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DIGITALIZATION AND ECONOMIC DEVELOPMENT: FOCUS ON TAX REVENUE MOBILIZATION, GOVERNANCE, AND TRADE FACILITATION

DIGITALISATION ET DÉVELOPPEMENT ÉCONOMIQUE : ZOOM SUR LA MOBILISATION DES RECETTES FISCALES, LA GOUVERNANCE ET LA FACILITATION COMMERCIALE

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Dédicace

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Summary

<u>Summary:</u> Digitalization and economic development: focus on revenue mobilization, governance, and trade.

Digitalization is process by which information is converted into numerical data to be processed and stored using Information and Communication Technologies (ICTs). By extension, it refers to the use of ICTs by individuals, businesses, public administrations, and others in their daily activities. It therefore allows a shift from manual or physical processing to automated processing using ICTs. Indeed, ICTS refers to the set of infrastructures, tools, hardware, and software that allow digital access and processing of data. Since the creation of the internet on August 6, 1991, many tools have been developed over the years such as smartphones, browser, connected devices, bigdata, e-commerce, online training, social networks, and many others, which are all related to information technology. This process is called ***"digitalization"*** or ***"digital transformation".*** Thus, the world has found itself in a process that will change our lifestyles forever.

Given this rapid rise in the adoption and use of ICTs, they are becoming an indispensable part of the global economy in the twenty-first century, with many issues and challenges for individuals, businesses, and public administrations. Indeed, digitalization has become an indispensable process for public administrations, in developed and developing countries. Most countries have therefore embarked on a process of digitalization, not only with a view to better public management and adapting the supply of public goods, but also in their interaction with individuals and businesses. Given the importance of the issues related to digitization, the economic literature is gradually beginning to focus on the importance and consequences of ICTs on the socio-economic development of countries around the world. It is in this sense that this thesis contributes through three research axes of two chapters each, to the economic literature.

The first axis analyses the effects of digitalization on the capacity to mobilize more tax revenues. The results suggest that digitization is leading to a change in the behavior of individuals, businesses, and the government with regard to the fiscal contract that binds them. Besides, access to and use of ICTs positively affects the mobilization of tax revenues through increased tax compliance and tax administration effectiveness and reducing corruption. The second axis measures the effects of digitalization on government effectiveness and efficiency. The results show that the government's use of ICTs improves its effectiveness by reducing corruption and increasing the quality of the regulator and accountability. The second chapter shows that ICT investment positively affects the

efficiency of public spending on health and education. The last section focuses on Mobile Money payment and intra-zone goods trade. The results suggest that countries that have adopted the use of mobile money services experience an increase in trade of 0.6 percent of GDP compared to those that have not. This result appears to be similar for all developing countries and for African countries.

We conclude with policy recommendations. Digitization and the massive use of technology today is an opportunity for developing countries. It is therefore necessary to facilitate access to ICT and to digitalize as much as possible the administrative steps and procedures. In addition, the infrastructure must be regularly maintained and renewed as needed.

Keywords: Africa, developed countries, developing countries, digitalization, direct tax revenue, education, efficiency, goods trade, government effectiveness, health, ICTs, ICT investments, impact analysis, merchant payment; mobile money, P2G, panel data, propensity score matching, public expenditures, tax revenues.

JEL Codes: C14, E62, F10; H1, H2, H4, H51, H52, H7, O1; O23; O30, O33; O5, O55

Résumé

<u>Résumé :</u> digitalisation et développement économique : zoom sur la mobilisation des recettes, la gouvernance et le commerce.

La digitalisation est un processus par lequel l'information est convertie en données numériques pour être traitée et stockée à l'aide des technologies de l'information et de la communication (TIC). Par extension, elle désigne l'utilisation des TIC par les particuliers, les entreprises, les administrations publiques et autres dans leurs activités quotidiennes. Elle permet donc de passer d'un traitement manuel ou physique à un traitement automatisé utilisant les TIC. En effet, les TIC désignent l'ensemble des infrastructures, outils, matériels et logiciels qui permettent l'accès, l'utilisation et le traitement numérique des données. Depuis la création de l'internet le 6 août 1991, de nombreux outils ont été développés au fil des années tels que les smartphones, le navigateur, les appareils connectés, le bigdata, le commerce électronique, la formation en ligne, les réseaux sociaux, et bien d'autres, qui sont tous liés aux technologies de l'information. Ce processus est appelé ***"digitalisation"*** ou ***"transformation digital".*** Ainsi, le monde s'est embarqué dans un processus qui va complètement bouleverser nos modes de vie.

