.1146)	(0.1867)	(0.1315)	(0.1454)	(0.1764)	(0.1486)

Robust standard errors in brackets. *p<0.10, **p<0.05, ***p<0.01. The lp and interaction term are considered endogenous, whereas the other variables are considered exogenous.

4.5. Region of location

In table 6, I examine the differences in price elasticities based on operators' country of location region. I therefore generate, for each country group, a dummy variable, Africa (similarly for America, Asia,

Europe, and Oceania[61]), which takes on the value 1 for African countries (similarly for American, Asian, European, and Oceania countries), and 0 otherwise. I then include, for each group, its dummy variable and its interaction with lp. A significant effect of the interaction term means that the concerned countries group exhibits differential price elasticity compared to the other groups.

The results for the developing countries are presented in columns 1 to 4 of table 6. They show that only the lp.Europe and lp.Asia coefficients are statistically significant at the level of 5 percent and 1 percent, respectively. The coefficient of lp.Europe is negative, indicating that operators in developing European countries experience higher price elasticity than those in other developing countries. For these operators' region, the short-run (long-run) price elasticity is -0.24[62] (-1.09) and is statistically significant at the 5 percent level (1 percent level). This result may be explained by the fact that this region has more mobile contract subscriptions, more fixed line telephones, and a deeper internet market penetration than other developing countries. For lp.Asia, the coefficient is positive, indicating that operators in developing Asian countries experience lower price elasticity than those in other developing countries. The short-run (long-run) price elasticity for this region is estimated to be -0.13 (-0.52) and is significant at the 5 percent level (1 percent level). This may be explained by the increased adoption of mobile virtual networks, which allows operators to set lower prices. Demand for better quality of communication services has also significantly increased investment in the region, which produces a significant evolution of the mobile industry in the region. Furthermore, Asian telecommunication industries, such as those in China, Japan, and South Korea, have become significant players in the industry.[63] The long-run price elasticity is significant at the 1 percent level and, respectively, is equal to -0.86 and -0.63 for operators in Africa and America.

[61] Oceania is missing from the developing countries sample, as is Africa from the developed countries sample.

[62] This estimate is obtained by adding the coefficient of lp.Europe to that of lp (-0.163-0.082=-0.245).

[63] https://www-statista-com.ezproxy.uca.fr/topics/5748/telecommunications-industry-in-asia-pacific/.

The results for the developed countries are presented in columns 5 to 8 of table 6. None of the terms for the interaction between the regional dummy variables and lp is significant, suggesting that, in developed countries, there is no evidence of price elasticity variation driven by operators' region. The long-run price elasticity estimate is significant at the 1 percent level and is, respectively, -1.32, -1.13, -1.16, and -1.06 for operators in the developed European, American, Asian, and Oceanian countries.

Table 6: Results by operators' region of location

	Developing countries				Developed countries			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
L.lmns	0.783***	0.776***	0.823***	0.743***	0.612***	0.640***	0.658***	0.685***
	(0.0719)	(0.0889)	(0.0724)	(0.0713)	(0.0600)	(0.0682)	(0.0681)	(0.0666)
lp	-0.187**	-0.163**	-0.111*	-0.239***	-0.512***	-0.407***	-0.397***	-0.334***
	(0.0753)	(0.0828)	(0.0591)	(0.0753)	(0.0722)	(0.0836)	(0.0716)	(0.0678)
lgdp	0.094**	0.067**	0.057**	0.069***	0.180***	0.173***	0.156***	0.146***
	(0.0418)	(0.0328)	(0.0273)	(0.0249)	(0.0492)	(0.0575)	(0.0518)	(0.0454)
time trend	-0.009***	-0.008**	-0.006**	-0.008***	-0.015***	-0.013***	-0.013***	-0.010***
	(0.0032)	(0.0039)	(0.0025)	(0.0026)	(0.0026)	(0.0031)	(0.0027)	(0.0024)
SIMpsubs	0.126*	0.154*	0.090*	0.175**	0.119*	0.130*	0.066	0.072
	(0.0708)	(0.0895)	(0.0529)	(0.0759)	(0.0649)	(0.0694)	(0.0705)	(0.0607)
lp.Africa	0.046							
	(0.0516)							
Africa	0.261							
	(0.1860)							
lp.Europe		-0.082**			0.070			
		(0.0391)			(0.0504)			
Europe		-0.330*			0.125			
		(0.1687)			(0.1128)			
lp.America			-0.046			-0.035		
			(0.0427)			(0.0734)		
America			-0.208			-0.005		
			(0.1539)			(0.2062)		
lp.Asia				0.105***			-0.086	
				(0.0384)			(0.0903)	
Asia				0.376**			-0.176	
				(0.1490)			(0.2211)	
lp.Oceania								0.064
								(0.0937)
Oceania								0.019
								(0.1482)
Constant	1.606***	1.730**	1.325***	1.693***	2.500***	2.197***	2.354***	1.758***
	(0.4620)	(0.6816)	(0.4843)	(0.4644)	(0.4602)	(0.4958)	(0.4665)	(0.4126)
Observations	2182	2182	2182	2182	2157	2157	2157	2157
Groups	92	92	92	92	82	82	82	82
Instruments	51	51	51	51	63	63	63	63
AR1-pvalue	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AR2-pvalue	0.19	0.22	0.28	0.25	0.34	0.19	0.16	0.05
Hansen-pvalue	0.12	0.65	0.67	0.34	0.39	0.93	0.92	0.99
LR price elasticity	-0.862***	-1.092***	-0.627***	-0.522***	-1.320***	-1.131***	-1.161***	-1.061***
Standard error	(0.1537)	(0.1969)	(0.1300)	(0.1550)	(0.1281)	(0.1370)	(0.1147)	(0.1427)

Robust standard errors in brackets. *p<0.10, **p<0.05, and ***p<0.01. The lp and interaction terms are considered endogenous, whereas the other variables are considered exogenous.

5. Conclusion

I analyze mobile voice communication demand price elasticity in developing and developed countries using a dynamic panel model with quarterly operator data. I find that the short-run demand price elasticity is -0.19 (-0.37) for operators in developing (developed) countries, while, for the same operators, the long-run price elasticity is -0.82 (-1.12). Controlling for cross-price elasticity with internet data usage prices reveals that voice communication is a substitute for internet data usage in developed countries. Any shock in internet data usage would thus be reflected in the demand for voice communication in these countries. Across operators in developing countries, I find that those in Asia (Europe) have a lower (higher) long-term price elasticity than the other operators. Furthermore, in developing countries, the telecommunications services price elasticity has decreased over time, and operators in markets with low penetration experience a higher price elasticity than those in more deeply penetrated markets. However, in developed countries, the price elasticity has not changed significantly over the years, and increases with market development level. In addition, for both country groups, I find no evidence of differential price elasticity between incumbents and followers.

As pointed out by Qiang and Pitt (2003), Li et al. (2005), and Howard and Mazaheri (2009), reforms in regulatory policies for the telecommunications sector have a considerable impact on economies. My results have important implications in terms both of regulatory and tax policies. Indeed, in most developing countries, the texts setting out telecommunications regulatory frameworks date from the time of sector liberalization, i.e., before 2007, approximately. However, as pointed out by Biglaiser and Riordan (2000) and Jeanjean (2015), the sector has undergone many developments in terms of structure, technological progress and the development of new generations of technologies. My results, therefore, highlight the need for these countries to update their regulatory frameworks in line with the development of the sector. Furthermore, as mentioned by Klemm and Van Parys (2012), some policies are adopted in some countries by mimicking other countries that have implemented them. This is specifically the case in terms of tax

policies.[64] Thus, finding different price elasticities based on different factors challenges the relevance of adopting policies that simply replicate those in other countries; important economic factors, such as income level and market development level or characteristics, must be considered. The high estimated price elasticities suggest that operators do not have an obvious interest in engaging in collusive behavior that would hinder competition. Moreover, the lack of evidence for a price elasticity differential driven by operators' position or market share supports the recommendations by Hausman and Ros (2013), who suggested that regulation should not be asymmetric on the dominant operator.[65]

[64] In Africa for example, there is a great similarity in the tax systems applied to mobile network operators (Rota-Graziosi and Sawadogo, 2020).

[65] The asymmetry in regulation refers to the application of a differentiated regulatory policy for dominant operators and other operators.

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Appendices

Table A.1: Descriptive statistics for the global sample

	Observations	Mean	Standard deviation	Minimum	Maximum
Minutes of use per subscriber	4,486	990.8	609.6	88.46	4,340
Effective price per minute	4,486	0.0890	0.106	0.000122	1.035
Effective price per megabyte	980	0.0391	0.160	7.61e-05	2.206
GDP per capita	4,468	21,133	19,414	510.8	90,918
SIMpsubs	4,486	1.677	0.285	1.050	2.779
fixed	1,159	48.76	28.39	0.900	100
mobile	1,286	84.68	13.83	19.94	102.4
computers	4,380	52.58	26.94	2.630	95.40
regulation	3,948	74.23	18.73	7.500	97.33
contmp	4,485	0.136	0.123	0	0.676
prepmp	4,465	0.240	0.153	0	1.019

Table A.2: Descriptive statistics for the developing countries sample

	Observations	Mean	Standard deviation	Minimum	Maximum
Minutes of use per subscriber	2,261	1,050	666.5	88.46	3,495
Effective price per minute	2,261	0.0398	0.0460	0.000122	0.400
Effective price per megabyte	735	0.0423	0.182	7.61e-05	2.206
GDP per capita	2,243	5,535	3,657	510.8	14,933
SIMpsubs	2,261	1.775	0.300	1.075	2.779
fixed	771	32.96	18.84	0.900	96.05
mobile	777	82.13	15.78	19.94	102.4
computers	2,179	31.68	20.65	2.630	76.16
regulation	2,126	67.89	20.05	7.500	95
contmp	2,260	0.0573	0.0647	0	0.390
prepmp	2,240	0.286	0.162	0.00130	1.019

Table A.3: Descriptive statistics for the developed countries sample

	Observations	Mean	Standard deviation	Minimum	Maximum
Minutes of use per subscriber	2,225	930.4	539.2	244.3	4,340
Effective price per minute	2,225	0.139	0.125	0.0112	1.035
Effective price per megabyte	245	0.0294	0.0527	0.000800	0.537
GDP per capita	2,225	36,858	15,837	10,538	90,918
SIMpsubs	2,225	1.577	0.231	1.050	2.394
fixed	388	80.14	14.89	37.77	100
mobile	509	88.57	8.842	57.60	100
computers	2,201	73.28	12.69	29.40	95.40
regulation	1,822	81.62	13.76	20.17	97.33
contmp	2,225	0.215	0.117	0.00200	0.676
prepmp	2,225	0.193	0.129	0	0.755

Table A.4: Variable definition and source

Variables	Definition	Source
lmns	Log of the total number of minutes of use per unique subscriber. Total minutes of use is defined as the "total minutes, including incoming, outgoing and roaming calls, transferred over the mobile network in the period." Total subscribers are defined as "Total unique users who have subscribed to mobile services at the end of the period, excluding M2M. Subscribers differ from connections such that a unique subscriber can have multiple connections."	GSMAi
lp	Log of the effective price per minute. The effective price per minute is defined as the ratio of the total voice revenue (turnover) to the total number of minutes of use. Voice revenue is defined as the "recurring (service) revenue generated from voice services in the period". Total minutes of use is defined as the "total minutes, including incoming, outgoing and roaming calls, transferred over the mobile network in the period.".	GSMAi
lpd	Log of the effective price per megabyte (MB). The effective price per MB is defined as the ratio of the total data revenue (turnover) to the total data traffic in MB. Data revenue is defined as the "recurring (service) revenue generated from data (non-messaging) services in the period". Total data traffic is defined as the "total data traffic transferred over the mobile network in the period, expressed in gigabytes (GB)." However, we convert it to megabytes (MB).	GSMAi
lgdp	Log of the GDP per capita in constant 2010 USD.	WDI
SIMpsubs	Number of SIMs per unique subscriber is the total unique active SIM cards per subscriber at the end of the period.	GSMAi
fixed	It represents the "proportion of households with a fixed line telephone."	ITU
mobile	It represents the "proportion of households with a mobile cellular telephone."	ITU
computers	Estimated proportion of households with a computer	ITU
regulation	ITU ICT overall regulatory score. "It pinpoints the changes taking place in the ICT regulatory environment. It facilitates benchmarking and the identification of trends in ICT legal and regulatory frameworks. The Tracker does not measure the quality, the level of implementation or the performance of regulatory frameworks in place, but records their existence and features."	ITU ICT regulatory tracker
contmp	"Contract (postpaid) connections at the end of the period, expressed as a percentage share of the total market population. A contract tariff is such that usage is billed at the end of each service period and a contract is signed for the service, typically for a fixed-term."	GSMAi
prepmp	"Prepaid connections at the end of the period, expressed as a percentage share of the total market population. A prepaid tariff is such that credit is purchased in advance of service use."	GSMAi

Table A.5: Summary of selected empirical studies

Author(s)	Sample	Period of study	Estimation model	Price elasticity estimates
Das and Srinivasan (1999)	India & 19 Indian States	1964 - 1997	Time series and panel models	-0.58
Röller and Waverman (2001)	21 OECD countries	1970 - 1990	Simultaneous equations model with GMM	-1.13
Martins (2003)	74 developing and developed countries	1980 and 1985	Deaton–Muellbauer Iterative (DMI) procedure	. Static model (Rich countries: -1.43; Poor countries: -1.62) . Dynamic model (Rich countries: -2.29; Poor countries: -2.42)
Madden et al. (2004)	56 countries	1995 - 2000	Panel fixed effects	. Global sample: - 0.55 . High income countries: -0.53
Waverman et al. (2005)	92 low and high income countries	1980 - 2003	system of 3 equations using GMM	-1.5
Lee and Lee (2006)	Korea	M1 1996 - M12 2004	OLS and GLS	. Pre-competition period: -0.9 . Post-competition period: -0.609
Garbacz and Thompson (2007)	53 developing countries	1996 - 2003	Panel fixed effects and IV method	. Connection charge: -0.37 to -0,029 . Monthly charge: -1.268 to -0.195
Dewenter and Haucap (2008)	3 Austrian mobile operators	M1 1998 - M3 2002	Difference-GMM	. Business tariffs (Short-Run (SR): -0,33 and Long-Run (LR): -0,74) . Private consumer tariffs (SR: -0,14 and LR: -0,37) . Postpaid tariffs (SR: -0,24 and LR: -0,67) . Prepaid tariffs (SR: -0,08 and LR: -0,20) . Among the 3 mobile operators (SR: -0,26 to -0,40 and LR: -0,47 to -1,10)
Kathuria et al. (2009)	19 Indian States	1999 - 2008	Panel 3SLS	. Global: - 2.12 . states with high penetration : -1.87 . states with low penetration: -1.92
Koutroumpis et al. (2011)	3 Greek mobile operators	2005 - 2010	Generalized least square (GLS)	-1.645
Caves (2011)	38 US States	2001 - 2007	Panel 2SLS and 3SLS	. Wireless: -1.76 to -1.63 . Wireline: -0,57 to -0.54
Karacuka et al. (2011)	5 Turkish mobile operators	M1 2006 - M12 2006	Difference-GMM	. Entire market (SR: -0,28 and LR: -0,45) . Prepaid market (SR: -0,36 and LR: -0,33) . Postpaid market (SR: -0,20 and LR: -0,72)
Hausman and Ros (2013)	17 countries, including 9 OECD countries, 5 Latin American countries, and 5 Asian countries	Q2 2004 - Q3 2011	Panel fixed effects and difference-GMM	. SR: -0.10 and . LR: -0.476
Hakim and Neaime (2014)	Middle East and North African countries	1995 - 2007	Panel 2SLS	-1.241 to -1.008

Chapter 3: Mobile money services adoption and intra-African goods trade

This chapter is joint work with Abdoul-Akim WANDAOGO. A slightly different version of this chapter is published in *Economics Letters*.

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1. Introduction

Introduced in Africa by Kenya since 2007, Mobile Money (MM) has gradually spread across the continent. Defined as a mobile payment system linked to a mobile phone number, MM allows its owners to carry out most transactions offered by a traditional bank. Over the years, MM has grown to become an important transaction tool in most developing countries, but also in some developed countries. However, in Africa, MM has become a preferred means not only for individuals rationed by the traditional banking system, but also for those who have access to the traditional system. As a matter of fact, before 2012, 31 percent of MM account holders in Africa used it at least once a year for bill payment or money transfer (Demirguc-Kunt and Klapper, 2012). According to Jack and Suri, 2014, from 2016 to 2017, the number of MM adopter accounts increased by 20.9 percent bringing the total accounts number to 104.5 million in west Africa. Moreover, in 2019, worldwide, there were 228 MM agents on average per 100,000 inhabitants, compared to 11 bank branches and 33 ATMs (GSMA, 2019). Furthermore, in the same year, there were more than 1 billion MM accounts for 290 MM services deployments, nearly 50 percent of which were in sub-Saharan Africa. This rapid development has made MM an almost inevitable service in adopting countries. MM has then enabled the financial inclusion of a large part of the population rationed by the conventional banking system in countries that adopted it, while providing them a simple, efficient and accessible mean of payment for their business interactions.

From money transfer to bill payment and commercial transactions, MM has become the favorite payment means for economic agents in many African markets. Furthermore, the flexibility and availability of MM services had contributed to make it transcend national borders with possibilities for inter-operator and international transactions with enterprises from micro to medium-sized and individuals. In fact, MM enable an intensification of intra-African trade as it promotes financial inclusion and financial development (CGAP, 2012; Claire and Arunjay, 2013; GSMA, 2014; Burns, 2015; Asongu, 2013; Donovan, 2012), which in turn increase international trade (Hajilee and Niroomand, 2019; Demir and Dahi, 2011; Hur et al., 2006). In fact, on average, 16.5% of users report using MM for commercial transactions (between 12% and 21%, depending on the operator offering the service). These transactions

include 74% for payments to suppliers, while 23% are for payments received from customers (Claire and Arunjay, 2013; Enberger, 2013).

The role of MM in business activities in Africa appears to be very important according to these studies. However, we can observe that no empirical studies have so far addressed the role of MM in increasing African trade. We then investigate the causal effect of MM adoption on the intensity of intra-African goods trade. The major contribution of this study on the literature, is the fact that it is the first studies to our knowledge, to investigate the effect of MM in trade intensification. In this sense, we highlight an important factor in determining trade openness between African countries. In addition, we consider several trade items.