Compte tenu de cette progression rapide de l'adoption et de l'utilisation des TIC, celles-ci sont en train de devenir un élément indispensable de l'économie mondiale du XXIe siècle, avec de nombreux enjeux et défis pour les particuliers, les entreprises et les administrations publiques. En effet, la digitalisation est devenue un processus indispensable pour les administrations publiques, dans les pays à faible revenu (PFR) et dans pays à revenu élevé (PRE). Ces derniers se sont donc engagés dans un processus de digitalisation, non seulement en vue d'une meilleure gestion publique et de l'adaptation de l'offre de biens publics, mais aussi dans leur interaction avec les individus et les entreprises. Compte tenu de l'importance des enjeux liés à la numérisation, la littérature économique commence progressivement à s'intéresser à l'importance et aux conséquences des TIC sur le développement socio-économique des pays du monde entier. C'est dans ce sens que cette thèse contribue à travers trois axes de recherche de deux chapitres chacun, à la littérature économique.

Le premier axe analyse les effets de la digitalisation sur la capacité à mobiliser davantage de recettes fiscales. Les résultats suggèrent que la digitalisation entraîne un changement de comportement des particuliers, des entreprises et du gouvernement à l'égard du contrat fiscal qui les lie. En outre, l'accès et l'utilisation des TIC ont un effet positif sur la mobilisation des recettes fiscales en

augmentant la conformité fiscale, en réduisant la corruption et en augmentant l'efficacité de l'administration. Le deuxième axe mesure les effets de la digitalisation sur l'efficacité et l'efficience du gouvernement. Les résultats montrent que l'utilisation des TIC par le gouvernement améliore son efficacité en réduisant la corruption et en augmentant la qualité du régulateur et la redevabilité. Le deuxième chapitre montre que les investissements dans les TIC ont un effet positif sur l'efficacité des dépenses publiques en matière de santé et d'éducation. Le dernier axe porte sur le paiement par Mobile Money et le commerce de marchandises intra-zone. Les résultats suggèrent que les pays qui ont adopté l'utilisation des services d'argent mobile connaissent une augmentation du commerce de 0,6 % du PIB par rapport à ceux qui ne l'ont pas fait. Ce résultat semble être similaire pour tous les pays en développement et pour les pays africains.

Nous terminons en émettant des recommandations de politiques. La digitalisation et l'utilisation massif aujourd'hui des technologies est une opportunité pour les pays en développement. Il faut donc faciliter l'accès au TIC et digitaliser autant que possible les démarches administratives et les procédures. De plus, les infrastructures doivent-être régulièrement entretenus et renouvelées au besoin.

Mots-clés : Afrique, analyse d'impact, commerce de marchandises, dépenses publiques, digitalisation, données de panel, éducation, efficacité du gouvernement, efficience, investissements en TIC, mobile money, P2G, paiement marchand, pays développés, pays en développement, PSM, recettes fiscales, recettes fiscales directes, santé, TIC.

JEL Codes : C14, E62, F10 ; H1, H2, H4, H51, H52, H7, O1, O23, O30, O33, O5, O55

Introduction Générale

1. Contexte

Beaucoup d'études montrent que la mobilisation des recettes publiques est un facteur clé dans le processus de développement des pays à faible revenu (Fjeldstad, 2014 ; Jenkins and Newell, 2013 ; Owens and Carey, 2009 ; Miller & Russek, 1997) car ces ressources permettent de financer l'offre de biens publiques ainsi que la réforme des institutions. Cependant, il se pose un ensemble de questionnement sur comment mobiliser davantage de recettes. Comment utiliser efficacement les revenues publiques ? La réponse à ces questions pourrait résider dans l'analyse même des performances du secteur public et dans la qualité des institutions. Un secteur public efficace et efficient pourrait facilement améliorer sa collecte de recettes publiques, offrir davantage de biens et services publiques, tout en évitant de disperser ses forces et ses ressources. Cependant, la littérature économique montre que les pays en développement en général manquent d'institutions de qualité (Mehlum et al., 2006 ; Dollar & Levin, 2005), efficientes dans l'allocation des ressources (Roll, 2014 ; Herrera & Pang, 2005 ; Lockheed & Hanushek,1988 ; Mills & Colclough, 1995) et efficaces dans l'offre de biens et de services publiques.

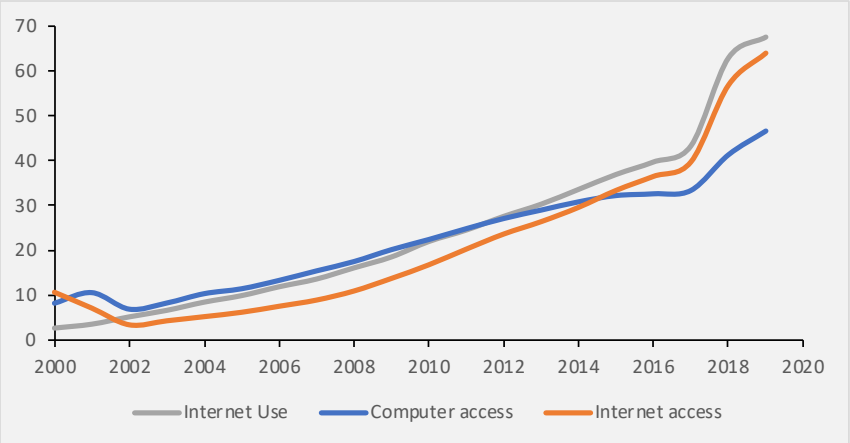
Dans la recherche de cette efficacité, les technologies d'information et de communication apparaissent comme un facteur clé dans la réforme du secteur public et le gain de performances économiques.

2. Évolution de la digitalisation

Ces dernières années, les Technologies d'Information et de Communication se sont vulgarisées à travers le monde entier. Leur accès et leur utilisation se sont rapidement développés. En effet, entre 2000 et 2019, en moyenne, la population mondiale ayant accès à un ordinateur au travail ou à la

maison est passé de 8% à 46,6%, tandis que le taux d'accès à internet est passé de 10,72% à 64% alors que le taux de son utilisation est passé de 2,6% en 2000 à 67,6% en 2019. Cependant, il y'a une grande disparité entre les pays en fonction du niveau de revenus ou des zones géographiques. En 2000, pour les PRE, ces chiffres étaient respectivement de 25,7%, 14,25% et 9,7% pour l'accès à l'ordinateur, à internet et l'utilisation de l'internet. Quant au PFR, on estime à 4,5% l'accès à un ordinateur, 6,2% et 1,7% pour l'accès et l'utilisation d'internet. L'écart entre ces deux groupes de revenu était relativement élevé en 2000. Une comparaison des chiffres pour 2019 montre que dans les PRE, les taux étaient de 76,2% (40,7% dans les PFR) pour l'accès à un ordinateur, 86,9% pour l'accès à internet (58,5% dans les PFR) et 86,3% pour son usage (62,7% pour les PFR). On constate que l'écart, même s'il reste conséquent entre ces deux groupes, s'est considérablement réduit au fil des années. Dans les PFR, le taux d'utilisation d'internet est plus élevé que le taux d'accès. Cela s'explique par le fait que dans ces pays, ceux qui n'ont pas accès à internet à domicile l'utilisent soit chez un proche, soit au travail ou dans des lieux dédiés.

Graphique 1 : Évolution de certains outils de télécommunication entre 2000 et 2019

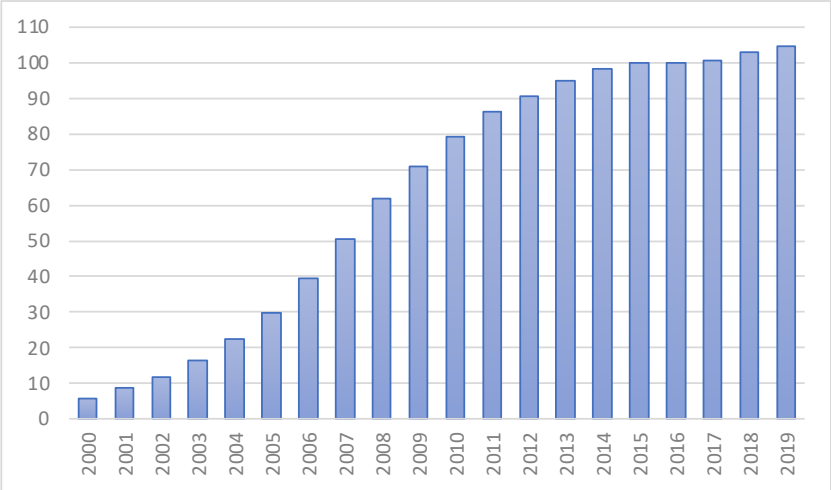


Source : construction de l'auteur avec données ITU

On observe sur le graphique 1 que le taux d'accès à internet et le taux d'utilisation ont la même tendance depuis 2002 avec un taux d'utilisation supérieur.