Using a propensity score matching method (PSM), our results suggest that MM adoption has led to increased intra-African trade. We also show that the effect is more important on exports than import. Regarding the category of goods, we found that food items goods category is the most affected by MM adoption, including import as export. When we use entropy balancing as alternative method, our result remains the same compared to PSM results.

The rest of the paper is organized as follow: The Section 2 deal with data and methodology, however the section 3 present and discuss empirical results. In section 4, we carry out further analysis to assess the robustness of our results. Section 5 concludes the study and gives policy implications.

2. Data and identification strategy

2.1. Data

To analyze the causal effect of MM adoption on intra-African trade, we consider panel data on 48 African countries from 1995 to 2018. The sample is composed by a treated group of 40 countries and a control group of 8 countries based on the availability of data. Table A in appendix present list of countries and the year of MM adoption.

Our main explanatory variable is MM which is a dummy variable taking value 1 if at least one MM service is available and 0 otherwise. The dependent variables are goods trade in share of GDP and its breakdown into imports and exports. Based on the literature, we retain a set of

control variables capturing income effects, country size, macroeconomic effects and that could affect both MM adoption and trade (Gnangnon and Iyer, 2018; Nath and Liu, 2017; Choi, 2010). Appendix A and B respectively present descriptive statistics of the data and variables details.

In fact, good economics through strong growth would lead to the adoption of solutions that would include financially excluded populations. Having a large potential number of users (relative to the total population) for a technology would increase the likelihood of adoption due to the underlying network effect. In addition, population concentration would reduce the cost of mobile money deployment, increasing the likelihood of adoption. Regarding financial depth and inflation, we expect the positive effect of financial depth (used as financial development) on MM adoption and inflation to be negatively correlated with MM adoption. Countries with a developed traditional banking system may face higher financial exclusion. Therefore, an alternative to the traditional system should be found to include them. While worse macroeconomic conditions as measured by inflation may discourage the adoption of alternative payment solutions. According to the regime of change, we retain the fixed regime measured by a dummy variable that takes 1 if the country has adopted a fixed exchange rate regime and 0 otherwise. This variable was constructed by the authors from the International Monetary Fund (IMF) classification of exchange rates. It is expected that the fixed regime, which is a guarantee of stability, will encourage the adoption of MM. Except for the data on the exchange rate regime, the rest of the data is taken from the World Bank's World Development Indicators (WDI). For natural resource rents, we are expecting a positive effect on the adoption of MM. Because a high natural resource rent implies a natural resource rich country. While natural resource areas attract not only artisanal exploitation but are also in rural areas. While artisanal miners and rural areas are the most financially excluded. In addition, this will impact the income of local populations who will seek alternative means of payment.

2.2. Methodology

We follow Sawadogo (2020), Girma et al. (2003), and Wagner (2002) using a Propensity Score Matching (PSM) method developed by Rosenbaum and Rubin, 1983. This estimation strategy is suitable for observational studies (non-randomized). PSM has the advantage to

permits correction for sample selection bias due to observable differences between the treatment and the control groups. In addition, it is suitable for dummy variables as variables of interest.

For the estimation, we follow two key steps. In a first step, using a probit approach, we estimate propensity score (PS) which is the probability for a country i to adopt MM giving a set of covariates also explaining trade variables:

$$e(y_i) = P(MM_i = 1/y_i) \quad \text{(eq.1)}$$

Thereafter, we estimated the Average Treatment effect on the Treated (ATT) which is the average difference between the trade share in GDP in countries with MM (TD^1) and the trade share in GDP they would have in non-MM adoption situation (TD^0).

$$ATT = E[(TD_i^1 - TD_i^0)/MM_i = 1] \quad \text{(eq.2)}$$

$$ATT = E(TD_i^1/MM_i = 1) - E(TD_i^0/MM_i = 1) \quad \text{(eq.3)}$$

In fact, the second term of (eq.2) is not observable. We then replace it by TD in countries that have not adopted MM but have comparable basic characteristics (y) than MM adopters as MM adoption is correlated with a set of basic characteristics y that can affect the level of trade. However, following Rosenbaum and Rubin (1983), we concentrate information from y in a unique variable $e(y_i)$ estimated in the first step. We can therefore rewrite the ATT:

$$ATT = E[TD_i^1/MM_i = 1, e(y_i)] - E[TD_i^0/MM_i = 0, e(y_i)] \quad \text{(eq.4)}$$

We then estimate the ATT using four matching methods. We first consider nearest neighbor matching which matches each MM adopter with the non-adopter with closest PS (we consider n=1, 2, and 3). We also consider radius matching which retain non-adopters having a PS comprises in a radius (we consider r=0.005, r=0.01, and r=0.05). Kernel estimator which consists in matching each MM adopter with a weighted average of all non-adopters is also used to estimate the ATT. Finally, we perform a local linear regression which improves kernel estimator by including a linear term in the weighting function (Fan, 1993).

3. Empirical results

3.1. Propensity scores estimates

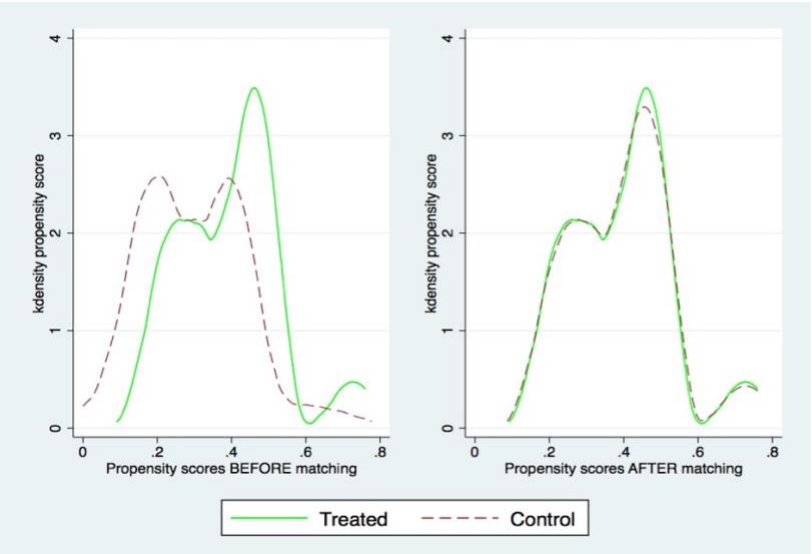
We present the results of the PS estimations in Table 1. The results show that population, financial depth, and fixed exchange rate regime have a positive and significant effect on MM adoption at conventional thresholds. We find that Log(GDP per capita) effect on MM adoption is negative but not significant. Worse macroeconomic situations measured by the inflation rate is negatively affecting MM adoption and its coefficient is significant at 1%. Furthermore, natural resource rents do not significantly affect the adoption of MM in African countries. We found a positive effect of adopting fixe regime on MM adoption.

Table 1: Propensity score estimation results

	Mobile Money
Log(Population)	0.2454***
	(0.0369)
Log(GDP per capita)	-0.0606
	(0.0564)
Financial depth	0.0067***
	(0.0022)
Inflation	-0.0191***
	(0.0064)
Natural resources rents	-0.0015
	(0.0040)
Fix regime	0.2094*
	(0.1082)
Constant	-4.0268***
	(0.7765)
Observations/Pseudo-R2	907/0.08

Note: standard errors in brackets.*** significance level at 1 percent; ** significance level at 5 percent; * significance level at 10 percent.

Figure 1: propensity score before and after matching



Source: Authors construction

3.2. Matching results

Matching results are presented in tables 2 to 4. To check the quality of the estimations, we run various diagnostic tests. First, the pseudo-R2 analyses how well the control variables explain the probability of adopting MM (Sianesi, 2004). In fact, Caliendo and Kopeinig (2008) argue that a good model performance should be associated to a "fairly low" value (all pseudo-R2 here are lower than 0.01 which is close to zero). That is mean our matching provided balanced score, so the estimations are robust. Furthermore, we test the conditional independence assumption regarding both observables and unobservables (Rosenbaum, 2002). On observables side, when we perform the standardized bias test which evaluates the marginal distance distributions of the retained control variables, it reveals the absence of statistical mean difference between MM adopters' characteristics and non-adopters' after matching, as the p-value are higher than all conventional thresholds. Concerning unobservables, we conducted the

Rosembaum (2002) lower bound sensitivity test[66] which analyses if there are no unobservables that could affect the effect of MM adoption on goods trade.

Table 7: Matching results for Log(Total goods trade/GDP)

Treatment variable: Mobile Money	1-Nearest Neighbor Matching	2-Nearest Neighbor Matching	3-Nearest Neighbor Matching	Radius Matching r=0.005	Radius Matching r=0.01	Radius Matching r=0.05	Local Linear Regression Matching	Kernel Matching
Dependent variable: Log(Total Goods trade/GDP)								
Average Treatment Effect (ATE)	0.4746***	0.4746***	0.4746***	0.4746***	0.4746***	0.4746***	0.4746***	0.4746***
	(0.0738)	(0.0714)	(0.0668)	(0.0655)	(0.0691)	(0.0707)	(0.0714)	(0.0727)
Average Treatment on the Treated (ATT)	0.6162***	0.6259***	0.6121***	0.6165***	0.6047***	0.5268***	0.6025***	0.5324***
	(0.1125)	(0.1103)	(0.1013)	(0.0903)	(0.0833)	(0.0668)	(0.0686)	(0.0677)
Observations/Treated observations	907/301							
Quality of the matching								
Pseudo-R2	0.007	0.009	0.009	0.009	0.007	0.003	0.007	0.003
Rosenbaum bounds sensitivity test	2.3	2.9	3.3	3.6	3.6	3.4	4.3	3.4
Standardized bias (p-value)	0.415	0.299	0.284	0.306	0.47	0.876	0.415	0.875
ATT by type of goods								
Agricultural raw materials	0.1724	0.1091	0.0829	0.1195	0.0868	-0.0181	0.0751	-0.0112
	(0.1787)	(0.1677)	(0.1677)	(0.1402)	(0.1365)	(0.0994)	(0.1063)	(0.1039)
Primary commodities excluding fuels	0.5560***	0.5795***	0.6211***	0.5817***	0.5925***	0.5017***	0.5881***	0.5109***
	(0.1476)	(0.1245)	(0.1216)	(0.1118)	(0.0999)	(0.0779)	(0.0804)	(0.0809)
All food items	0.6194***	0.6636***	0.7013***	0.6444***	0.6608***	0.5638***	0.6633***	0.5735***
	(0.1306)	(0.1275)	(0.1209)	(0.1145)	(0.1008)	(0.0770)	(0.0761)	(0.0784)

Standard errors in brackets. *** significance level at 1%, ** significance level at 5%, * significance level at 10%. **Bootstrap replications=500**

Table 2 present the results of MM adoption on total goods trade and its breakdowns. We observe that all estimated ATT are positive and significant at 1 percent level. On average, countries that adopted MM, experience higher goods trade share in GDP of about 0.6 percent (local linear regression), representing 58 percent of log(Total goods trade/GDP) standard deviation (corresponding to 1.031); therefore, making this result economically meaningful. These results are consistent with our basic assumptions. The adoption of MM is thus a potential factor for improving intra-African trade.

We also investigate the effect of MM adoption on both aggregated goods imports and exports. In each table, we report first the ATE, and then the ATT. Its coefficient is respectively 0.47, 0.40, and 0.76 percent for respectively total trade, imports, and exports meaning that MM increases trade volume for both adopters and non-adopters. As for the ATT, the coefficient is respectively 0.68 percent (from 0.59 to 0.71 percent) and

[66] The test is conducted at 5 percent level.

0.56 percent (ranging from 0.523 to 0.576 percent) on average for respectively imports (table 3) and exports (table 4), showing that MM adoption effect on goods trade is higher on imports than exports.

Table 8: Matching results for Log(Total goods imports/GDP)

Treatment variable: Mobile Money	1-Nearest Neighbor Matching	2-Nearest Neighbor Matching	3-Nearest Neighbor Matching	Radius Matching			Local Linear Regression Matching	Kernel Matching
				r=0.005	r=0.01	r=0.05		
Dependent variable: Log(Goods Imports/GDP)								
Average Treatment Effect (ATE)	0.4009***	0.4009***	0.4009***	0.4009***	0.4009***	0.4009***	0.4009***	0.4009***
	(0.0773)	(0.0778)	(0.0753)	(0.0793)	(0.0778)	(0.0795)	(0.0815)	(0.0774)
Average Treatment on the Treated (ATT)	0.7143***	0.7251***	0.7170***	0.7116***	0.7030***	0.5924***	0.6639***	0.6026***
	(0.1397)	(0.1277)	(0.1223)	(0.1135)	(0.1031)	(0.0739)	(0.0748)	(0.0778)
Observations/Treated observations	907/301							
Quality of the matching								
Pseudo-R2	0.007	0.009	0.009	0.009	0.007	0.003	0.007	0.003
Rosenbaum bounds sensitivity test	2.4	3	3.3	3.5	3.6	3.3	3.9	3.4
Standardized bias (p-value)	0.415	0.299	0.284	0.306	0.47	0.876	0.415	0.875
ATT by type of goods								
Agricultural raw materials	0.2279	0.2434	0.3159**	0.3046**	0.3088***	0.2267***	0.3017***	0.2333**
	(0.1681)	(0.1530)	(0.1341)	(0.1228)	(0.1076)	(0.0852)	(0.0836)	(0.0934)
Primary commodities excluding fuels	0.5220***	0.5580***	0.5670***	0.5566***	0.5541***	0.4687***	0.5411***	0.4769***
	(0.1171)	(0.1196)	(0.1041)	(0.0977)	(0.0924)	(0.0747)	(0.0768)	(0.0760)
All food items	0.6514***	0.6677***	0.6789***	0.6532***	0.6714***	0.5738***	0.6606***	0.5836***
	(0.1255)	(0.1190)	(0.1110)	(0.1061)	(0.0997)	(0.0732)	(0.0752)	(0.0774)

Standard errors in brackets. *** significance level at 1%, ** significance level at 5%, * significance level at 10%. **Bootstrap replications=500**

Furthermore, we find that MM adoption benefits more to food items trade. In fact, food items are generally produced in rural areas by populations excluded from the traditional financial system. MM therefore allows them to carry out transactions and interact with external partners at lower cost than traditional banking transactions. We do not find any significant effect on agricultural raw materials total trade. However, the effect on their imports and exports taken separately is significant but is less than that of primary commodities and food items.

Table 9: Matching results for Log(Total goods exports/GDP)

Treatment variable: Mobile Money	1-Nearest Neighbor Matching	2-Nearest Neighbor Matching	3-Nearest Neighbor Matching	Radius Matching			Local Linear Regression Matching	Kernel Matching
				r=0.005	r=0.01	r=0.05		
Dependent variable: Log(Goods Exports/GDP)								
Average Treatment Effect (ATE)	0.7604***	0.7604***	0.7604***	0.7604***	0.7604***	0.7604***	0.7604***	0.7604***
	(0.0892)	(0.0849)	(0.0838)	(0.0803)	(0.0829)	(0.0788)	(0.0859)	(0.0860)
Average Treatment on the Treated (ATT)	0.5230***	0.5672***	0.5756***	0.5742***	0.5627***	0.5283***	0.6024***	0.5283***
	(0.1408)	(0.1263)	(0.1282)	(0.1159)	(0.1046)	(0.0870)	(0.0863)	(0.0803)
Observations/Treated observations	907/301							
Quality of the matching								
Pseudo-R2	0.007	0.009	0.009	0.009	0.007	0.003	0.007	0.003
Rosenbaum bounds sensitivity test	1.8	2.4	2.7	2.9	2.9	2.9	3.5	2.9
Standardized bias (p-value)	0.415	0.299	0.284	0.306	0.47	0.876	0.415	0.875
ATT by type of goods								
Agricultural raw materials	0.5811*	0.5321**	0.3591	0.4276*	0.3633*	0.2634*	0.3756**	0.2698
	(0.2978)	(0.2540)	(0.2528)	(0.2196)	(0.2093)	(0.1573)	(0.1535)	(0.1660)
Primary commodities excluding fuels	0.6537***	0.6807***	0.7806***	0.7228***	0.7323***	0.6417***	0.7523***	0.6504***
	(0.2052)	(0.1877)	(0.1801)	(0.1474)	(0.1592)	(0.1101)	(0.1208)	(0.1108)
All food items	0.7592***	0.8297***	0.9078***	0.8146***	0.8046***	0.7292***	0.8437***	0.7362***
	(0.2220)	(0.2145)	(0.1859)	(0.1726)	(0.1629)	(0.1273)	(0.1257)	(0.1219)

Standard errors in brackets. *** significance level at 1%, ** significance level at 5%, * significance level at 10%. **Bootstrap replications=500**

3.3. Considering an alternative matching method: entropy balancing

To test the sensitivity of our results to the matching method, we carry out the entropy balancing method (Hainmueller, 2012 and Hainmueller and Xu, 2013). This method consists of reweighting the covariates to rebalance the control group relative to the treatment group. We therefore first estimate the weighting variable, and then evaluate the effect of our treatment variable (MM adoption) on the intensity of intra-African goods trade using weighted least squares estimations.

In table 5, we present the synthetic control group, while the estimation results are on table 6. We can observe that in first time, the mean difference between MM adopters and non-adopters is significant regarding majores of covariables (column 1, 2, 3 and 4). It is precisely, total population, GDP per capita, inflation rate and natural resources rents. However, after applying the weights, the average difference between both groups shrinks and is no longer significant (column 5, 6 and 7).

Table 5: Building the synthetic control group

	1	2	3	4	5	6	7
	a	b	c=a-b	d	e	f=b-e	g
Variables	Non_MM	MM	difference	p_value	Wight*Non_MM	difference	p_value
Log(Population)	17.41841	26.10497	-8.68656	0.00	26.10471	0.00026	1.000
Log(GDP per capita)	15.7516	16.45936	-0.70776	0.00	16.45937	-0.00001	1.000
Financial depth	7.15563	7.14722	0.00841	0.899	7.14721	0.00001	1.000
Inflation	10.5432	5.97671	4.56649	0.002	5.97712	-0.00041	0.999
Natural resources rentes	13.79339	12.04871	1.74468	0.033	12.04875	-0.00004	1.000
Fix regime	0.41914	0.43189	-0.01275	0.715	0.43189	0.0000	1.000
Observations	606	301			301		

The results in table 6, show that countries adopting MM have increase intra-African goods trade. In addition, the magnitudes of the effects are close to previous estimation with PSM.

Table 6: Entropy balancing matching results

	Total goods	Agricultural raw material	Primary Commodities	All food items
Log(Total goods trade/GDP)	(1)	(2)	(3)	(4)
Mobile Money	0.5816***	0.0486	0.5450***	0.6080***
	(0.0561)	(0.0810)	(0.0626)	(0.0644)
Observations	907	904	907	907
R-Squared	0.29	0.25	0.32	0.32
Log(Total goods imports/GDP)				
Mobile Money	0.6530***	0.2647***	0.5276***	0.6663***
	(0.0608)	(0.0776)	(0.0605)	(0.0607)
Observations	907	905	907	907
R-Squared	0.41	0.26	0.33	0.44
Log(Total goods exports/GDP)				
Mobile Money	0.5865***	0.3358***	0.6864***	0.7604***
	(0.0756)	(0.1283)	(0.0934)	(0.1016)
Observations	907	901	907	907
R-Squared	0.12	0.11	0.22	0.24

Standard errors in brackets. *** significance level at 1%, ** significance level at 5%, * significance level at 10%.

3.4. Endogeneity issue

We assume here that the adoption of MM leads to an increase in the share of trade in GDP. Nonetheless, the magnitude of trade could also lead to the need of alternative payments solutions, thus being able to influence MM adoption which is a source of endogeneity. Furthermore, the previous estimation methods do not consider the panel structure of our sample. We therefore estimate a panel two step system GMM[67] (Blundell and Bond, 1998) to consider any potential endogeneity as in

[67] This also permits us to consider the panel structure of the data.

Choi, C. (2010) first, and then to capture the panel dimension of the sample. Next, we include time-fixed effects in addition to country-fixed effects. To overcome the proliferation of instruments, we restrict and collapse the set of instruments (Roodman, 2009) and we use Windmeijer (2005) standard errors to correct the finite sample bias. The AR(2) and Hansen tests p-values support the validity of our results. Table 5 presents the results. The estimated coefficients of MM are significant and respectively equal to 0.54, 0.50, and 0.61 percent for the specification with Log(Total trade/GDP), Log(Exports/GDP), and Log(Imports/GDP) respectively (columns 4 to 6); and comparable to those estimated in tables 2, 3, 4 and 6.

Table 7: MM adoption and Goods trade: panel two step system GMM.

	Log (Total trade/GDP)	Log (Exports/GDP)	Log (Imports/GDP)	Log (Total trade/GDP)	Log (Exports/GDP)	Log (Imports/GDP)
	(1)	(2)	(3)	(4)	(5)	(6)
Mobile Money	0.592***	0.520***	0.597***	0.540***	0.501**	0.615***
	(0.1676)	(0.1756)	(0.1498)	(0.1634)	(0.2278)	(0.1951)
Log(Population)	-0.262*	0.126	-0.390***	-0.120	0.217	-0.307***
	(0.1536)	(0.1794)	(0.1411)	(0.1201)	(0.1717)	(0.1187)
Log(GDP per capita)	-0.225	-0.144	-0.186	0.062	0.258	-0.087
	(0.3960)	(0.5243)	(0.4297)	(0.5024)	(0.4616)	(0.6253)
Financial depth	0.000	0.008	-0.008	-0.008	0.017	-0.018
	(0.0178)	(0.0118)	(0.0167)	(0.0171)	(0.0144)	(0.0154)
Inflation	-0.002	-0.003*	-0.001	-0.002**	-0.003*	-0.001
	(0.0010)	(0.0015)	(0.0010)	(0.0008)	(0.0015)	(0.0010)
Natural resources rents	0.006	0.014*	0.007	0.002	0.013	0.003
	(0.0072)	(0.0083)	(0.0089)	(0.0069)	(0.0087)	(0.0095)
Fix regime	0.173	0.408	0.055	0.249	0.498	0.128
	(0.3093)	(0.3810)	(0.3260)	(0.2970)	(0.3471)	(0.3494)
Time fixed effects				Yes	Yes	Yes
Observations	876	876	876	876	876	876
Groups	48	48	48	48	48	48
Instruments	18	18	18	40	40	40
AR1-pvalue	0.00	0.00	0.01	0.00	0.00	0.01
AR2-pvalue	0.93	0.13	0.90	0.97	0.14	0.99
Hansen-pvalue	0.29	0.65	0.36	0.32	0.46	0.20

Note: Robust standard errors in brackets.*** significance level at 1 percent; ** significance level at 5 percent; * significance level at 10 percent. Included instruments are (Mobile Money)t-1, (Mobile Money)t-2, Log(GDP per capita)t-1, Log(GDP per capita)t-2, (Financial depth)t-1, (Financial depth)t-2, (Natural resources rents)t-1, (Natural resources rents)t-2, Log(Population)t-1, (Inflation)t-1, (Fix regime)t-1.

4. Conclusion

We find that countries that adopted MM register a greater goods trade share in GDP of about 0.6 percent in comparison to non-adopters. Furthermore, we find that this positive effect is higher for food items. Adopting MM services then have positive effects on intra-African trade as it facilitates money payments and transfers.

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Appendices

Appendix A: List of studied countries

	Country	Adoption year		Country	Adoption year
1	Algeria		25	Liberia	2011
2	Angola		26	Libya	
3	Benin	2010	27	Madagascar	2010
4	Botswana	2011	28	Malawi	2012
5	Burkina Faso	2012	29	Mali	2010
6	Burundi	2010	30	Mauritania	2013
7	Cameroon	2010	31	Morocco	2010
8	Cape Verde		32	Mozambique	2011
9	Chad	2012	33	Namibia	2010
10	Comoros		34	Niger	2010
11	Congo	2011	35	Nigeria	2011
12	Cote d'Ivoire	2008	36	Rwanda	2009
13	Democratic Republic of the Congo	2012	37	Sao Tome and Principe	
14	Djibouti		38	Senegal	2008
15	Egypt	2013	39	Sierra Leone	2010
16	Equatorial Guinea		40	South Africa	2009
17	Ethiopia	2013	41	Sudan	2016
18	Gabon	2012	42	Swaziland	2011
19	Gambia	2016	43	Togo	2013
20	Ghana	2009	44	Tunisia	2010
21	Guinea	2012	45	Uganda	2009
22	Guinea-Bissau	2010	46	United Republic of Tanzania	2008
23	Kenya	2007	47	Zambia	2009
24	Lesotho	2012	48	Zimbabwe	2011

Note: The year of adoption is blank for countries that had not yet adopted mobile money at the end of 2018.

Appendix B: Descriptive statistics

Variables	Obs.	Mean	Std. Dev.	Min	Max
Total goods trade gdp/GDP	1,182	0.0129	0.0175	0.000321	0.107
Total goods import/GDP	1,182	8.81e-05	0.000134	1.49e-06	0.000927
Total goods export/GDP	1,182	4.06e-05	5.65e-05	1.00e-07	0.000454
Total agricultural raw materials trade/GDP	1,173	3.83e-06	7.49e-06	1.84e-10	8.03e-05
Total agricultural raw materials import/GDP	1,182	1.52e-06	3.66e-06	0	3.60e-05
Total agricultural raw materials export/GDP	1,173	2.30e-06	5.58e-06	0	6.58e-05
Total all food idem trade/GDP	1,178	2.60e-05	3.82e-05	2.76e-07	0.000287
Total all food idem import/GDP	1,181	1.41e-05	2.54e-05	1.83e-07	0.000217
Total all food idem export/GDP	1,179	1.18e-05	2.11e-05	2.95e-10	0.000217
Total primary commodities import/GDP	1,182	2.08e-05	3.43e-05	4.70e-07	0.000283
Total primary commodities trade/GDP	1,180	3.75e-05	5.25e-05	9.63e-07	0.000390
Total primary commodities export/GDP	1,180	1.67e-05	2.66e-05	4.38e-10	0.000231
Mobile Money	1,224	0.279	0.449	0	1
GDP per capita	1,155	2,090	2,749	183.5	20,533
Financial depth	1,060	19.65	23.40	0.403	160.1
Inflation	1,038	9.962	32.91	-60.50	541.9
Total natural resources rents	1,178	12.99	12.74	0.0342	84.23
Fix regime	1,224	0.409	0.492	0	1
Population	1,217	1.886e+07	2.663e+07	131,678	1.959e+08

Appendix C: Variables detail

Variables	Definitions	Sources
Mobile Money	Mobile money is a dummy variable taking 1 if a mobile money service is adopted in the country and 0 if not	Authors construction using information from Global System for Mobile Communications Association (GSMA)
Agricultural raw materials (% GDP)	It denotes the sum of import from African countries and exports to African countries of agricultural raw materials in percentage of GDP	United Nations Conference on Trade and Development (UNCTAD) statistics
Goods trade (% GDP)	It denotes the sum of imports from African countries and exports to African countries of goods in percentage of GDP	UNCTAD
Foods items (% GDP)	It denotes the sum of imports from African countries and exports to African countries of foods items, including tea, coffee, cocoa and spices in percentage of GDP	UNCTAD
Primary commodities excluding fuels (% GDP)	It denotes the sum of imports from African countries and exports to African countries of primary commodities excluding fuel in percentage of GDP	UNCTAD
Financial Depth (% GDP)	Domestic credit to private sector in percentage of GDP	World Development Indicators (WDI)
GDP per capita	Per capita gross domestic product constant 2010 US dollar	WDI
Inflation, consumer prices (annual %)	Annual percentage change in the cost to the average consumer of acquiring a basket of goods and services.	WDI
Total natural resource (% GDP)	sum of oil rents, natural gas rents, coal rents (hard and soft), mineral rents, and forest rents.	WDI
Total Population	Total population is the estimate of all residents at mid-year, regardless of legal status or citizenship.	WDI
Fixed regime	Fixed regime is a dummy variable taking 1 if country adopted fixed regime and zero if not	Authors construction using International Monetary Fund exchange rates classification

Chapter 4: Peer-to-government mobile payment services adoption and tax revenue mobilization in developing countries

This chapter is joint work with Jesse Lastunen and Abdoul-Akim WANDAOGO.

1. Introduction

Several studies have demonstrated a positive link between domestic tax revenue mobilization and economic development (Jenkins and Newell, 2013; Owens and Carey, 2009). Yet it is well established that developing countries, with tax revenues of 10–20 per cent of GDP, collect taxes much less effectively than their higher-income counterparts (Besley and Persson, 2014). In addition to structural economic weaknesses, tax revenue mobilization in poorer countries is limited by their weak institutions, fragmented polities, and a poor norm of tax compliance (De Paepe and Dickinson, 2014; Brun et al., 2020). The lack of sufficient resources makes it difficult for public administrations to function effectively and to provide public goods and services.

While alternatives exist for the financing of development goals, domestic taxation is generally considered a more reliable and sustainable revenue source than development aid, foreign direct investment (FDI), or debt (Rodríguez Bolívar et al., 2016; Moore and Prichard, 2020). Development aid, for instance, is generally more unpredictable than tax revenue and its volatility tends to increase with the degree of aid dependence (Bulir and Hamann, 2001), typically high in less-developed economies. Aid dependence can also reduce incentives for governments to maintain efficient institutions, such as an effective tax revenue administration (Djankov et al., 2008). The inflows of FDI are similarly unstable and also dependent on the economic conditions of countries of origin, while debt financing comes with well-known sustainability challenges. Tax revenues are critical for developing countries because they provide governments with reliable and independent revenue.

Several studies have assessed the determinants of tax revenue and factors that can improve tax revenue mobilization (Baunsgaard and Keen, 2010; Besley and Persson, 2009; Brückner, 2012; Clist and Morrissey, 2011; Gnangnon and Brun, 2019a, 2019b; Lotz and Morss, 1970; Mahdavi, 2008). Among other factors, larger tax revenues are associated with trade openness, democracy, quality of institutions, foreign aid and assistance, and population size.

With the rise of information and communication technology (ICT), more attention has been directed in recent years to the effects of digitalization on tax revenue. Moore and Prichard (2020) argue that ICTs

can help developing countries collect more taxes by improving transparency and centralizing the tax compliance process. Eilu (2018) emphasizes the critical need to better integrate ICTs into national tax systems in order to improve revenue collection and related enforcement.

Empirical research provides support for these arguments. Many studies have assessed the impact of the internet on tax revenue, generally relying on the two-step system generalized method of moments (GMM) estimator. They show that internet access has increased domestic (non-resource) tax revenue (Gnangnon and Brun, 2018; 2019a), promoted related tax transition reforms (Gnangnon, 2020a), and reduced tax revenue instability (Gnangnon, 2020b). Using fixed time effects models, Koyuncu et al. (2016) show that the penetration of computers, mobile phones, and other ICTs improved tax revenues in a sample of 157 countries between 1990 and 2013. Similarly, using a panel of 96 developing countries from 2005 to 2016, Brun et al. (2020) find that ICT usage has had a positive effect on tax collection, channelled especially through government effectiveness, control of corruption, and better tax compliance.

This general evidence raises the question of which specific information technologies can further promote the mobilization of tax revenue in the developing world. More than a decade ago, Bird and Zolt (2008) argued that the widespread use of cell phones for conducting financial transactions in less-developed countries implies that electronic tax filing and payment using this method may soon be possible. Since the beginning of the 2000s, Mobile Money (MM) services have in fact emerged as a plausible method of conducting such transactions.

First implemented in Russia in 2002, MM is a payment system that uses a mobile phone with an associated financial account to send and receive money. While several types of MM services exist,[68] this study focuses specifically on person-to-government (P2G) transfers, adopted in several developing countries over the past two decades. P2G payments are money transfers from individuals or businesses to governments, including agencies and other institutions at the municipal, state, and national level. P2G transfers can be statutory payments, such as fees or

[68] Other MM services include person-to-person transfers, government-to-person transfers, merchant payment transfers, airtime top-ups, international remittances, and bill payments.

tax payments, or payments to government-owned utilities for obtaining documents such as marriage certificates or business licences (GSMA, 2020). This study asks whether the adoption of P2G as a means of payment can increase direct tax revenues in developing countries, and, if so, how different country characteristics mediate this effect.

In most developing countries, tax collection has remained traditional until recent years. The collection process typically entails taxpayers visiting local tax authorities to discharge their tax obligations, usually by cash or cheque. Self-declaration, data entry, and manual collection often take several weeks and are fraught with a high risk of corruption, losing declarations, and also reducing taxpayer morale. Streamlining these processes can reduce both taxpayers' compliance costs and tax authorities' collection costs, ideally leading to greater revenue mobilization.

Existing literature has established several channels through which P2G payments can improve tax collection, especially in countries characterized by inefficient domestic revenue mobilization. First, P2G payments can reduce corruption in the tax administration by limiting physical interactions and payments by cash or cheque (Barasa, 2021; Nwachi, 2020).[69] Second, P2G transactions can address compliance challenges associated with the large informal sectors present in many developing countries (Besley and Persson, 2014; Joshi et al., 2014). Small, informal enterprises are difficult for tax administrators to identify and target. Even when taxes can be levied, these companies often face long and complex procedures to discharge their tax obligations. Since informal and small firms already use MM payments in other contexts quite widely (GSMA, 2019), dedicated P2G platforms can improve their compliance behaviour, help tax administrators identify more such firms, and thereby promote the broader formalization of the economy. Empirical evidence indicates that MM services can in fact induce formalization (Jacolin et al., 2019).

Despite the opportunities offered by P2G payment services, there are no studies, to the authors' knowledge, that assess the impact of their adoption on tax revenue. This paper addresses this gap by estimating the effect of P2G adoption on direct tax revenue, relying on a sample of 96

[69] See Brun et al. (2020) on the advantages of dematerializing tax payments.

developing countries. The choice of direct (instead of indirect or overall) tax revenue as the main outcome is based on the notion that P2G payments are typically used by taxpayers to settle tax obligations imposed on them directly with the tax administration. In addition to providing the first empirical estimates on the impact on tax revenue of adopting P2G services, the work highlights how structural factors that differ across countries mediate the impact, demonstrating which types of countries are most likely to benefit from the technology.

In the analysis, propensity score matching (PSM) is used to estimate the average treatment effect on the treated, namely the effect of P2G adoption on direct tax revenues in developing countries that had adopted the technology by the end of 2018. The robustness of the results is tested using matching quality tests and alternative estimation methods, including function control, 2SLS, and system GMM. The main hypothesis is that P2G adoption improves direct tax revenues in adopting developing countries through providing a new, convenient mechanism for settling tax obligations, hence improving compliance, and through reducing corruption and improving administrative efficiency.

After investigating the existence of a common trend in pre-treatment direct tax revenues for P2G adopters and non-adopters, the matching estimates in the study show that PG2 adoption has a positive and significant effect on direct tax revenue, including both corporate income tax (CIT) and personal income tax (PIT). Using various matching estimates, the adoption of P2G services increases direct tax revenue by 1.21 to 1.32 percentage points. This effect is larger for revenues from PIT (0.68–0.85) than those from CIT (0.44–0.60). When assessing heterogeneity by income level using the control function method, the positive effect is only observed for low-income and lower-middle-income countries.

In addition, P2G adoption is more effective for tax mobilization for countries characterized by an ineffective bureaucracy, extensive informality, and low levels of financial inclusion. Moreover, we provide suggestive evidence that improvements in tax discipline, domestic revenue mobilization efficiency by the tax administration, and reduction in the size of the informal sector are potential transmission channels through which P2G services adoption affects direct tax revenues in

developing countries. Allowing and encouraging the use of P2G services for tax transactions in such countries would be a critical step towards improving tax compliance and overcoming existing institutional barriers to domestic tax revenue mobilization.

The treatment effects are also positive and significant for countries with low levels of development assistance and resource rents—potentially incentivizing tax collection reforms—and countries with high rates of labour force participation and school enrolment—indicating that reaping benefits from P2G services requires a large and capable user base.

The rest of the paper is structured as follows. Section 2 presents the data and the identification strategy. Section 3 presents the empirical results. Conclusions and policy implications are provided in Section 4.