L'autre outil technologique qui a connu une vulgarisation spectaculaire est le téléphone mobile. En effet, le taux de pénétration moyen mondial du téléphone mobile se situait autour de 5,6% en 2000 (dont 21,4% dans les PRE, contre seulement 3,67% dans les PFR), tandis qu'en 2019, il est estimé à 104,7% (avec 138,9% dans les PRE et 100,71% pour les PFR)[1]. Le taux de pénétration de la téléphonie mobile a donc été multiplié par plus de 27 dans les PFR contre seulement 6,5 dans les PRE en 20 ans. Cela s'explique tout simplement par le fait qu'en 2000, le téléphone portable était déjà un peu plus diffusé dans les PRE. Les taux de plus de 100% ne signifient pas nécessairement que toute la population dispose d'un abonnement mobile. Il s'explique par le fait que certaines personnes disposent de plus d'un abonnement (soit disposant des téléphones à plus d'une Carte SIM, soit ayant plus d'un téléphone). La figure 2 retrace l'évolution du taux de pénétration du téléphone mobile dans le monde de 2000 à 2019.

Figure 2 : Taux de pénétration mondial de téléphone mobile entre 2000 et 2019



Source : construction de l'auteur à partir de données de l'ITU.

Cette évolution fulgurante a fait du téléphone portable l'outil le plus accessible ces dernières années et a favorisé l'accès à d'autres services. En effet, depuis le début des années 2000, s'est développé un système de portefeuille électronique à travers le téléphone portable appelé Mobile Money. Ceci

[1] Selon les données de l'ITU 2020.

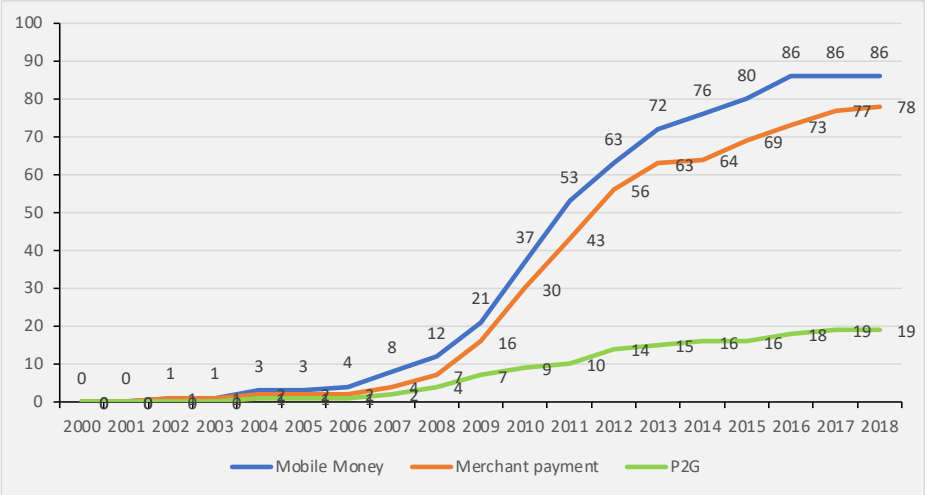
est particulièrement vrai dans les PFR. Le Mobile Money (MM) est un système de paiement mobile lié à un numéro de téléphone portable et permet à l'utilisateur d'effectuer les transactions financières basiques du quotidien. En effet, le MM a été introduit pour la première fois en Russie entre 2001 et 2002. Le MM permet de faire des transactions entre individus, des transactions entre individus et administrations publiques, entre entreprises et administrations publiques, entre individus et entreprises. Aujourd'hui le MM s'est répandu dans la plupart des PFR. En 2018, le nombre de PFR l'ayant adopté était de 86. Dans 78 d'entre eux, il était possible d'utiliser le MM pour des transactions commerciales (MPAY). De plus, à la même date, le nombre de pays qui permettaient d'effectuer des transactions d'individus vers l'administration publique (P2G) était de 19. Tous ces services offerts par le MM lui confère une place très importante dans les économies en développement de façon générale et dans les économies africaines en particulier. Au cours de ces dernières années, certains gouvernements permettent aux usagers d'utiliser le MM pour des paiements lors de leurs démarches administratives pour des services publics tels qu'obtenir des documents comme des certificats de naissance ou de mariage ou des licences commerciales, des paiements statutaires tels que des droits, des taxes ou des contraventions, et des paiements pour des services publics appartenant au gouvernement (GSMA, 2020). A cet effet, en Côte d'Ivoire, les usagers peuvent payer leurs amendes ou contraventions à travers le MM, mais aussi certains impôts et taxes. Au Burkina Faso, il est possible de s'acquitter de ses obligations fiscales en utilisant le service P2G. L'introduction de ce service permet à l'administration fiscale non seulement d'identifier facilement un contribuable, mais aussi de simplifier les procédures de déclarations et de paiement. Ils incitent les contribuables à la discipline fiscale d'autant plus que le service MM est accessible à tous sans condition de revenu.