2. Data and methodology

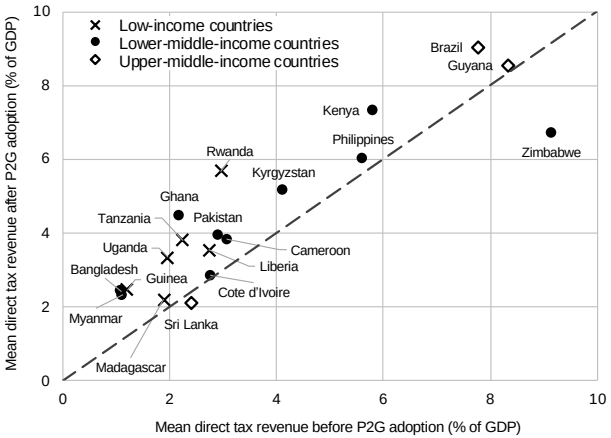
2.1. Data

The study uses data from 96 developing countries from 1994 to 2018. The data on tax revenue are compiled from the UNU-WIDER Government Revenue Dataset (GRD; UNU-WIDER 2021). The treatment variable for P2G adoption ('P2G') is constructed using the GSMA Mobile Money tracker, which records the year that mobile financial services were adopted for each adopter operator in each country. For a given country, 'P2G' is assigned a value of one for the years in which the service has been available, and zero otherwise. The rest of the control variables come from the World Development Indicators (WDI; World Bank, 2021)).

Figure 1 illustrates mean direct tax revenues as a share of GDP in the adopter countries before and after P2G adoption; 17 out of 19 adopter countries experienced an increase in direct tax revenue after adopting the technology (i.e., they are located above the first bisector).[70]

[70] The list of adopter countries is provided in Table A1 in Appendix A, while the description of the variables and descriptive statistics are provided in Tables B1 and B2 in Appendix B.

Figure 1: Direct tax revenue to GDP ratio before and after P2G adoption



Note: ratio of mean direct tax revenue to GDP calculated from either all available years before P2G adoption (x- axis) or the first and following years after P2G adoption (Y axis); the ratio increased after P2G adoption for countries above the bisector.
Source: authors' elaboration of data from UNU-WIDER (2021) and World Bank (2021).

2.2. Methodology

We use PSM to evaluate the causal effect on direct tax revenue of adopting P2G services. The methodology, developed by Rosenbaum and Rubin (1983), has become increasingly popular in empirical economics (e.g., Combes et al., 2019; Imai and Azam, 2012; Levchenko et al., 2009; Sawadogo, 2020), including research on tax revenue topics (Balima et al., 2016; Ebeke et al., 2016; Lucotte, 2012).

In non-randomized or observational studies, individual baseline characteristics generally influence exposure to a particular treatment. When baseline characteristics differ with treatment exposure, assessing the causal effect of the treatment on a given outcome requires such difference to be accounted for (i.e., addressing selection bias). PSM suits this study, as it can be used to evaluate the causal impact of a binary variable on any output from observational data (see e.g., Austin, 2014).

This study implements a general three-step procedure to analyse the impact of P2G adoption on direct tax revenue. The first step entails the

estimation of propensity scores (PS), or the probability of exposure to the treatment. The second step involves generating matched sets of P2G adopters and non-adopters with similar average PS. Finally, we estimate the average treatment effect on the treated (ATT) using various matching methods.

First, the PS is denoted by $l(Y_i)$, the probability of adopting P2G services given selected covariates:

$$l(Y_i) = P(P2G_i = 1|Y_i) \qquad (1)$$

where $P2G_i$ signifies the treatment (P2G services adoption) and Y_i is a set of covariates that can simultaneously explain both P2G adoption and direct tax revenue.

The ATT can be formulated as follows:

$$ATT = E[(TX_i^1 - TX_i^0)|P2G_i = 1] \qquad (2)$$

representing the average difference between tax revenue mobilized with and without P2G adoption (TX_i^1 and TX_i^0, respectively) in adopter countries ($P2G_i = 1$). Alternatively:

$$ATT = E(TX_i^1|P2G_i = 1) - E(TX_i^0|P2G_i = 1) \qquad (3)$$

The last term, representing average tax revenue in adopter countries in a hypothetical case in which they had not adopted P2G services, is unobservable. Replacing it with mean tax revenue in non-adopter countries would lead to self-selection bias, because P2G adoption may be correlated with a set of observable characteristics across countries (Dehejia and Wahba, 2002; Heckman et al., 1998; Lin and Ye, 2007). Instead, the second term is replaced with tax revenue in non-adopter countries with basic characteristics comparable to those of their adopter pair:

$$ATT = E[TX_i^1|P2G_i = 1, l(Y_i)] - E[TX_i^0|P2G_i = 0, l(Y_i)] \qquad (4)$$

where $l(Y_i)$ is the probability of P2G adoption given selected covariates from Equation 1.

The ATT is then estimated using various matching methods available in the literature, including: (1) nearest neighbour matching, which consists of matching each P2G adopter with the non-adopter with the closest PS (using $n = 1, 2, 3$); (2) radius matching (Dehejia and Wahba, 2002),

which retains non-adopters with a PS between a radius (using $r = 0.005, 0.01, 0.05$); (3) kernel estimator (Heckman et al., 1997, 1998), which matches each P2G adopter with a weighted average of all non-adopters; and (4) local linear regression (Heckman et al., 1997, 1998), which improves kernel estimator by adding a linear term in the weighting function (Fan, 1993).[71]

3. Results

3.1. Propensity scores estimation

PS are estimated using a probit model, in which the probability of adopting P2G services depends on various characteristics drawn from existing literature on MM service adoption and domestic tax revenue (Ebeke et al., 2016; Gupta et al., 2003; Imam and Jacobs, 2007; Keen and Lockwood, 2010; Khattry and Raos, 2002; Le et al., 2008; Tanzi, 1977).

In total, nine covariates are included in the model: total population growth rate, mobile phone market penetration, growth rate of GDP per capita, agriculture value added, domestic credit to the private sector, trade openness, inflation, natural resource rents, and control of corruption. Table 1 presents the PS estimation results, with the basic specification shown in the first column.

[71] For more details, see Imbens (2004) and Smith and Todd (2005). Caliendo and Kopeinig (2008) cover the general background, advantages, and challenges concerning different matching strategies.

Table 1: Probit estimation of propensity scores

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Agriculture VA	-0.0087	-0.0041	-0.0065	-0.0156**	-0.0054	0.0097	-0.0058	-0.0426***	-0.0022	-0.0162**	-0.0137*	-0.0482***
	(0.0061)	(0.0057)	(0.0060)	(0.0070)	(0.0069)	(0.0073)	(0.0080)	(0.0098)	(0.0077)	(0.0068)	(0.0070)	(0.0092)
Domestic credit	-0.0140***	-0.0161***	-0.0168***	-0.0148***	-0.0113***	-0.0202***	-0.0176***	-0.0011	-0.0153***	-0.0127***	-0.0157***	-0.0140***
	(0.0032)	(0.0031)	(0.0033)	(0.0042)	(0.0037)	(0.0052)	(0.0047)	(0.0058)	(0.0033)	(0.0028)	(0.0040)	(0.0035)
Trade openness	-0.0184***	-0.0180***	-0.0175***	-0.0192***	-0.0145***	-0.0109***	-0.0182***	-0.0259***	-0.0173***	-0.0204***	-0.0223***	-0.0219***
	(0.0028)	(0.0027)	(0.0027)	(0.0037)	(0.0036)	(0.0039)	(0.0038)	(0.0037)	(0.0030)	(0.0032)	(0.0033)	(0.0036)
GDP per capita growth	0.0680***	0.0712***	0.0722***	0.0567**	0.0755***	0.0742***	0.0828***	0.0360	0.0645***	0.0692***	0.0591**	0.0320
	(0.0214)	(0.0201)	(0.0200)	(0.0285)	(0.0241)	(0.0266)	(0.0262)	(0.0270)	(0.0217)	(0.0245)	(0.0265)	(0.0237)
Inflation	-0.0246**	-0.0167**	-0.0148*	-0.0231*	-0.0245*	-0.0300**	-0.0018	-0.0280*	-0.0266**	-0.0145	-0.0425**	-0.0354***
	(0.0114)	(0.0081)	(0.0090)	(0.0120)	(0.0133)	(0.0137)	(0.0022)	(0.0159)	(0.0119)	(0.0098)	(0.0166)	(0.0120)
Resource rents	-0.0804***	-0.0803***	-0.0769***	-0.0935***	-0.0839***	-0.0891***	-0.0721***	-0.0500***	-0.0789***	-0.0877***	-0.0797***	-0.0619***
	(0.0098)	(0.0102)	(0.0097)	(0.0144)	(0.0124)	(0.0131)	(0.0105)	(0.0115)	(0.0098)	(0.0122)	(0.0116)	(0.0099)
Population growth	0.4387***	0.4686***	0.4417***	0.6124***	0.4789***	0.5076***	0.5072***	0.4951***	0.4481***	0.4729***	0.4241***	0.4414***
	(0.0636)	(0.0571)	(0.0540)	(0.1146)	(0.0743)	(0.0824)	(0.0812)	(0.1061)	(0.0652)	(0.0738)	(0.0683)	(0.0809)
Mobile phone penetration	0.0159***	0.0147***	0.0140***	0.0148***	0.0164***	0.0184***	0.0170***	0.0134***	0.0157***	0.0173***	0.0085***	0.0196***
	(0.0018)	(0.0016)	(0.0015)	(0.0020)	(0.0020)	(0.0021)	(0.0025)	(0.0028)	(0.0018)	(0.0019)	(0.0023)	(0.0021)
CCE	-1.2494***			-1.3380***	-1.0252***	-1.5486***	-1.2936***	-1.4209***	-1.2129***	-1.2816***	-1.3226***	-1.2931***
	(0.1624)			(0.2036)	(0.1797)	(0.2106)	(0.1902)	(0.2959)	(0.1688)	(0.1479)	(0.1966)	(0.1705)
rle		-0.5754***										
		(0.1304)										
gee			-0.4034***									
			(0.1520)									
School enrollment				0.0168***								
				(0.0049)								
Social conditions					-0.1317**							
					(0.0566)							
Bureaucracy quality						0.5133***						
						(0.1119)						
Tax compliance							0.1788***					
							(0.0502)					
Public administration quality								0.1519				
								(0.2970)				
Net ODA									-0.0312			
									(0.0204)			
Labor force										0.0303***		
										(0.0066)		
Paying taxes: score											0.0107***	
											(0.0041)	
Urban population												-0.0418***
												(0.0051)
Observations	1320	1322	1320	1097	918	918	826	514	1297	1281	845	1320
Pseudo R2	0.34455	0.29428	0.28190	0.36536	0.32910	0.35890	0.33724	0.36097	0.34406	0.36919	0.36598	0.43047

Note: Robust standard errors in brackets. *p<0.10, **p<0.05, and ***p<0.01. A constant is included in all regressions.

Columns 2–12 refer to alternative specifications that use institutional, economic, social, demographic, and administrative characteristics that can potentially explain both P2G adoption and tax revenue. The PSs resulting from these alternative specifications are used to assess the robustness of the results using different matching methodologies later, in Table 2. Given that McFadden's pseudo R2s range from 0.28 to up to 0.43, the tested specifications can be considered adequate in explaining the adoption of P2G services.

From the nine main variables, the first three demonstrate an expected positive association with P2G adoption. Rapid population growth and mobile phone penetration can facilitate adoption, as a growing number of potential users increases the utility of the technology via network effects. Countries with a strong economy, characterized by fast per capita GDP growth, are in turn expected to be well equipped and willing to adopt innovative payment solutions in general.

The next three variables are negatively correlated with P2G adoption, again in line with ex ante expectations. Significant domestic credit to the private sector is likely to reflect more-developed, traditional banking systems that are generally associated with lower financial exclusion and thereby lower incentives to adopt innovative payment solutions. High inflation is a sign of poor macroeconomic conditions, potentially discouraging the extensive adoption of new technologies. As for corruption control, an indicator of stable institutions, Evans and Pirchio (2014), Jacolin et al. (2019), and Pénicaud (2013) argue that countries with high institutional quality may not favour the adoption of novel innovations such as P2G due to their generally restrictive regulatory environments.

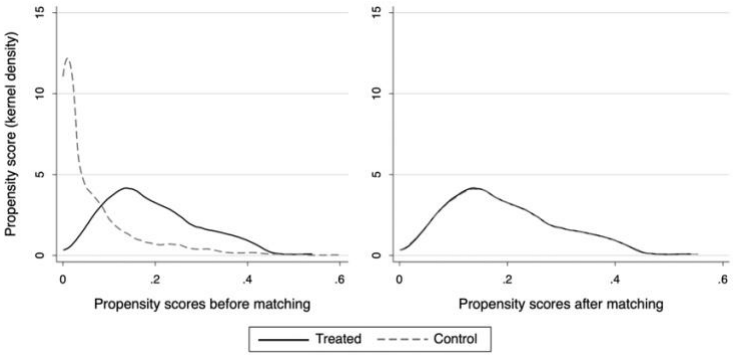
The remaining three variables are also negatively correlated with P2G adoption, with largely insignificant coefficients for agricultural value added and significant coefficients for trade openness and resource rents. On one hand, countries with a large informal sector, reflected by high levels of value added from

agriculture, might favour P2G services to facilitate the formalization of their labour markets via new tax payment solutions. High agricultural value added may, however, also reflect poor socioeconomic conditions that reduce the likelihood of P2G adoption, explaining the negative coefficient.

The negative coefficient for trade openness could be explained by the notion that more-open economies are also more likely to have developed traditional financial systems and related services, with limited demand for alternative payment solutions. Such factors may be more important than the expected positive effect of trade openness on technology transfer, which could in turn facilitate P2G adoption.[72] Finally, the negative coefficient for natural resource trends may be explained by a version of the resource curse where less-diversified countries are less willing to adopt innovative technological solutions across the economy.

Figure 2 presents the distribution of PS across countries in the sample before and after matching for P2G adoption.

Figure 2: Density plot for PS before and after matching for P2G



Source: authors' elaboration.

[72] Keen and Lockwood (2010) find a similar non-intuitive sign for trade openness when estimating its effect on VAT adoption.

3.2. Common trends assumption

The use of PSM requires validation of the common trends' assumption: direct tax revenues should follow the same trend for adopters and non-adopters during the pre-treatment period. That implies that no time variables affect direct tax revenues differently for adopters and non-adopters, apart from the adoption of P2G services (Riley, 2018). Accordingly, it is essential to demonstrate that the pre-treatment trends are similar and that there are sufficient matches for valid inference. For that purpose, we define a new placebo treatment variable for which the treatment group remains countries that have adopted P2G services. We thus exclude the actual adoption periods for each treated country, and we define a treatment period that begins in 1999, i.e., the midpoint between 1994 (the first year in our sample) and 2004 (the first year of P2G services adoption). Second, we use this new treatment variable reflecting pre-adoption periods to estimate the ATTs. Suppose the coefficients obtained after matching are significant. In that case, the conclusion is that direct tax revenues of the adopter group and the control group do not follow the same trend. Conversely, non-significant ATTs would mean that the pre-adoption trends are similar and that the choice of PSM as an estimation method is appropriate. None of the estimated coefficients in Table 2 is significant. That allows us to validate the existence of a parallel trend in direct tax revenue evolution prior to P2G services adoption.

Table 2: Parallel trends

Treatment variable: pre-P2G-adoption	1-Nearest neighbor matching	2-Nearest neighbor matching	3-Nearest neighbor matching	Radius matching			Local linear regression matching	Kernel matching
				r=0.005	r=0.01	r=0.05		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Dependent variable: Direct taxes as percentage points of GDP							
ATT	0.2592	0.1287	0.1591	0.2309	0.2910	0.1995	0.1962	0.2151
	(0.2781)	(0.2645)	(0.2279)	(0.1952)	(0.2008)	(0.1826)	(0.1877)	(0.1819)
Observation/Treated	***1123/ 130***							
	Quality of the matching							
Pseudo-R2	0.005	0.008	0.009	0.007	0.006	0.007	0.005	0.007
Standardized bias (p-value)	0.99	0.94	0.92	0.97	0.98	0.95	0.99	0.96
Rosenbaum upper bound sensitivity test	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

standard errors in brackets. *p<0.10, **p<0.05, and ***p<0.01. **Bootstrap replications=500.**

3.3. Matching results

Table 3 presents the evaluation results using a variety of matching techniques, along with selected statistics for standard diagnostic tests.

First, the pseudo R2 demonstrates the extent to which the control variables explain the probability of P2G services adoption and hence generate balanced scores (Sianesi, 2004). Good model performance is associated with 'fairly low' values (Caliendo and Kopeinig, 2008). Given that all pseudo R2s are lower than 0.03, the matchings yield balanced scores, and the results broadly satisfy the common support assumption.

Second, the conditional independence assumption is tested for observables using the standardized bias test and for unobservables using the Rosenbaum upper bound sensitivity test (Rosenbaum, 2002). The standardized bias test, which evaluates the marginal distance distributions of the control variables, generates p-values between 0.53 and 0.91. This suggests that there is no statistical difference between the characteristics of P2G adopters and non-adopters after matching.[73] The Rosembaum upper bound sensitivity test evaluates whether unobservables exist that could affect the estimated tax impact of P2G services adoption. The critical values vary between 2.4 and 2.7 and are comparable to those of other studies (Balima et al., 2016; Caliendo and Künn, 2011), indicating that the results are robust to the conditional independence hypothesis.[74]

The estimated treatment effect on direct tax revenue of adopting P2G services is between 1.21 and 1.32 percentage points, depending on the matching method, and consistently significant

[73] Rosenbaum and Rubin (1985) propose a critical value of 0.2. In line with the larger p-values obtained, Figure 2 shows that the distribution of propensity scores after matching is comparable for P2G adopters and non-adopters.

[74] The test is conducted at a 5% level. The simulation-based sensitivity analysis presented by Ichino et al. (2008) is also implemented to test the robustness of the estimates under the failure of the conditional independence assumption. Based on the test, any unobserved factor correlated with each of the covariates used in this study would not be sufficient to drive the estimated average treatment effect to zero.

at the 1 per cent level. Developing countries that have adopted P2G services raise considerably more direct tax revenue than they would have raised without the adoption of the technology. The effect is sizeable, representing 45–49 per cent of the standard deviation of direct tax revenues.[75] The estimated ATTs also remain positive, significant, and comparable to the main estimates after including a range of alternative variables into the standard PS specification (see Table 1) and then re-evaluating the matching models (see Lines 1–11 in Table 3).

Finally, the ATTs are estimated separately for direct tax revenue from CIT and PIT. The estimates, again in percentage points of GDP, are significant, and consistently larger for PIT (0.68–0.85) than for CIT (0.44–0.60). This result may be explained by the fact that P2G services are more widely used by small and medium-sized companies, which contribute little to CIT revenues and more to PIT revenues.

[75] The standard deviation of direct tax revenue is 2.71, as reported in Table B2 in Appendix B.

Table 3: Matching results for the effect of P2G on direct taxes

Treatment variable: P2G	1-Nearest Neighbor Matching	2-Nearest Neighbor Matching	3-Nearest Neighbor Matching	Radius Matching			Local Linear Regression Matching	Kernel Matching
				r=0.005	r=0.01	r=0.05		
Dependent variable: Direct taxes in percentage points of GDP								
Average Treatment on the Treated (ATT)	1.2833***	1.2068***	1.3229***	1.2627***	1.2857***	1.2549***	1.2509***	1.2666***
	(0.2978)	(0.2712)	(0.2766)	(0.2538)	(0.2332)	(0.2245)	(0.2250)	(0.2282)
Observations/Treated observations	1326/103							
Quality of the matching								
Pseudo-R2	0.025	0.021	0.022	0.013	0.013	0.012	0.025	0.012
Rosenbaum bounds sensitivity test	2.4	2.4	2.7	2.7	2.6	2.5	2.4	2.5
Standardized bias (p-value)	0.529	0.649	0.609	0.884	0.896	0.911	0.529	0.914
Sensitivity analysis of the main results								
[1] Controlling for Rule of Law	1.2147***	1.1809***	1.1604***	1.1235***	1.0924***	0.9809***	0.9614***	0.9923***
	(0.3168)	(0.3001)	(0.2614)	(0.2321)	(0.2233)	(0.2135)	(0.2176)	(0.2131)
[2] Controlling for Gov Effectiveness	1.1433***	1.0699***	1.1011***	1.0802***	1.0135***	0.9550***	0.9372***	0.9629***
	(0.3079)	(0.2895)	(0.2494)	(0.2129)	(0.2069)	(0.1907)	(0.2053)	(0.1939)
[3] Controlling for school enrollment	1.0260***	1.0794***	1.0510***	0.7498***	0.8189***	0.8196***	0.8003***	0.8276***
	(0.3604)	(0.3254)	(0.3151)	(0.2740)	(0.2729)	(0.2457)	(0.2468)	(0.2487)
[4] Controlling for social conditions	1.3503***	1.3395***	1.4306***	1.3991***	1.3648***	1.2361***	1.2125***	1.2500***
	(0.3397)	(0.3095)	(0.2885)	(0.2823)	(0.2701)	(0.2332)	(0.2394)	(0.2344)
[5] Controlling for bureaucracy quality	1.0959***	1.1259***	1.1455***	1.0419***	1.2290***	1.1504***	1.0652***	1.1589***
	(0.3380)	(0.3137)	(0.3037)	(0.2791)	(0.2607)	(0.2351)	(0.2209)	(0.2335)
[6] Controlling for tax compliance	1.3865***	1.5301***	1.4760***	1.4035***	1.4787***	1.4170***	1.4201***	1.4253***
	(0.3708)	(0.3446)	(0.3290)	(0.3387)	(0.3094)	(0.2729)	(0.2771)	(0.2935)
[7] Controlling for pub admin quality	1.3309***	1.1967***	1.1500***	0.9074***	0.9758***	1.1617***	1.2129***	1.1567***
	(0.3574)	(0.3226)	(0.3151)	(0.3299)	(0.3101)	(0.2813)	(0.2799)	(0.2691)
[8] Controlling for ODA	1.0507***	1.1438***	1.2117***	1.1654***	1.2764***	1.2594***	1.2426***	1.2614***
	(0.3094)	(0.2831)	(0.2569)	(0.2452)	(0.2411)	(0.2313)	(0.2190)	(0.2287)
[9] Controlling for labor force	1.4116***	1.4268***	1.3775***	1.1180***	1.1105***	1.1142***	1.1248***	1.1175***
	(0.3095)	(0.2964)	(0.2679)	(0.2626)	(0.2343)	(0.2253)	(0.2125)	(0.2358)
[10] Controlling for time to pay taxes	1.2553***	0.9727***	1.0318***	0.9297***	1.0262***	1.0638***	1.0511***	1.0519***
	(0.3241)	(0.3055)	(0.2939)	(0.3421)	(0.2865)	(0.2476)	(0.2405)	(0.2584)
[11] Controlling for urban population	1.0167***	1.2208***	1.1896***	1.2695***	1.1014***	1.3222***	1.3299***	1.3102***
	(0.3087)	(0.2968)	(0.2921)	(0.2657)	(0.2559)	(0.2379)	(0.2164)	(0.2273)
ATT by type of direct tax								
Corporate Income Tax (CIT)	0.4584**	0.5981***	0.5596***	0.4998***	0.4872***	0.4379***	0.4461***	0.4372***
	(0.2161)	(0.1862)	(0.1696)	(0.1478)	(0.1310)	(0.1305)	(0.1124)	(0.1225)
Personal Income Tax (PIT)	0.6808***	0.7894***	0.7627***	0.7614***	0.8541***	0.8195***	0.8185***	0.8195***
	(0.2416)	(0.2237)	(0.2029)	(0.1781)	(0.1834)	(0.1671)	(0.1593)	(0.1629)

Standard errors in brackets. *p<0.10, **p<0.05, and ***p<0.01. **Bootstrap replications=500**

4. Further analysis

4.1. Falsification test

To avoid statistical artefacts in the estimated results, we perform a falsification test. This test consists of generating random placebo dates of P2G services adoption over the study period. Then, based on these falsified adoption periods, we re-estimate the effect of P2G on direct tax revenues. The results presented in Table 4 show that the estimated ATTs are not statistically significant regardless of the type of matching. The falsification test confirms that our main results are not driven by measurement error.

Table 4: Effect of P2G services adoption on direct tax - Falsification test

Treatment variable: P2G	1-Nearest neighbor matching	2-Nearest neighbor matching	3-Nearest neighbor matching	Radius matching r=0.005	Radius matching r=0.01	Radius matching r=0.05	Local linear regression matching	Kernel matching
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Dependent variable: Direct taxes as percentage points of GDP							
ATT	0.2107	0.1051	0.1326	0.0350	0.0372	0.0783	0.0370	0.0733
	(0.2110)	(0.1812)	(0.1645)	(0.1259)	(0.1315)	(0.1269)	(0.1347)	(0.1255)
Observation/Treated	1326/633							
	Quality of the matching							
Pseudo-R2	0.001	0.002	0.001	0.001	0.001	0.002	0.001	0.002
Standardized bias (p-value)	0.96	0.93	0.96	0.99	0.99	0.91	0.96	0.89
Rosenbaum upper bound sensitivity test	1.00	1.00	1.00	1.00	1.01	1.00	1.00	1.00

standard errors in brackets. *p<0.10, **p<0.05, and ***p<0.01. **Bootstrap replications=500**

4.2. Heterogeneity

Several studies have demonstrated notable heterogeneities in economic development and institutional characteristics across developing countries (Acemoglu et al., 2019; Balima et al., 2016; Lin and Ye, 2009; Easterly, 2002). To test whether and how such heterogeneities mediate the impact on direct tax revenue of adopting P2G services, this section follows Lin and Ye (2009) by using a control function regression methodology. The analysis is motivated by the following model:

$$tax\_revenue_{it} = \alpha + \beta * P2G_{it} + \gamma * PS_{it} + \tau * X_{it} + \delta * (P2G_{it} * X_{it}) + \varepsilon_{it} \quad (5)$$

where $tax\_revenue_{it}$ refers to direct tax revenues as a share of GDP, $P2G_{it}$ to the treatment variable, and PS_{it} to the estimated propensity score for country i in year t. Vector X_{it} includes a set of macroeconomic and institutional variables, while δ is the coefficient of interest for the

interaction term between the treatment variable and vector X_{it}. In practice, however, the regression specification used in this analysis excludes the terms with the control vector ($\tau * X_{it} + \delta * P2G_{it} * X_{it}$). The coefficient for P2G adoption, β, in this reduced model is estimated separately for two groups for each institutional variable, separated based on its average value. As an exception, countries are divided into three standard groups based on income levels. Table 3 shows the related ATTs of P2G adoption on direct tax revenue.

Before the main heterogeneity analysis, direct tax revenue is regressed on the dummy for adoption of P2G services in Column 1. The coefficient for P2G is negative but not significant. Column 2 incorporates the estimated PS from Column 1 of Table 1 to control for self-selection in the model. The significant coefficient for the PS points to the presence of self-selection bias in the model, justifying the use of PSM. The estimated coefficient for P2G after controlling for self-selection bias becomes positive and significant at the 1 per cent level and is equal to 0.86 percentage points of GDP. This is in line with the previous finding and shows that countries that have adopted P2G services collect more direct tax revenue than their non-adopter peers.

The remaining columns in Table 5 demonstrate how different country characteristics mediate the impact of P2G adoption on direct tax revenue.

Table 5: Heterogeneity analysis of the effect of P2G adoption on direct taxes

	No control	Self selectivity	Adoption pre-conditions	Experience	LIC	LMIC	UMIC	Control of corruption		Tax compliance		Paying taxes: score		Public administration quality	
								Low	High	Low	High	Low	High	Low	High
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
P2G	-0.2248	0.8616***	-0.6770**	-0.3408	0.3190	1.6486***	-1.2648	1.3317***	-0.3057	2.0328***	0.3087	1.4317***	-0.1228	0.8067*	0.4759
	(0.2039)	(0.2444)	(0.3097)	(0.4292)	(0.2059)	(0.3454)	(1.4759)	(0.2353)	(0.5872)	(0.4510)	(0.3364)	(0.4036)	(0.3236)	(0.4764)	(0.3023)
PSCORE		-4.6641***	-6.1343***	-4.9970***	-0.9104*	-5.0110***	-5.8515***	-0.7969*	-5.7291***	-6.7389***	-4.6302***	-5.7391***	-4.1500***	0.1324	-3.7672***
		(0.4577)	(0.4961)	(0.4841)	(0.4683)	(0.8526)	(0.7675)	(0.4621)	(1.0289)	(1.0184)	(0.8712)	(0.7104)	(0.8030)	(0.9981)	(0.5700)
P2G*(PS- $\overline{PS}$)			8.8020***												
			(1.1975)												
P2G*time				0.2382***											
				(0.0591)											
Constant	4.6421***	4.9159***	5.0022***	4.9355***	3.1550***	4.8232***	5.6959***	3.4258***	5.9123***	4.8430***	5.2110***	5.4292***	5.6485***	3.1279***	4.9660***
	(0.0794)	(0.0906)	(0.0924)	(0.0913)	(0.1341)	(0.1323)	(0.1480)	(0.1056)	(0.1206)	(0.1720)	(0.1614)	(0.1977)	(0.1433)	(0.2103)	(0.1456)
Observations	1320	1320	1320	1320	276	487	557	653	667	295	531	363	482	138	376
R2	0.00049	0.04153	0.06187	0.04780	0.00787	0.05856	0.03956	0.04107	0.02702	0.07788	0.03796	0.08174	0.06195	0.02587	0.05709

	Agriculture VA		School enrollment		Domestic credit		Resource rents		Net ODA		Labor force		Urbanisation rate	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)
P2G	0.4393	1.4692***	0.2337	0.5946*	1.3132***	-0.2687	0.9203***	0.4250	0.8314***	0.4036	0.4457	1.1368***	1.3472***	0.5511
	(0.3251)	(0.3093)	(0.3429)	(0.3301)	(0.2405)	(0.5180)	(0.2803)	(0.4141)	(0.2860)	(0.3808)	(0.2989)	(0.3775)	(0.2703)	(0.4762)
PSCORE	-4.9804***	-1.8440***	-4.2038***	-5.3453***	-2.6241***	-5.2082***	-5.6649***	-3.8164***	-5.3166***	-3.4528***	-5.4377***	-4.0473***	-2.7469***	-6.0954***
	(0.6750)	(0.4696)	(0.5828)	(0.8603)	(0.4816)	(0.9534)	(0.4989)	(1.4039)	(0.5857)	(0.6298)	(0.5722)	(0.7171)	(0.6458)	(0.5810)
Constant	5.7212***	3.2178***	4.3971***	5.2876***	3.8786***	6.1041***	5.4050***	3.7412***	5.2972***	3.9198***	4.8896***	4.9704***	3.8774***	5.7976***
	(0.1135)	(0.1049)	(0.1337)	(0.1343)	(0.1073)	(0.1347)	(0.1081)	(0.1461)	(0.1129)	(0.1403)	(0.1342)	(0.1318)	(0.1107)	(0.1302)
Observations	845	475	428	669	767	553	978	342	956	341	657	624	650	670
R2	0.03933	0.05386	0.06347	0.03473	0.03249	0.03835	0.07135	0.01506	0.05298	0.03219	0.05776	0.03112	0.03533	0.06246

Note: Robust standard errors in brackets. *p<0.10, **p<0.05, and ***p<0.01. We use the mean of each variable to separate the sample in two groups, i.e., a group of countries with low values and another of high values.

The first question analysed is whether countries that meet the preconditions for adoption of P2G services perform better in direct tax revenue mobilization. Column 3 adds an interaction between P2G and the difference between the estimated PS and its sample average to the previous specification in Column 2. The P2G coefficient turns negative, but the interaction term itself is positive and significant at the 1 per cent level. This suggests that countries that better meet the preconditions for P2G adoption collect more direct tax revenue. The result highlights the fact that meeting these preconditions is critical for a country to fully benefit from adopting P2G services.

The second estimate of interest is the experience effect, measured by time since the adoption of P2G services. This duration (in years) is interacted with the P2G dummy in Column 4. The coefficient for the interaction term is positive and significant at the 1 per cent level, suggesting that P2G-induced tax revenue mobilization improves over time. It is likely that taxpayers and tax administrations become progressively more familiar with the technology with time, increasing the utility derived from P2G services for facilitating tax transactions.

The third question is how the impact of P2G adoption on tax revenue differs depending on income levels. In Columns 5–7, the model is run separately for countries in three conventional income groups, using the standard model specification in Column 2.[76] The estimated coefficient for P2G adoption is positive and significant at the 1 per cent level only in lower-middle-income countries (LMIC). The ATT is 1.65 percentage points of GDP. This result may be explained by the fact that P2G services are more developed in this group of countries, which also better meet the preconditions for adoption compared with other income clusters.[77]

[76] The countries are divided into low-income countries (LIC), lower-middle-income countries (LMIC), and upper-middle-income countries (UMIC), of which six, ten, and three, respectively, had adopted P2G services by the end of 2018.

[77] Mobile money services, including P2G services, facilitate financial inclusion by allowing informal workers and firms to access banking services at lower cost and without income criteria. Such enterprises, generally excluded from the mainstream banking system, are particularly prevalent in low-income and lower-middle-income economies, which explains why P2G is used more in such countries.

The remaining columns reflect the mediating effects of countries' socioeconomic conditions, corruption, bureaucracy quality, and urbanization. Countries in the sample are divided into two groups in the case of each variable, using the sample average as the cut-off point.

A significant revenue-increasing impact of P2G adoption is found for countries with low control of corruption, low tax compliance, low taxpaying score (i.e., low administrative burden of paying taxes), and low quality of public administration (Columns 8–15), the latter being significant only at the 10 per cent level. As discussed earlier, P2G can help to improve administrative quality, tax compliance, and corruption control by centralizing payments, reducing physical contact with tax administrators, and increasing the transparency of payment transactions.

The adoption of P2G services also has a positive and significant effect on direct tax revenue in countries with high levels of value added from the agricultural sector (Column 17), a proxy for the size of the informal sector, and correspondingly for countries with low levels of urbanization (Column 28). These findings are in line with Jacolin et al. (2019), who find that the adoption of mobile financial services has contributed to the decline of the informal sector in developing and emerging economies. Relatedly, countries with low levels of private sector credit (Column 20), which generally have low levels of financial inclusion, also appear to benefit from P2G. Mobile services that are used for tax payment transactions may facilitate financial inclusion for many individuals excluded from the traditional banking system.

A positive effect is also found for countries with high rates of school enrolment (Column 19). Adopting and setting up the service may alone be insufficient for a country to reap benefits from P2G; this also requires that the service is widely used in practice. The use of mobile-based payment services is likely more common among a more educated population, with sufficient knowledge of both the technology and related procedures for managing firms, such as budgeting and accounting.

P2G adoption has a positive and significant effect in countries with low levels of resource rents (Column 22) and ODA (Column 24), while their high-level counterparts do not appear to benefit from P2G (Columns 23 and 25). Notable resource rents and development assistance may both work to offset revenue needs from taxation, and especially taxation of

the informal sector, disincentivizing capacity development projects and technology adoption that would facilitate tax collection.

Finally, the adoption of P2G services has a positive and significant impact only in countries with an above-average labour force participation rate (Column 27). This may reflect a larger potential user base for P2G. In general, of course, more direct tax revenue is likely to be mobilized in countries with a larger tax base, which is closely linked with labour force participation.

4.3. Transmission channels

Our findings show that P2G services adoption positively affects direct tax revenue mobilization in developing countries. In this section, we explore the underlying mechanisms. Earlier in the paper, we explained that P2G services adoption could improve direct tax revenue mobilization through several channels. These channels include improved efficiency in domestic revenue mobilization by the tax administration, better tax compliance, and a reduction in the size of the informal sector proxied by the primary sector value added.

Based on the PSM methodology, we test the existence of a significant association between P2G services adoption and each of these three transmission channels by estimating the ATTs. In each case, we ensure that the transmission variable is not among the control variables. Table 6 presents the results. All estimated ATTs are significant at the 1 percent level, thus allowing us to validate our transmission channels. Thus, we can conclude that P2G services adoption improves direct tax revenues in developing countries by improving tax compliance and efficiency in domestic revenue mobilization and increasing the taxable base by reducing the informal sector.