La figure 3 retrace l'évolution du nombre de pays qui ont adopté le MPAY, le P2G ainsi que d'autres services MM entre 2000 et 2018. L'évolution était lente entre 2000 et 2007 passant de 0 à

8 adoptants. Entre 2007 et 2016, on constate une évolution fulgurante passant de 8 à 86 adoptants. Le nombre d'adoptants s'est toutefois stabilisé depuis 2016.

L'ensemble des statistiques qui précèdent montrent à quel point les TIC font partie intégrante de l'économie à tous les niveaux que ce soit au niveau des individus, des pouvoirs publiques ou des entreprises.

Figure 3 : Évolution du nombre de pays adoptants du MM entre 2000 et 2018



Source : Construction de l'auteur à partir de données de l'ITU.

3. Digitalisation et performance des administrations publiques

3.1. Digitalisation et collecte de recettes fiscales

En l'absence de procédures électroniques, la saisie des informations par les administrations fiscales est très souvent sujette à des erreurs. A travers la digitalisation, l'administration fiscale peut améliorer les recettes collectées. Les e-procédures permettent de transmettre en temps réel les informations produites par les contribuables dans le système d'information de l'administration fiscale. Cela élimine les erreurs de saisie de la part de l'administration fiscale. Si les paiements des revenus salariés et non-salariés sont informatisés et liés au système de l'administration fiscale, cela permet d'identifier tout de suite le revenu gagné par le contribuable et calculer l'impôt à payer.

Également, une partie importante du personnel de l'administration fiscale est consacrée à la réception et à la saisie des informations contenues dans les déclarations papiers. Avec la digitalisation, ces personnes seront donc réaffectées vers d'autres tâches. En simplifiant les procédures, la digitalisation va également inciter les contribuables à la discipline fiscale et donc permettre une amélioration des recettes fiscales. Enfin, la digitalisation peut permettre d'identifier les contribuables notamment ceux ayant des revenus non salariaux. Elle va aussi permettre de détecter de nouveaux contribuables, d'éviter les fraudes et l'évasion fiscale.

3.2. Digitalisation et bonne gouvernance

Les TIC par leur évolution permanente, vont transformer drastiquement les sociétés, les cultures, les économies ainsi que la façon dont les individus interagissent entre eux, et interagissent avec leurs gouvernements. Les décideurs politiques quant à eux, sont souvent conscients du rôle que jouent les TIC dans la transformation des institutions publiques et les performances de ces dernières. La digitalisation peut permettre de mettre en place des institutions efficaces, inclusives et responsables. De plus, la digitalisation peut permettre une prestation rapide, efficiente, efficace et équitable des services publics. Ce qui est un moyen pour les gouvernements de renforcer la confiance du public et d'assurer la transparence, la participation et la collaboration dans le processus de développement.

4. Digitalisation et facilitations commerciales de biens

Avec le développement du MM, les agents économiques ont beaucoup plus de facilité à avoir accès à un moyen de paiement accessible à tous sans condition de revenu. La figure 3 montre que le MPAY est le service du MM le plus répandu. Ainsi, on peut s'attendre à ce que le MM soit beaucoup plus utilisé pour les transactions commerciales. En effet, le MM aujourd'hui a dépassé les frontières des pays. Il est possible d'envoyer ou de recevoir de l'argent à travers le monde entier avec les

services MM. Le MM permettrait donc une intensification du commerce entre les pays qui l'ont adopté car il favorise l'inclusion financière et le développement financier. Le rôle des services MM dans l'activité économique semble être très important pour ces pays.

5. Questions de recherches

La question est de savoir si réellement la digitalisation peut contribuer au développement. Autrement dit, la digitalisation est-elle importante dans l'amélioration de facteurs qui constituent des clés du développement économique ? Il s'agit plus particulièrement d'analyser l'effet de la digitalisation sur la mobilisation de recettes fiscales internes, la qualité de la gouvernance et la facilitation commerciale. Cette question de recherche se divise en trois sous-questions.

Premièrement, au vu du besoin crucial de financement des pays en développement et de la nécessité de mobiliser davantage de ressources, est-ce que la digitalisation peut améliorer les recettes internes collectées dans les pays en développement ? A ce niveau, la thèse s'intéresse à l'accès et l'utilisation des TIC ainsi que de nouveaux moyens de paiement comme le P2G. L'accent est mis sur les recettes fiscales.