Table 6: Transmission channels

Treatment variable: P2G	1-Nearest neighbor matching	2-Nearest neighbor matching	3-Nearest neighbor matching	Radius matching r=0.005	Radius matching r=0.01	Radius matching r=0.05	Local linear regression matching	Kernel matching
	(1)	(2)	(3)	-4	(4)	(6)	(7)	(8)
Domestic revenue mobilization efficiency								
ATT	0.2429***	0.2048***	0.2175***	0.2307***	0.2486***	0.2072***	0.2315***	0.2087***
	(0.0848)	(0.0782)	(0.0659)	(0.0590)	(0.0529)	(0.0453)	(0.0427)	(0.0443)
Observation/Treated	752/105							
Tax compliance								
ATT	0.4704	0.6193*	0.7473**	0.9481***	0.9733***	0.9170***	0.9469***	0.9221***
	(0.4226)	(0.3539)	(0.3226)	(0.2259)	(0.2194)	(0.1791)	(0.1767)	(0.1865)
Observation/Treated	1070/80							
Informal sector								
ATT	-4.0138**	-3.6295***	-3.2820**	-4.0487***	-3.9964***	-3.1679***	-3.2162***	-3.2460***
	(1.6267)	(1.3502)	(1.3352)	(0.8401)	(0.8478)	(0.8458)	(0.7801)	(0.8189)
Observation/Treated	1714/126							

Standard errors in brackets. *p<0.10, **p<0.05, and ***p<0.01. **Bootstrap replications=500.**

4.4. Addressing endogeneity

While the previous analysis suggests that the adoption of P2G services has led to an increase in direct tax revenue, the causality may also run in the opposite direction. Namely, the need to expand tax bases may give rise to the demand for innovative payment solutions and thus influence P2G adoption. Another potential source of endogeneity in the analysis could arise from the simultaneity of P2G adoption with other reforms in the tax administration.

To correct for endogeneity bias, a panel two-stage least squares (2SLS) estimator is adopted that uses the proportion of neighbouring P2G-adopter countries and the rate of mobile phone penetration as instruments. The first instrument follows Keen and Lockwood (2010), who use the proportion of VAT-adopter countries in the region as an instrument for VAT adoption. Likewise, P2G adoption in several neighbouring countries is likely to increase the probability of adopting the same service, for instance due to the imitation effect in policy adoption prevalent in developing countries (Klemm and Van Parys, 2012), without direct impact on tax revenues in the country of interest. As for the second instrument, GSMA (2016) and Jacolin et al. (2019) argue that the adoption of mobile financial services such as P2G is closely associated with the development of the national mobile phone market.

The 2SLS estimates are presented in Columns 1–3 in Table 7. The coefficient for P2G adoption is positive and significant at the 10 per cent

level in all specifications, in line with a positive causal effect of P2G adoption on tax revenues. Columns 5–7 show the estimated coefficients from the first-stage equations. The coefficients for the two instruments have the expected signs and are significant at the 1 per cent level. The p-values from the associated F-tests are below 1 per cent, endorsing the strength of the instruments, while p-values from the under-identification test by Kleibergen and Paap (2006) demonstrate that the instruments are correlated with the endogenous variable. Finally, the null hypothesis of the Hansen test is not rejected, supporting the validity of the instruments.

Table 7: Estimation results correcting for endogeneity bias and considering the persistence of tax revenues

	2SLS-1	2SLS-2	2SLS-3	System-GMM	First stage-1	First stage-2	First stage-3
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
P2G	**1.8343***	**1.6612***	**1.8894***	**0.448***			
	(0.9983)	**(0.9621)**	**(1.0194)**	**(0.2341)**			
Agriculture VA	0.0171	0.0195*	0.0255**	0.067	-0.0046**	-0.0049**	-0.0051**
	(0.0105)	(0.0103)	(0.0105)	(0.0532)	(0.0020)	(0.0021)	(0.0021)
Domestic credit	0.0215***	0.0209***	0.0205***	0.024**	-0.0020***	-0.0021***	-0.0021***
	(0.0039)	(0.0039)	(0.0039)	(0.0099)	(0.0005)	(0.0005)	(0.0005)
Trade openness	0.0078***	0.0097***	0.0083***	0.001	-0.0007*	-0.0008**	-0.0007*
	(0.0024)	(0.0026)	(0.0024)	(0.0036)	(0.0004)	(0.0004)	(0.0004)
GDP per capita (log)	1.0477***	1.0883***	1.1029***	0.492	0.0376	0.0368	0.0384
	(0.2699)	(0.2647)	(0.2683)	(0.5338)	(0.0479)	(0.0482)	(0.0491)
Inflation	0.0019	0.0020*	0.0019	0.007	0.0002	0.0002	0.0002
	(0.0012)	(0.0012)	(0.0012)	(0.0101)	(0.0002)	(0.0002)	(0.0002)
Total population (log)	1.8431***	1.9712***	1.7780***	-0.046	0.4086***	0.4010***	0.4044***
	(0.6218)	(0.6048)	(0.6434)	(0.0777)	(0.0841)	(0.0844)	(0.0848)
School enrollment	-0.0045	-0.0048*	-0.0057**	0.007**	-0.0007	-0.0006	-0.0006
	(0.0028)	(0.0028)	(0.0028)	(0.0036)	(0.0006)	(0.0006)	(0.0006)
Resources rents		-0.0103	-0.0097	0.001		-0.0005	-0.0005
		(0.0079)	(0.0077)	(0.0089)		(0.0010)	(0.0010)
FDI			0.0321***	-0.020			-0.0014
			(0.0085)	(0.0397)			(0.0010)
Lag(Direct tax revenue)				0.779***			
				(0.0748)			
Mobile phone penetration					**0.0005*** **	**0.0005*** **	**0.0005*** **
					(0.0002)	**(0.0002)**	**(0.0002)**
Neighbors with P2G					**0.3040*** **	**0.3010*** **	**0.2966*** **
					(0.0986)	**(0.0986)**	**(0.0993)**
Observations	1305	1296	1291	1040	1305	1296	1291
Countries	96	96	96	92	96	96	96
R2 centered	0.23	0.26	0.24				
KP LM underidentification test (p-value)	0.00	0.00	0.00				
Hansen J test (p-value)	0.21	0.16	0.18	0.11			
Instruments	2	2	2	21			
AR(1) test (p-value)				0.00			
AR(2) test (p-value)				0.45			
F-test instruments (p-value)					0.0002	0.0001	0.0002
P2G (long-run coefficient)				**2.030***			
				(1.0706)			

Note: Robust standard errors in brackets. *p<0.10, **p<0.05, and ***p<0.01. In the system-GMM estimation, the two-step estimator is used with Windmeijer's (2005) standard errors. P2G is instrumented with its first and second order lagged value and the two retained external instruments. The lagged dependent variable is instrumented with its first and second order lagged values. We include the first and second order lagged of FDI, resources rents, total trade, GDP per capita, Total population (log), and school enrollment values as instruments. The set of instruments has been collapsed to overcome instruments proliferation (Roodman, 2009). For the system-GMM estimation, the long-run coefficient of P2G standard error is determined using the delta-method (Greene, 2003).

It is also possible that tax revenues are persistent (Gupta, 2007; Leuthold, 1991), which is addressed by including lagged direct tax revenues in the model using system-GMM estimation (Blundell and Bond, 1998). The related results are shown in Column 4 in Table 4. The p-values of the second-order autocorrelation test (AR2) and the Hansen test both support the validity of the estimation. The large and significant coefficient for the lagged dependent variable indicates that direct tax revenues are in fact persistent. The short-run (0.448) and long-run (2.030) coefficients for P2G adoption are positive and significant at the 10 per cent level, bolstering the previous finding that the positive effects of P2G services adoption increase over time.

5. Conclusion

Several studies have explored the determinants of tax revenues in developing countries. With the rise of ICT, more focus has been directed in recent years towards the contribution of different ICTs to tax revenue mobilization. This study contributes to the literature by assessing the causal effect on direct tax revenue in developing countries of person-to-government payment services using mobile phones (P2G). The adoption of P2G services can help developing countries to reduce corruption, strengthen tax compliance, and overcome a variety of institutional and technical barriers to domestic tax revenue mobilization.

Estimates using PSM point to positive and statistically significant average treatment effects for countries that have adopted P2G. Adopters experience a 1.2–1.3 percentage point boost in direct tax revenue compared with their non-adopter pair. The result remains robust to matching quality tests and alternative estimation methods, namely function control, 2SLS, and system GMM. The effect size also appears to increase with time since adoption.

Alternative model specifications are estimated to test how heterogeneities between countries mediate the impact of P2G adoption on tax revenue. Notably, the treatment effects are positive only for low-income and lower-middle-income countries, and significant only for the latter. Effects are also positive and significant for countries with high levels of value added from agriculture, low rates of urbanization, and low levels of domestic credit, control of corruption, and tax compliance—

characteristics that reflect extensive informality, low levels of financial inclusion, and weak institutions. Additionally, effects are positive for countries with high rates of labour force participation and high levels of schooling, indicating that the benefits of P2G are contingent on a large and capable user base. Countries with low levels of natural resource rents and development assistance, both potential substitutes for tax revenue, also benefit disproportionally from P2G services. Finally, we provide suggestive evidence that improvements in tax discipline, domestic revenue mobilization efficiency by the tax administration, and reduction in the size of the informal sector proxied by agricultural value added are potential transmission channels through which P2G services adoption affects direct tax revenues in developing countries.

Considering these findings, developing countries, especially those with weak governance institutions and low levels of financial inclusion, should promote the adoption and use of MM services for tax transactions. In addition to improving tax revenue mobilization, P2G has the potential to reduce corruption, facilitate transparency between citizens and the public administration, and contribute to the broader socioeconomic inclusion of vulnerable and excluded populations.

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Appendices

Appendix A: Adoption of P2G services

Country	Year of P2G adoption	Direct tax before P2G % of GDP)	Direct tax after P2G (% of GDP)
Low-income countries			
Tanzania	2008	2.24	3.82
Rwanda	2009	2.96	5.69
Uganda	2009	1.96	3.34
Guinea	2012	1.20	2.47
Madagascar	2012	1.90	2.21
Liberia	2016	2.74	3.54
Lower-middle-income countries			
Philippines	2004	5.62	6.02
Kenya	2007	5.81	7.32
Cote d'Ivoire	2008	2.77	2.86
Ghana	2009	2.18	4.47
Bangladesh	2010	1.09	2.43
Cameroon	2010	3.07	3.84
Zimbabwe	2011	9.14	6.70
Pakistan	2012	2.90	3.93
Kyrgyzstan	2014	4.13	5.15
Myanmar	2017	1.12	2.33
Upper-middle-income countries			
Sri Lanka	2012	2.40	2.11
Guyana	2013	8.32	8.53
Brazil	2016	7.76	9.03

Source: authors' elaboration based on UNU-WIDER (2021), World Bank (2021) and GSMA mobile money tracker.

Appendix B: Data description

Table B1 describes the variables used in the analysis, while Table B2 shows the descriptive statistics.

Table B1: Variable descriptions

Source	Variable	Definition
GRD	Direct tax revenue	Total direct tax revenues excluding social contributions and resource revenues
GRD	PIT	Taxes on income, profits, and capital gains
GRD	CIT	Corporate and other business tax revenues
Authors' construction using GSMA mobile tracker	P2G	Transfers of funds from individuals or businesses to governments for public services; recipient agencies and institutions may be at the municipal, state, or national level, and include, for example, public schools, police forces, and tax authorities
WDI	Agriculture value added	Silviculture, forestry, hunting and fishing, agriculture, and breeding; value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs; the measure captures primary sector value added
WDI	Domestic credit to the private sector	Financial resources provided to the private sector by financial corporations
WDI	GDP per capita	GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products; it is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources; GDP per capita is GDP divided by mid-year population
WDI	GDP per capita growth	Annual percentage growth rate of GDP at market prices, based on local currency in constant prices; aggregates are based on constant 2010 US dollars
WDI	Trade openness	The sum of a country's exports and imports as a share of its GDP; the measure captures the degree of openness of a country to the rest of the world
WDI	Resource rents	The sum of rents from oil, natural gas, hard and soft coal, minerals, and forests
WDI	Inflation	The annual percentage change in the cost to the average consumer of acquiring a basket of goods and services that can be set or changed at annual intervals

WDI	Population growth rate	The growth rate of the population, expressed as the speed at which the population increases from one year to the next
WDI	School enrolment	Ratio of total enrolment in school, regardless of age, to the population in the age group that officially corresponds to the level of education
WDI	Net ODA	Net ODA consists of disbursements of loans made on concessional terms (net of repayments of principal) and grants by official agencies of the members of the Development Assistance Committee (DAC), by multilateral institutions, and by non-DAC countries, to promote economic development and welfare in countries and territories on the DAC list of ODA recipients; it includes loans with a grant element of at least 25% (calculated at a discount rate of 10%)
WDI	Urban population share	Urban population refers to people living in urban areas as defined by national statistical offices; the indicator is calculated using population estimates from the World Bank and urban ratios from the United Nations World Urbanization Prospects; the share is calculated in relation to total population
International Telecommunication Union (ITU)	Total market penetration	Mobile-cellular subscriptions per 100 inhabitants
Worldwide Governance Indicators (WGI)	CCE: control of corruption	An assessment of corruption within the political system; such corruption is a threat to foreign investment for several reasons: it distorts the economic and financial environment; it reduces the efficiency of government and business by enabling people to assume positions of power through patronage rather than ability; and it introduces an inherent instability to the political process
WGI	GEE: government effectiveness	Perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government 's commitment to such policies
WGI	RLE: rule of law	Perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development
International Country Risk Guide (ICRG)	Social conditions	Assessment of socioeconomic pressures at work in the society that could limit government action or fuel social discontent; the measure takes into account unemployment, poverty, and consumer confidence; the score ranges from 0 (a weak socioeconomic environment) to 12 (a very strong socioeconomic environment)
ICRG	Bureaucracy quality	Countries with strong bureaucracies that have the strength and expertise to govern without radical policy change or disruption of government services are assigned high points; those countries that lack the cushioning effect of a strong bureaucracy receive low points because a change in government tends to be traumatic in terms of policy formulation and day-to-day administrative functions

Economic Freedom database	Tax compliance	Measures the level of tax compliance in a country
World Bank Group, CPIA database	Public administration quality	Assesses the extent to which civilian central government staff is structured to design and implement government policy and deliver services effectively
International Labour Organization's ILOSTAT database	Labour force participation rate	The ratio between the labour force and the overall size of their cohort, i.e., national population of the same age rang; the labour force includes people aged 15 and older who are currently employed, unemployed but looking for work, or first-time job-seekers
World Bank's Doing Business project	Paying taxes: score	An indicator that captures the mandatory taxes and assessments that a medium-sized company must pay each year, as well as the administrative burden of paying taxes, assessments, and complying with post-filing procedures
Authors' construction	Neighbour	Neighbouring country that adopted P2G

Source: authors' elaboration based on UNU-WIDER (2021), World Bank (2021), and other databases as listed in Column 1.

Table B2: Descriptive statistics

Variables	Observations	Mean	St. Dev	Min	Max
Direct tax revenues	1,326	4.624	2.712	0.147	17.44
Personal Income Tax	1,000	2.076	1.820	0	10.25
Corporate Income Tax	982	2.414	1.541	0	13.79
P2G	1,326	0.0777	0.268	0	1
Agriculture VA	1,326	16.28	12.10	0.893	79.04
Domestic credit	1,326	34.99	30.51	0	160.1
GDP per capita	1,313	3,500	3,168	221.1	20,533
GDP per capita growth	1,326	2.483	4.145	-31.33	50.24
Total trade	1,326	77.23	38.25	0.274	311.4
Resource rents	1,326	7.272	10.53	0	81.95
Inflation	1,326	7.075	16.43	-18.11	513.9
Population growth rate	1,326	1.638	1.173	-2.171	6.568
Total population	1,326	5.944e+07	2.038e+08	69,650	1.386e+09
Total market penetration	1,320	61.02	48.18	0	207.8
CCE	1,326	-0.493	0.592	-1.773	1.647
GEE	1,326	-0.444	0.583	-2.271	1.267
RLE	1,326	-0.496	0.582	-1.905	0.925
School enrollment	1,101	103.0	17.20	29.01	151.8
Social conditions	921	4.358	1.743	0	10.29
Bureaucracy quality	921	1.665	0.772	0	3
Tax compliance	826	6.074	2.104	0	9.047
Public administration quality	519	3.047	0.499	2	4
Urban population share	1,326	47.55	19.91	7.412	90.98
Net ODA	1,303	5.269	7.788	-0.475	92.14
Labor force	1,287	65.52	11.40	41.53	90.34
Paying taxes: score	851	61.09	23.66	0	95.83
Neighbor	1,326	0.0448	0.129	0	1
Number of idp	96	96	96	96	96

Source: authors' elaboration based on UNU-WIDER (2021), World Bank (2021), and other databases as listed in Table B1, Column 1.

General Conclusion

It has been shown in the economics literature that there are significant advantages in promoting digital inclusion through broader mobile phone network coverage and affordable access and usage costs. However, the increasing telecommunications tax burden through special taxes on mobile network operators (MNOs) or consumers raises important concerns. For MNOs, such policies may hurt innovation and investment in the sector and widen the digital divide between industrialized and developing countries. The purpose of this thesis is thus to explore several issues raised by the development of telecommunication services in developing countries by addressing the following questions: What is the tax burden on telecommunications companies? How does the demand for telecommunication services vary with prices? How could innovations in the telecommunications sector help governments promote the diffusion of positive externalities? Throughout the thesis, the different chapters offered some analysis and discussions on those questions.

Chapter 1 measures the tax burden on MNOs through the Average Effective Tax Rate (AETR) in twenty-five African countries and finds that the AETR varies significantly across countries, ranging from 33 percent in Ethiopia to 118 percent in Niger. In addition, it finds that special taxes and fees represent a large share of the AETR, illustrating some taxation by regulation and a potential tax competition (a race to the top) between the MoF and the RA. Chapter 2 estimates the demand price elasticity of mobile voice communication in developed and developing countries and finds that for developed countries, the demand is more price elastic, and voice communication is a substitute for internet data usage. Another important finding of that chapter is that, for operators in developing countries, the price elasticity decreases with the market development level as opposed to those in developed countries. Demand for mobile voice communication is thus more sensitive to price changes in the less penetrated markets in developing countries and the mature markets in developed countries. Furthermore, price elasticity has decreased over time across operators in developing countries. The results also highlight that estimated price elasticities are high, suggesting that operators do not have an obvious interest in engaging in collusive behavior that would hinder competition. Chapter 3 studies the causal effect of mobile money (MM) services adoption on intra-African goods

trade and concludes that countries that adopted MM services register a higher goods trade as a share of GDP compared to non-adopters, with a higher effect on food items trade. Chapter 4 assesses the causal effect of person-to-government (P2G) mobile payment services adoption on direct tax revenue and highlights that countries that adopt P2G services experience a 1.2–1.3 percentage point boost in direct tax revenue as a share of GDP. P2G adoption increases corporate and personal income tax revenues, with a more important effect on the latter. Moreover, the average treatment on the treated is higher among lower-middle-income countries and countries characterized by limited tax compliance and corruption control and low levels of urbanization and domestic credit to the private sector. Improvements in tax discipline, domestic revenue mobilization efficiency by the tax administration, and reduction in the size of the informal sector are the potential transmission channels through which P2G services adoption affects direct tax revenues in developing countries.

From the results of this dissertation, the following policy recommendations can be formulated: (i) First, beyond the level of taxation, the form of taxation (based on profit, turnover, or volume) matters in terms of economic distortions, telecommunication development, and digital inclusion. Governments should pay attention to this issue by moderating special telecommunications taxation and enforcing the collection of more neutral taxes as CIT. (ii) Second, to complement such policies, developing countries' governments, particularly those with poor institutions and low levels of financial inclusion should promote the adoption and usage of mobile money services to benefit from the different advantages and externalities they offer to increase trade, growth, and tax revenue. (iii) There is a need for developing countries to update their regulatory frameworks in line with the sector's development. In addition, when adopting policies on the sector, important economic factors, such as income level and market development level or characteristics, must be considered. Moreover, the sector's regulation should not be asymmetric on the dominant operator.

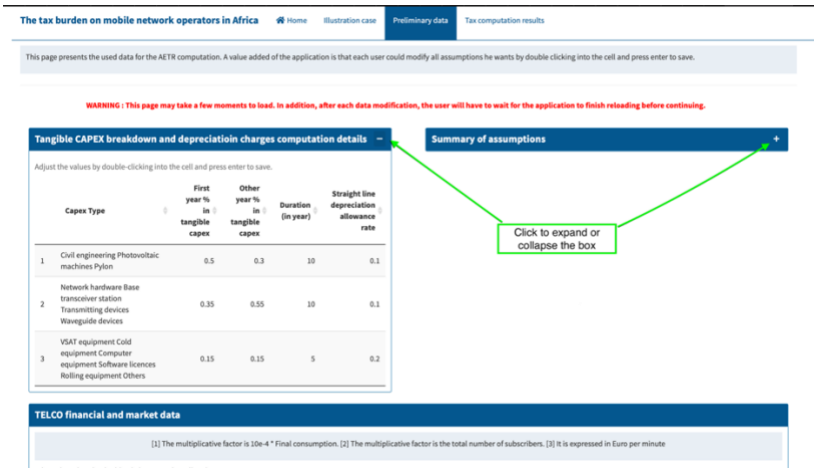
Like any research project, this thesis has limitations. First, the unavailability of data from operators in various countries due to

confidentiality led to the construction of a representative telecom company in Africa. It would have been more interesting to consider financial data from actual companies. Second, the AETR analysis only includes taxes for the mobile telecommunications segment and does not consider the mobile money segment. That may affect the AETR estimates, especially in countries like those in East Africa. Therefore, possible extensions of chapter 1 could include the mobile money segment in the approach. In addition, future research avenues could address (i) the estimation of the tax incidence of indirect taxes on telecommunication services, including mobile money. (ii) The effect of taxes on mobile network operators on investment in the sector. (iii) The determinants of mobile phone and mobile money diffusion and the role of factors such as taxation, inequality, and regulation. (iv) The effect of mobile money adoption on entrepreneurship.

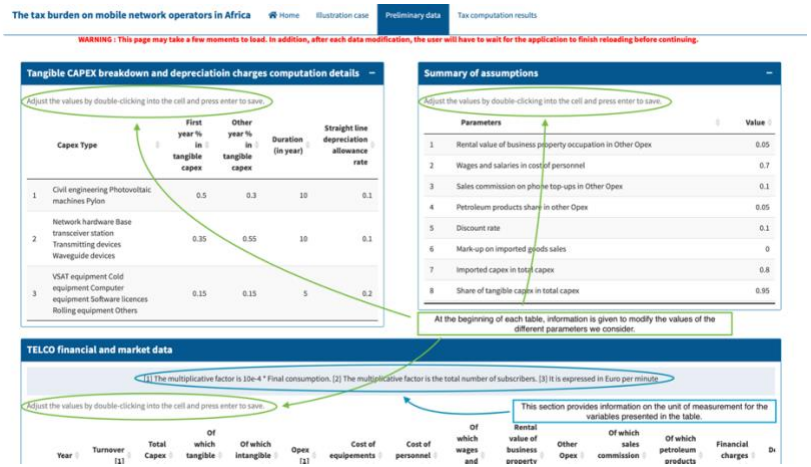
Navigating the online web application

This appendix presents the online application and its various functionalities. It includes four tabs: the home page, the illustration case, the preliminary data, and the calculation results. The first tab presents the analysis framework, the methodology we follow, and the sample we use in the analysis. The second tab considers the case of Cameroon to illustrate the approach to determining the AETR. Finally, the third tab presents our analysis's various data and hypotheses, presented in different boxes.

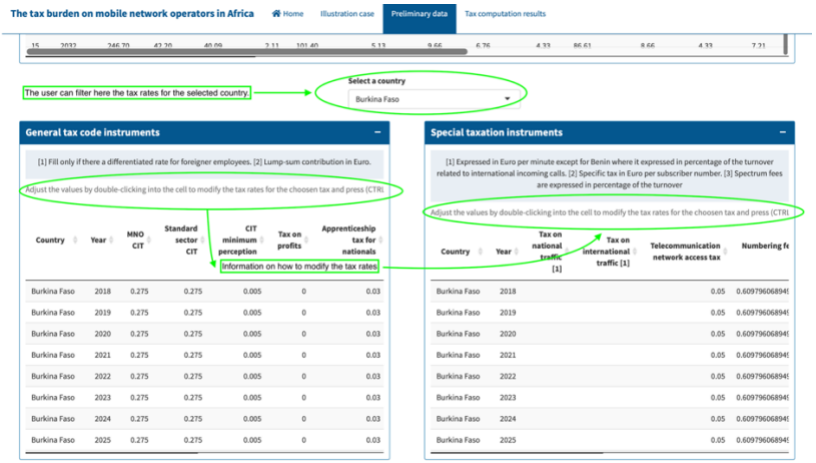
The screenshot below shows how they are displayed. Thus, the user can access the data of each box by clicking on the + sign to the right of the title of each box.



All data and assumptions included in the different boxes can be modified by the user. At the beginning of each box, information is given on how to proceed with modifying the data. In addition, the bluish headers at the beginning of each box show the unit of measurement for the different variables or give additional information about the box's content.

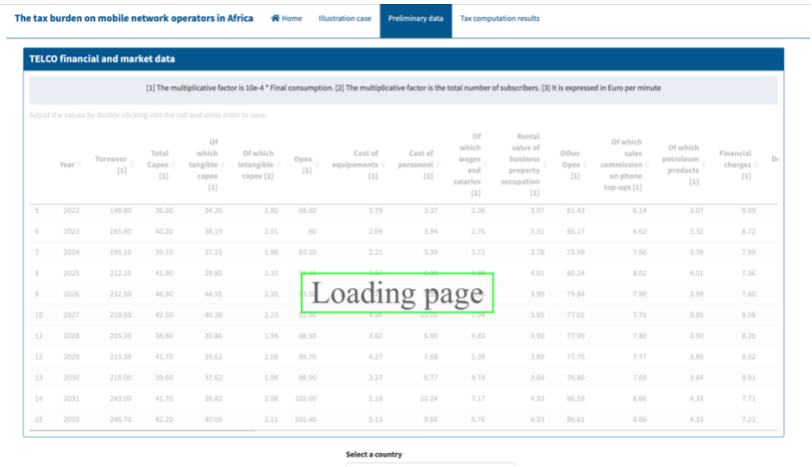


The last part of the tab on preliminary data presents the tax system to which MNOs are subjugated in the selected country. Each user is given the option to filter this data by country.



When a user modifies one or more data, he must wait for the corresponding table to refresh before continuing so that his request can

be considered. The screenshot below shows how a table is displayed each time it is modified.

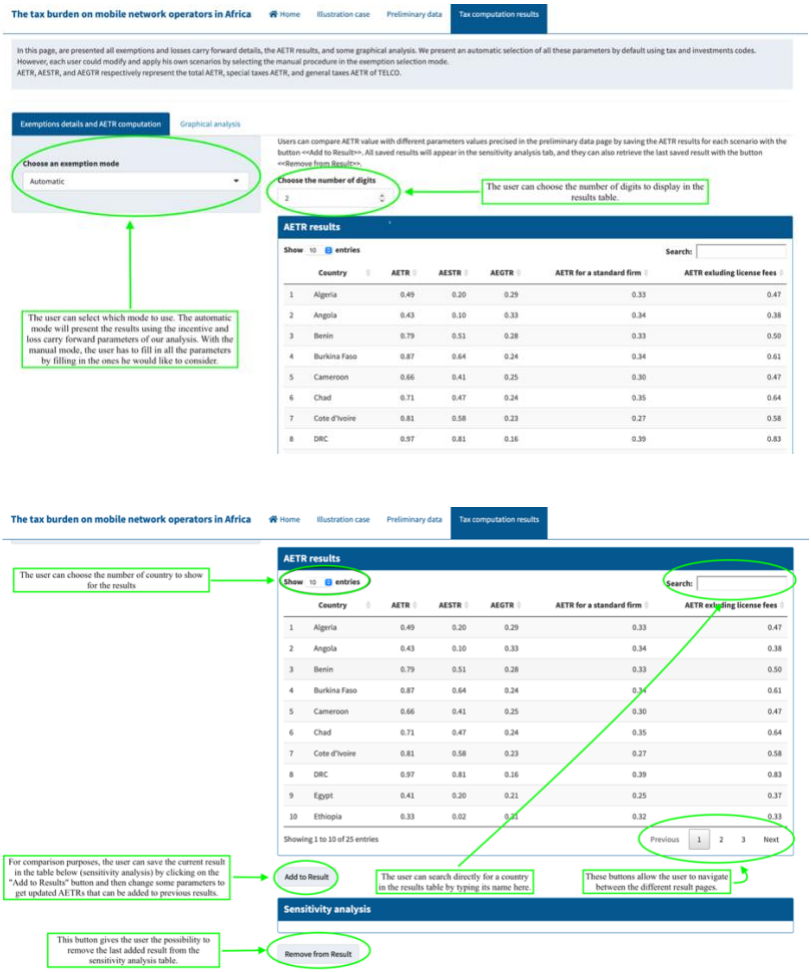


The "Tax computation results" tab shows the results of the AETR computation. Two computation modes are present:

- The automatic mode automatically considers all our parameters and information on tax incentives and losses carry forward.

- The manual mode allows the user to modify the tax incentives granted and the loss carry forward details for each country.

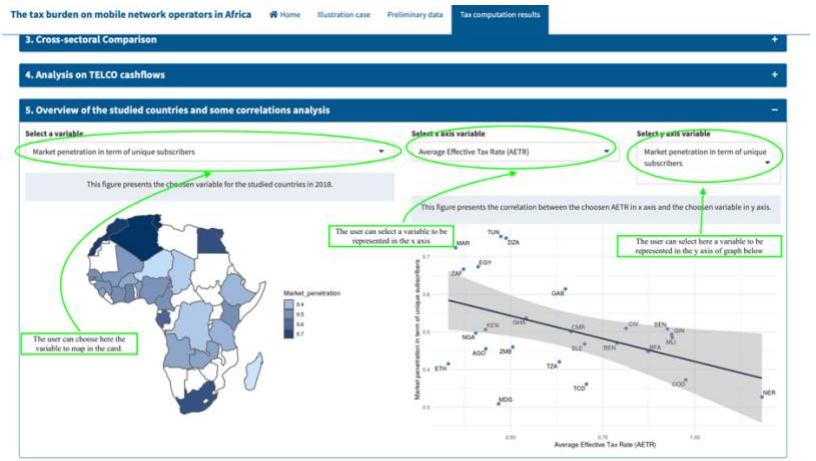
By choosing the default mode, i.e., the automatic mode, the "AETR results" table presents the results of the computations. The table options allow the user to set the number of digits to be displayed for the results, to filter the results by searching directly for a country, to save the results for comparison as a sensitivity analysis, and to be able to remove the saved results from the sensitivity analysis table. The screenshots below give more information on that.



The "Graphical analysis" sub-tab allows you to conduct a graphical analysis of the results obtained. Several analyses can be performed. For example, section 4 presented in the screenshot below allows the user to perform a graphical analysis of the distribution and evolution of cash flows. Each user can select the country he wants and analyze the evolution of cash flows. The bluish headers above each graph show what

is being analyzed and give additional information on the different possible selections/options.

Information on section 5 of the graphical analysis is presented in the screenshot below.

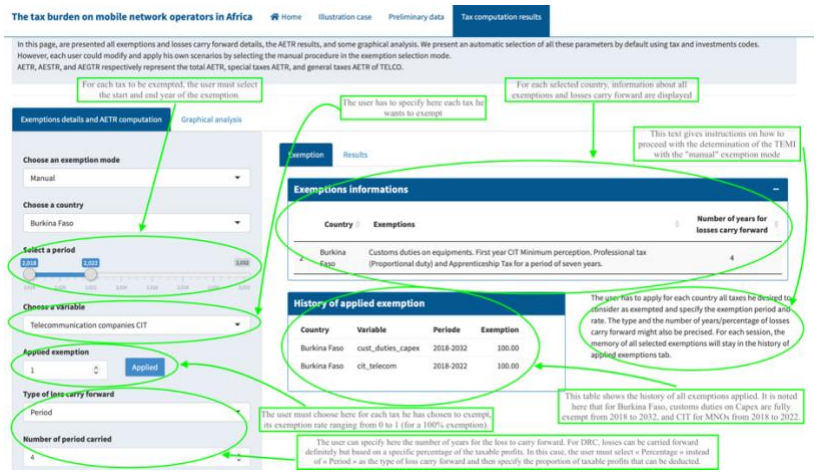


A user can decide to apply its owner tax incentives and the loss carry forward parameters to compute the AETRs. In this case, the user must select the manual mode in the "Tax computation results" tab. Once this is done, additional choice windows appear, and it is up to the user to make the choices.

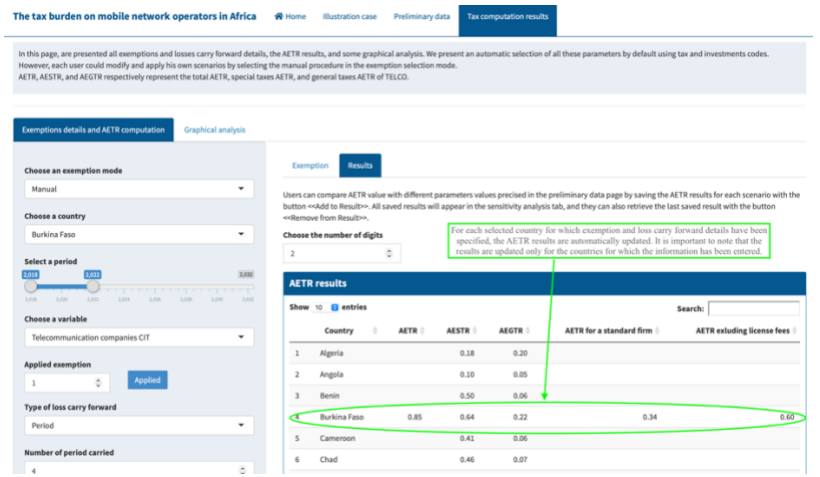
The user must first select the country for which he wants to determine the AETR with his parameters. The user will then see the default information for the country selected in our analysis in the "Exemption information" table. Once he has applied exemptions, their history will be displayed in the "History of applied exemption" table, as shown in the screenshot below.

Next, the user must select the exemption period to be applied by moving the lower and upper bounds of the slider, indicating the exemption period. Then, he must select the tax to be exempted followed by the exemption rate to be applied between 0 and 1 (for example, 0.5 for a 50% exemption) and click on "Applied" to consider his modifications.

Next, come the parameters to be considered for losses carry forward. That is done either according to a certain number of years or percentage of the taxable profit (for DRC). The user must then select the type of loss carry forward to be considered and specify the number of years (when it is a duration) or the percentage of taxable profit that can be deducted as losses (when it is a percentage; for example, 0.6 when losses to carry forward cannot exceed 60% of the profit).



In the "Results" sub-tab that appears above the "Exemption information" table, the results are updated for the countries for which the user has entered the exemption and losses carry forward parameters. Accordingly, the AESTR and AEGTR columns are automatically updated for these countries, and the results for the different types of AETRs are displayed as shown in the table below for Burkina.



In manual mode, the user must enter the exemption and losses carry forward parameters for all countries before continuing to the "Graphical analysis" sub-tab to get a complete analysis for all sections.

Resumé Extensif en Français

1. Introduction

Les télécommunications représentent de nos jours l'un des secteurs les plus dynamiques dans de nombreux pays en développement. Les services de télécommunication améliorent à la fois la productivité des économies et le bien-être des individus. Il y aurait donc des avantages à promouvoir l'inclusion numérique en élargissant la couverture des réseaux de téléphonie mobile et en proposant des coûts d'accès et d'utilisation abordables. Cependant, depuis 2004, de nombreux pays ont augmenté la charge fiscale du secteur des télécommunications par le biais de taxes spéciales sur les opérateurs de réseaux mobiles (ORM) ou les consommateurs. Pour les ORM, de telles politiques peuvent nuire à l'innovation et à l'investissement dans le secteur et élargir la fracture numérique entre les pays industrialisés et les pays en développement.

L'objectif de cette thèse est d'explorer plusieurs problématiques soulevées par le développement des services de télécommunication dans les pays en développement en répondant aux questions suivantes : Quelle est la charge fiscale pesant sur les entreprises de télécommunications ? Comment la demande de services de télécommunication varie-t-elle en fonction des prix ? Comment les innovations dans le secteur des télécommunications pourraient-elles aider les gouvernements à promouvoir la diffusion d'externalités positives ?

2. Présentation et contributions de la thèse

2.1. La pression fiscale sur les opérateurs de réseaux mobiles en Afrique

En plus des taxes de droit commun, le secteur des télécommunications est soumis à plusieurs taxes spéciales sur la consommation des utilisateurs et les activités des opérateurs. Les impôts indirects spéciaux comprennent les droits d'accises et les taxes sur l'accès et l'utilisation des services, comme celles sur les abonnements par carte SIM ou le trafic de communication vocale (national ou international). Les taxes supportées par les opérateurs de télécommunications comprennent l'impôt sur les

sociétés de télécommunications, les contributions au service universel, à la recherche et au développement, au financement de la réglementation, et d'autres taxes annuelles ad valorem fixées en pourcentage des revenus des ORM. Les autres contributions auxquelles les sociétés de télécommunications sont soumises comprennent les frais de spectre, de licence et de numérotation.