Deuxièmement, s'il est important de mobiliser suffisamment de ressources, il est cependant encore plus important de les utiliser de façon efficiente afin d'offrir des biens et services publics. Alors, se pose la question de savoir si la digitalisation permet non seulement d'optimiser les dépenses publiques, mais aussi d'améliorer l'efficacité des administrations publiques. A ce niveau, la thèse s'intéresse d'une part au lien entre les investissements en TIC et l'efficience des dépenses publiques, et d'autre part à la relation entre l'utilisation des TIC par le gouvernement et l'efficacité de ce dernier.

Enfin, le développement de la téléphonie mobile et des nouveaux moyens de paiement, devrait faciliter l'accès aux marchés des personnes qui en sont exclues par manque de moyens de paiement.

Alors, le MM accroît-t-il les transactions commerciales ? Cette partie consiste à analyser l'effet de l'adoption des services de MM sur le commerce des biens dans les pays en développement.

6. Contributions de la thèse

Pour répondre aux trois questions de recherches posées précédemment, cette thèse est organisée en trois parties de deux chapitres chacune.

6.1. Partie I : Digitalisation et recettes fiscales internes

Le premier chapitre de cette thèse analyse l'effet de l'accès au TIC et leur utilisation sur les recettes fiscales internes. Pour ce faire, nous utilisons une méthode de panel avec effets fixes. Les résultats suggèrent que l'accès aux TIC, bien qu'ayant un effet positif sur la mobilisation des recettes, l'effet n'est pas significatif. Cependant, l'utilisation des TIC permet d'améliorer les recettes fiscales internes. L'effet est plus important lorsque l'on considère l'utilisation par tous les acteurs de l'économie (entreprises, individus et administrations publiques).

Le second chapitre s'intéresse à l'effet de l'adoption du service MM par les particuliers pour le paiement de l'impôt (P2G). Il analyse l'effet causal du P2G sur les recettes fiscales directes en utilisant la méthode du « propensity score matching (PSM) ». Les résultats montrent que l'utilisation du P2G augmente les recettes tirées des impôts directs dans les pays en développement.

6.2. Partie II : Digitalisation, efficacité et efficience

Le chapitre 3 de cette deuxième partie, analyse l'effet de la digitalisation sur l'efficacité du gouvernement. En utilisant une méthode de panel à effets fixes, les résultats montrent que la digitalisation permet d'améliorer l'efficacité du gouvernement que ce soit dans PRE ou dans les PFR.

Le chapitre 4 analyse l'effet des investissements en TIC sur l'efficience des dépenses publiques de santé et d'éducation. Il utilise une méthodologie d'estimation en deux étapes. La première étape, mesure le niveau d'efficience des dépenses publiques de santé et d'éducation grâce à une méthode de Data Envelopment Analysis (DEA). Les résultats suggèrent que les pays en développement manquent d'efficience dans l'allocation des ressources publiques. Dans la seconde étape, les investissements en TIC sont régressés sur les scores d'efficiences. Les résultats suggèrent qu'investir dans les TIC est un facteur qui aide les pays en développement à accroître leur niveau d'efficience dans l'allocation des ressources.

6.3. Mobile money et commerce intra-zone

La troisième partie de la thèse traite de l'effet de l'adoption du MM comme moyen de paiement sur les échanges commerciaux d'abord entre pays en développement, puis entre pays africains. L'analyse repose sur l'approche PSM avec différentes méthodes de Matching. Le chapitre 5, évalue l'effet du MPAY sur le commerce sud-sud. Le chapitre 6, analyse l'effet du MM sur le commerce intra-africain. Les résultats indiquent que l'adoption du MM, en permettant l'inclusion financière et l'accès aux marchés, permet aux pays africains en particulier et, de façon plus générale, aux pays en développement d'accroitre le volume et la valeur des échanges commerciaux entre eux.

Cette thèse contribue à la littérature économique de façon générale en montrant le rôle que peut jouer la digitalisation sur certains facteurs du développement comme le renforcement du rôle de l'État, et l'amélioration de la facilité commerciale. De plus, ces derniers doivent accélérer la digitalisation en dématérialisant autant que possible les procédures, en facilitant l'accès et l'utilisation des technologies d'information et de communication. Les infrastructures existantes doivent être entretenues et aussi les pays doivent en acquérir de nouvelles afin de répondre aux besoins et normes récents. Au-delà, la volonté politique des décideurs est une condition indispensable, de même, qu'une vision claire du rôle des TIC dans le développement des pays.