Depuis le début des années 2000, les taux des taxes spéciales dans le secteur ont connu une tendance à la hausse. Dans les 25 pays africains de l'échantillon considéré dans ce chapitre, alors que le taux d'imposition des sociétés de télécommunications a, en moyenne, suivi une tendance à la baisse, passant d'un taux moyen de 32,5 % à 29,2 %, le taux d'imposition spécial sur le chiffre d'affaires des ORM a augmenté de plus de 80 %, passant de 2,6 % en 2005 à 4,7 % en 2018, en moyenne.

En outre, le rapport de la GSMA (2015) sur l'inclusion numérique et la fiscalité du secteur mobile montre qu'en 2013, la part des contributions fiscales du secteur dans le total des revenus du secteur mobile variait de 10,6 % au Nigeria à 58,3 % en Turquie, avec une valeur moyenne de 31,9 %. La fiscalité spéciale représente une part importante des recettes fiscales totales du secteur des télécommunications (GSMA, 2007, 2011 et 2015). En outre, selon les rapports de la GSMA, le rapport entre les taxes et le coût total de possession d'un téléphone mobile a augmenté au fil du temps, passant de 17,4 % en 2007 à 18,2 % en 2011 et 20,1 % en 2014.

Pour Matheson et Petit (2021), cela est principalement dû à trois raisons. Premièrement, le dynamisme du secteur et la croissance des revenus générés par la forte demande de services de télécommunications sont souvent avancés comme la raison principale. Ensuite, il y a l'idée que les opérateurs mobiles génèrent des bénéfices économiques en raison de la structure du marché, qui se caractérise par une forte concentration. Enfin, il y a la faiblesse des administrations fiscales, qui conduit les gouvernements des pays en développement à se concentrer sur les grandes entreprises formelles (comme les opérateurs de

télécommunications ou les banques) et les taxes indirectes sur la consommation. Cela soulève certains points. Premièrement, des recettes élevées ne sont pas nécessairement synonymes de rendement financier, compte tenu des dépenses opérationnelles et d'investissement du secteur. Deuxièmement, la structure du marché des télécommunications a considérablement changé. En 2000, par exemple, le secteur comptait deux opérateurs ou moins dans 62 % des pays. En 2017, seuls 31 % des pays ont conservé cette structure de marché.

Ce chapitre estime la charge fiscale pesant sur le secteur de la téléphonie mobile dans vingt-cinq pays africains en considérant les flux de trésorerie avant impôt comme une mesure de rentabilité. Notre approche complète les études précédentes sur la taxation du secteur des télécommunications, notamment celles fournies par la GSMA (Katz & al., 2010, Rogers & Pedros, 2017 ; Pedros & Sivakumaran, 2019) et l'Union internationale des télécommunications (ITU, 2013). Ces travaux étudient l'accessibilité financière des services de téléphonie mobile, notamment dans les pays en développement. Par conséquent, ils se concentrent principalement sur la fiscalité indirecte, comme la taxe sur la valeur ajoutée (TVA), les droits d'accises et les taxes spéciales sur les services de téléphonie mobile, comme les frais ou les surtaxes sur les SMS, les cartes Sim et les appels internationaux entrants. En revanche, nous considérons toutes les taxes qu'une entreprise doit payer pour exploiter sa licence de téléphonie mobile. La charge fiscale englobe donc les taxes de droit commun et spéciales sous le contrôle du ministère des Finances (MdF) et les taxes perçues par l'Agence nationale de régulation des télécommunications (AR). Compte tenu du manque de données financières au niveau du pays, un opérateur de réseau mobile représentatif, TELCO, est construit à partir de la base de données GSMA Intelligence. Dans ce chapitre, le taux effectif moyen d'imposition (TEMI) est calculé pour cette entreprise en tenant compte des taxes et redevances générales et spéciales prélevées uniquement sur le secteur des télécommunications. Le TEMI varie considérablement d'un pays à l'autre, allant de 33% en Éthiopie à 118% au Niger. Les taxes et redevances spéciales représentent une part

importante du TEMI; ce qui illustre une certaine imposition par la régulation et une concurrence fiscale potentielle (une course vers le haut) entre le MdF et l'AR. L'analyse comprend une comparaison du TEMI de TELCO avec celui d'une entreprise aurifère représentative et d'une entreprise standard ayant un rendement brut similaire. La charge fiscale du secteur des télécommunications est plus élevée que celle du secteur minier dans 15 des 19 pays pour lesquels il existe des données sur le secteur minier aurifère. Le chapitre 1 comprend également une application web (https://data.cerdi.uca.fr/telecom/) qui a été développée pour permettre aux lecteurs de reproduire notre analyse ou de modifier les paramètres de TELCO et ceux fiscaux.

2.2. Élasticité du prix de la demande de communication vocale mobile : Une analyse comparative des données au niveau des entreprises

De nombreuses études se sont penchées sur la question de l'élasticité du prix de la demande de services de télécommunications dans la littérature économique et ont considéré différents marchés. Certaines ont considéré le marché du téléphone fixe (Das et Srinivasan, 1999 ; Röller et Waverman, 2001 ; Martins, 2003), d'autres le marché de la téléphonie mobile (Madden et al., 2004 ; Lee et Lee, 2006 ; Dewenter et Haucap, 2008 ; Kathuria et al, 2009 ; Koutroumpis et al., 2011 ; Karacuka et al., 2011 ; Hausman et Ros, 2013 ; Hakim et Neaime, 2014), tandis que d'autres ont étudié les deux marchés (Waverman et al., 2005 ; Garbacz et Thompson, 2007 ; Caves, 2011). Concernant le type de données utilisées, la plupart des études ont considéré des données de panel ou de séries chronologiques au niveau agrégé du pays pour estimer les élasticités-prix (Hausman et Ros, 2013 ; Garbacz et Thompson, 2007 ; Waverman et al., 2005). Certains auteurs ont également utilisé des données d'opérateurs au niveau national pour analyser la demande de services de télécommunications (Koutroumpis et al., 2011 ; Dewenter et Haucap, 2008 ; Karacuka et al., 2011).

Martins (2003), Madden et al. (2004), et Waverman et al. (2005) ont comparé l'élasticité des prix en fonction du niveau de revenu des pays et ont constaté que la demande était plus élastique dans les pays en développement. Lee et Lee (2006) ont intégré la concurrence dans leur analyse en comparant l'élasticité-prix de la demande entre les périodes de pré-concurrence et de post-concurrence et ont constaté qu'elle diminuait entre les deux périodes. Kathuria et al. (2009) ont pris en compte le niveau de développement du marché et ont comparé l'élasticité-prix entre les États indiens à faible et à forte pénétration. Leurs résultats ont montré que les États à faible pénétration étaient confrontés à une élasticité prix de la demande plus élevée que ceux à forte pénétration. Dewenter et Haucap (2008) et Karacuka et al. (2011), en considérant les données des opérateurs, ont comparé l'élasticité prix de la demande entre les marchés mobiles prépayés et postpayés en Autriche et en Turquie respectivement : les deux études ont conclu que l'élasticité prix était plus élevée pour les marchés postpayés. Dewenter et Haucap (2008) font également la différence entre l'élasticité du prix dans l'utilisation privée et professionnelle. Hausman et Ros (2013) ont estimé l'élasticité des prix pour évaluer la variation du bien-être des consommateurs au Mexique, et ont suggéré que les autorités réglementaires devraient éviter une réglementation asymétrique. Cependant, ils n'ont pas inclus explicitement la position des opérateurs ou leurs parts de marché dans leur analyse.

Le chapitre 2 estime l'élasticité-prix de la demande de communication vocale mobile dans les pays développés et en développement en utilisant les données trimestrielles des opérateurs de 2000 à 2017. La nouveauté de ce chapitre est que les données permettent de prendre en compte les deux types de données mentionnés précédemment, c'est-à-dire les données au niveau de l'opérateur et les données couvrant de nombreux pays, y compris les pays en développement et les pays développés ; cela permet des comparaisons basées sur les caractéristiques de l'opérateur et du marché. Bien que Dewenter et Haucap (2008), Karacuka et al. (2011), et Hausman et Ros (2013) utilisent la méthode des moments généralisés

en différence comme stratégie d'estimation, il considère une estimation par la méthode des moments généralisés en système, qui produit des estimations plus efficaces et cohérentes que le premier et qui est plus approprié pour les données de panel non équilibrées. Contrairement à Kathuria et al. (2009), qui utilisent le taux de pénétration médian pour définir le niveau de développement du marché, ce chapitre utilise la théorie de la diffusion de l'innovation de Rogers (1976) pour identifier trois niveaux de développement du marché, c'est-à-dire les marchés à faible pénétration, en croissance et matures. En outre, pour compléter l'analyse de Hausman et Ros (2013), elle étudie la différence potentielle des élasticités-prix en fonction des positions ou des parts de marché des opérateurs. Par ailleurs, dans les études énumérées dans cette section, les données de 2011 de Hausman et Ros (2013) sont les plus récentes ; alors que depuis 2011, le secteur a connu des changements importants. Par conséquent, cette étude constitue une mise à jour de la littérature sur la demande de communication vocale mobile. Les résultats montrent que l'élasticité prix de la demande est plus élevée pour les opérateurs des pays développés. Le contrôle de l'élasticité-prix croisés avec les prix des données internet mobile révèle que la communication vocale est un substitut à l'utilisation des données internet dans les pays développés. Un autre résultat important est que, pour les opérateurs des pays en développement, l'élasticité-prix diminue avec le niveau de développement du marché, alors qu'elle augmente pour ceux des pays développés. La demande de communications vocales mobiles est donc plus sensible aux variations de prix sur les marchés moins pénétrés des pays en développement et sur les marchés matures des pays développés. En outre, au fil du temps, l'élasticité prix de la demande a diminué chez les opérateurs des pays en développement, ce qui souligne la nécessité d'actualiser les cadres réglementaires du secteur des télécommunications pour tenir compte de ces diverses évolutions. En outre, lors de la formulation des politiques réglementaires et fiscales, certains facteurs économiques importants, tels que le niveau de revenu et les caractéristiques du marché intérieur, devraient être pris en compte pour

éviter les pertes de bien-être des consommateurs. Les élasticités-prix estimées élevées suggèrent que les opérateurs n'ont pas un intérêt évident à adopter un comportement collusif qui entraverait la concurrence. En outre, comme il n'y a pas d'effet différentiel dû à la position des opérateurs ou à leurs parts de marché, il convient d'éviter une réglementation asymétrique des opérateurs dominants.

2.3. Adoption des services Mobile Money et commerce intra-africain de marchandises

Introduits pour la première fois en Russie entre 2001-2002, les services de transactions par Mobile Money (MM) se sont progressivement répandus au sein des pays en développement, notamment en Afrique subsaharienne. En effet, en 2020, on comptait 1,2 milliard de comptes MM dans le monde, dont 46% en Afrique subsaharienne (GSMA, 2021). La même année, le volume des transactions MM était de 767 milliards de dollars, l'Afrique subsaharienne représentant 64% de ces transactions. Le MM est un système de paiement mobile lié à un numéro de téléphone et permet à ses détenteurs d'effectuer la plupart des transactions proposées par les banques traditionnelles. Le MM a ainsi permis l'inclusion financière d'une grande partie de la population rationnée par le système bancaire traditionnel dans les pays qui l'ont adopté tout en leur fournissant un moyen de paiement simple, efficace et accessible pour leurs interactions commerciales.

Aujourd'hui, le MM offre un large éventail de possibilités, allant des transferts d'argent de personne à personne et des entrées/sorties d'argent (dans 97 pays) aux services de transfert de gouvernement à gouvernement (dans 35 pays). Depuis plusieurs années, il est ainsi devenu le moyen de paiement de prédilection de nombreux agents économiques sur plusieurs marchés africains.

Le MM permet une intensification du commerce intra-africain car il favorise l'inclusion financière et le développement financier (Burns, 2015, Asongu, 2013, Donovan, 2012), qui à leur tour amplifient le

commerce international (Hajilee et Niroomand, 2019, Demir et Dahi, 2011, Hur et al., 2006). Cependant, aucune étude empirique ne s'est jusqu'à présent penchée sur le rôle du MM dans la stimulation du commerce intra-africain. Par conséquent, le chapitre 3 étudie l'effet causal de l'adoption des services mobile money sur le commerce intra-africain de marchandises en considérant les données de 48 pays africains de 1994 à 2018 et la méthode d'appariement par les scores de propension. Il montre que les pays qui ont adopté les services de MM enregistrent un commerce de biens (en tant que part du PIB) plus élevé que les non-adoptants, avec un effet plus important sur le commerce des produits alimentaires.

2.4. Adoption des services de paiement mobile de particuliers au gouvernement et mobilisation des recettes fiscales dans les pays en développement

Les pays en développement ont besoin de lever des recettes fiscales suffisantes pour financer leur développement. La mobilisation des recettes est souvent entravée dans les pays en développement par un respect limité des obligations fiscales, la faiblesse des institutions et les problèmes techniques liés au recouvrement des impôts. Une solution à ces défis est le paiement par téléphone portable de personnes à gouvernement (P2G), adopté dans plusieurs pays en développement depuis le début des années 2000. Malgré les opportunités offertes par les services de paiement P2G, il n'existe pas, à notre connaissance, d'études évaluant l'impact de leur adoption sur les recettes fiscales. Cet article comble cette lacune en estimant l'effet de l'adoption des P2G sur les recettes fiscales directes, en s'appuyant sur un échantillon de 96 pays en développement et la méthode d'appariement par les scores de propension. Le choix des recettes fiscales directes (plutôt qu'indirectes ou globales) comme résultat principal repose sur l'idée que les contribuables utilisent généralement les paiements P2G pour régler les obligations fiscales qui leur sont imposées directement par

l'administration fiscale. En plus de fournir les premières estimations empiriques de l'impact de l'adoption des services P2G sur les recettes fiscales, ce travail met en évidence la manière dont les facteurs structurels qui diffèrent d'un pays à l'autre médiatisent cet impact, démontrant ainsi quels types de pays sont les plus susceptibles de bénéficier de cette technologie. Cette étude évalue l'effet causal de l'adoption des services P2G sur les recettes fiscales en utilisant l'appariement des scores de propension. L'hypothèse principale est que l'adoption du P2G améliore les recettes fiscales directes dans les pays en développement en fournissant un nouveau mécanisme pratique pour le règlement des obligations fiscales, ce qui améliore la conformité, réduit la corruption et améliore l'efficacité administrative. Selon les estimations de l'appariement, les pays qui adoptent les services P2G connaissent une augmentation de 1,2 à 1,3 points de pourcentage des recettes fiscales directes en pourcentage du PIB. L'adoption des services P2G augmente les recettes de l'impôt sur les sociétés et de l'impôt sur le revenu des personnes physiques, avec des effets plus importants sur ce dernier. Les résultats restent robustes aux tests de qualité de l'appariement et aux méthodes d'estimation alternatives, y compris le contrôle de fonction, les moindres carrés à deux étapes et la méthode des moments généralisés en système. Les effets moyens du traitement sont plus importants dans les pays à revenu moyen inférieur et dans les pays caractérisés par une conformité fiscale et un contrôle de la corruption limités, ainsi que par de faibles niveaux d'urbanisation et de crédit intérieur au secteur privé. Les analyses montrent que l'amélioration de la discipline fiscale, de l'efficacité de la mobilisation des recettes fiscales domestiques par l'administration fiscale et la réduction de la taille du secteur informel sont les canaux de transmission potentiels par lesquels l'adoption des services P2G affecte les recettes fiscales directes dans les pays en développement. Les résultats suggèrent que les pays en développement, en particulier ceux qui ont des institutions défaillantes et de faibles niveaux d'inclusion financière, devraient promouvoir l'adoption et l'utilisation de services d'argent mobile pour les transactions fiscales.

3. Recommandations, limites, et pistes de recherches futures

3.1. Principales recommandations

Les résultats de cette thèse permettent de formuler les recommandations politiques suivantes : (i) Premièrement, au-delà du niveau d'imposition, la forme d'imposition (basée sur les bénéfices, le chiffre d'affaires ou le volume) est importante en termes de distorsions économiques, de développement des télécommunications et d'inclusion numérique. Les gouvernements devraient prêter attention à cette question en modérant les taxes spéciales sur les télécommunications et en imposant la perception de taxes plus neutres comme l'impôt sur les sociétés ou l'impôt sur les bénéfices. (ii) Deuxièmement, pour complémenter ces politiques, les gouvernements des pays en développement, en particulier ceux qui ont des institutions défaillantes et de faibles niveaux d'inclusion financière, devraient promouvoir l'adoption et l'utilisation des services Mobile Money afin de bénéficier des différents avantages et externalités qu'ils offrent pour stimuler le commerce, la croissance et la mobilisation des recettes fiscales. (iii) Il est nécessaire que les pays en développement actualisent leurs cadres réglementaires en fonction du développement du secteur. En outre, lors de l'adoption de politiques relatives au secteur, il convient de tenir compte de facteurs économiques importants, tels que le niveau de revenu et le niveau ou les caractéristiques de développement du marché. Par ailleurs, la réglementation du secteur ne doit pas être asymétrique par rapport à l'opérateur dominant.

3.2. Limites de la thèse et pistes de recherches futures

Comme tout projet de recherche, cette thèse a des limites. Tout d'abord, l'indisponibilité des données (particulièrement financières et fiscales) provenant des opérateurs des différents pays pour des raisons de confidentialité a conduit à la construction d'une société de télécommunications représentative en Afrique. Il aurait été plus

intéressant de considérer des données financières et fiscales d'entreprises réelles. Deuxièmement, l'analyse du TEMI n'inclut que les taxes pour l'exploitation des licences de téléphonie mobile et ne prend pas en compte l'exploitation des licences Mobile Money. Cela peut affecter les estimations du TEMI, en particulier dans des pays comme ceux d'Afrique de l'Est. Par conséquent, des extensions possibles du chapitre 1 pourraient inclure les licences d'exploitation de services Mobile Money dans l'approche. En outre, les futures pistes de recherche pourraient porter sur (i) l'estimation de l'incidence fiscale des taxes indirectes sur les services de télécommunication, y compris le Mobile Money. (ii) L'effet des taxes sur les opérateurs de réseaux mobiles sur les investissements dans le secteur. (iii) Les déterminants de la diffusion de téléphones portables et du Mobile Money et le rôle de facteurs tels que la fiscalité, les inégalités et la réglementation. (iv) L'effet de l'adoption de services Mobile Money sur l'entreprenariat.

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