PART I: digitalization and domestic revenues mobilization

Chapter I: Are ICT's boosting tax revenues? Evidence from developing countries

This article is a joint work with BRUN Jean-François, Gérard CHAMBAS, and Jules TAPSOBA

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PART I: DIGITALIZATION AND DOMESTIC REVENUES MOBILIZATION

Abstract: This paper investigates the effect of ICT readiness and ICT usage on tax revenue mobilization in developing countries. The paper uses a panel fixed effect methodology on a sample of 96 developing countries from 2005 to 2016. The study provides evidence that, although ICT readiness positively affects tax revenues, the effect is not significant. However, overall ICT usage increases tax revenue. This positive and significant effect remains valid for main taxes: direct taxes and VAT. While the effect is positive and significant for low-income and lower-middle-income countries, it is not significant for upper middle-income countries. ICT usage has greater impact in countries with low quality institutions. In addition, business, government, and individual use of ICTs have a greater effect on tax revenues than global ICT usage. Finally, the positive effect is stronger over the sub-period 2011-2016, which corresponds to a more intense ICT use.

Keywords: ICTs, Tax revenues, Developing countries, Panel data

JEL classification : H2 ; O1 ; O3

Résumé : Cet article étudie l'effet de l'accessibilité et de l'utilisation des TIC sur la mobilisation des recettes fiscales dans les pays en développement. Il utilise une méthodologie de panel à effet fixe sur un échantillon de 96 pays en développement de 2005 à 2016. L'étude montre que, bien que le niveau d'accessibilité aux TIC ait un effet positif sur les recettes fiscales, cet effet n'est pas significatif. Cependant, l'utilisation globale des TIC augmente les recettes fiscales. Cet effet positif et significatif reste valable pour les principaux impôts : impôts directs et TVA. Bien que l'effet soit positif et significatif pour les pays à faible revenu et à revenu moyen inférieur, il n'est pas significatif pour les pays à revenu moyen supérieur. L'utilisation des TIC a un impact plus important dans les pays dont les institutions sont de faible qualité. En outre, l'utilisation des TIC par les entreprises, les administrations et les particuliers a un effet plus important sur les recettes fiscales que l'utilisation globale des TIC. Enfin, l'effet positif est plus fort sur la sous-période 2011-2016, qui correspond à une utilisation plus intense des TIC.

Mots-clés : TIC, Recettes fiscales, Pays en développement, Données de panel.

Classification JEL: H2; O1; O3

1. Introduction

In order to support developing countries to achieve development towards 2030, the United Nations (UN) has adopted the Sustainable Development Goals (SDGs), which are integrated into the development strategy of all member countries, especially the least developed countries. However, the achievement of these objectives undoubtedly requires significant financial resources. Thus, developing countries must mobilize the necessary resources both domestically and externally. Domestic revenues remain the most reliable resource to enable the country to finance the public goods needed for development as international donors often fail to deliver on their promises. Nevertheless, developing countries often face difficulties in mobilizing domestic tax revenues by granting large exemptions, applying complex tax systems and through failures in tax administration.

Moreover, periods of crisis, such as the one implied by the recent COVID-19 pandemic, may exert a negative impact on domestic revenue mobilization (McDonald and Larson, 2020; Gupta and Liu, 2020; Gupta and Jalles, 2021). In addition, the COVID-19 can negatively affect the capacity of tax administrations to do their usual tasks, particularly for ill-prepared ones.[2] Gupta and Jalles (2021) argue that because of COVID-19, developing countries would see their public revenues deteriorate more than those of advanced economies, especially in Sub-Saharan Africa. Tax administrations relying heavily on digitalization would likely be less affected.

Since the beginning of the 2000s, some tax administrations in developing countries have progressively extended the use of information and communication technologies to collect tax revenues. Today, many countries are implementing electronic invoicing (e-invoicing) on a broad scale (Barreix and Zambrano, 2018), paving the way for radical changes in tax collection, auditing, and beyond. Countries like Brazil, India, and China link tax payments to other public services, using combined data-based services, biometric IDs, and social coding (Shahin and Zheng, 2018). There is an abundant literature on the determinants of tax revenue mobilization in developing countries (Merrifield, 2000; Baunsgaard and Keen, 2010; Auriol and Warlters, 2005; Lucotte, 2012). Paradoxically, very little research addresses the effect of the introduction and use of ICTs on the revenue mobilization process and tax performance in developing countries. Using a theoretical model, Agrawal and Wildasin (2020) analyze the effects of technology on tax revenues through e-commerce. Moreover, Gupta et al. (2017) studied the effects of the digital revolution on public

[2] Bad policy response may have a larger impact on domestic revenue mobilization than the COVID-19 itself.

finances (notably the modernization of tax administration, the tax system's improvement, and the issues raised by digitalization concerning taxation). Indeed, few applied papers look at the impact of Internet usage on domestic revenue mobilization or public revenue structure. Gnangnon and Brun (2018) analyze the effect of closing the Internet gap on mobilizing non-resource tax revenues. In another paper, Gnangnon and Brun (2019) show that Internet usage may drive changes in the structure of public revenue, particularly a shift towards non-resource taxes. In addition, Gnangnon (2020) analyses the impact of Internet usage on tax reform in developing countries from 1995 to 2015. Moreover, some studies, such as Ali et al. (2015a, 2015b), Mascagni and al. (2018), and Bellon et al. (2019), deal with the impact of electronic sales recording machines (ESRM) or electronic invoicing on tax revenues mobilization and tax compliance.

However, the scope of these papers is limited. First, looking at access to the internet captures only certain (though probably key) aspects of digitalization, encompassing broader aspects than the internet. Second, the papers on ESRM and e-invoicing are usually microeconomic studies or concern only a few countries. The results cannot, therefore, be generalized. This paper aims at empirically assessing the effects of economic digitalization on tax revenue collection in developing countries. It uses exhaustive indicators of digitalization and considers the multidimensional features of digitalization. Specifically, this study investigates the effects of ICT readiness and ICT usage on tax revenue mobilization and different components of tax revenue in developing countries. It considers availability, affordability, and skills on the one hand. It integrates ICTs at different levels (individual, business, and government) on the other hand.

The rest of the article is structured as follows. Section 2 discusses the context and theoretical assumptions, while Section 3 describes the dataset and provides descriptive statistics. Section 4 focuses on methodology. In Section 5, the main results are presented. Sections 6 and 7 are dedicated to robustness checks.

2. Background and theoretical considerations

2.1. Digitalization and changes in domestic tax revenues mobilization system

Tax administration was initially based on the principle of direct administration. This meant that the tax administration had to identify the tax bases, list the taxpayers, and collect the tax revenues itself.

This system was inefficient because it was time-consuming, costly, and there was a risk that the largest taxpayers would be missed, and the focus would be on the smallest. Self-declaration systems that place the taxpayer at the heart of the tax collection process were introduced to correct the shortcomings of direct administration. With self-declaration, the taxpayer must know and declare his or her taxable base, calculate the amount of tax due and attach the payment to the tax return. The tax authorities verify the accuracy of the information provided by the taxpayer. The tax administration must manage taxpayers, centralize, and enter the information contained in the tax returns, centralize, and secure the tax payments it receives, ensure that taxpayers comply with their tax obligations, and verify the accuracy of the returns. These tasks must be accomplished in a timely manner to guarantee the efficiency of the tax administration. To this end, new information technologies have been introduced in recent years.

The 1980s saw the first step of the computerization of tax administrations.[3] Then, the need for crosschecking and overall tax management led to the use of news information systems resulting in significant efficiency gains. However, the dispersion of information collected remains an obstacle to crosschecking activities and steering and auditing tasks. From the 2000s onwards, many sub-Saharan African countries introduced integrated information systems within their tax administration, which is a milestone in the digitalization progress. Some of these systems are locally designed while others are imported from similar and/or neighboring countries either from companies based in OECD countries.[4] Despite significant difficulties in their implementation,[5] These systems are gaining importance. They facilitate the implementation of a steering unit, planning audit activities. This phase contributed to a more efficient mobilization of domestic tax revenues. The expected effect is even more significant since, in modern organizational schemes, VAT is collected by a small number of large and medium-sized enterprises. They can transmit regular returns on the revenue they have collected and send payment at the same time.

2.2. Transmission channels

By enabling the benefits of current digital information processing techniques, which are rapidly growing in most developing countries, the digitalization of tax administrations could have a positive

[3] Table G in the appendix presents the digitalization process in some African countries.
[4] Examples of the Côte d'Ivoire SINTAX software also applied in Burkina Faso, very recently, the SIGIT software in Cameroon and SIGTAS applied in Mali and Senegal.
[5] Including the continued use in many countries of multiple information systems (often excel spreadsheets) alongside integrated information systems.

effect on tax revenue mobilization. Several transmission channels can support the potential impact of digitalization on tax revenue mobilization.

The first channel relies on the efficiency of companies acting as tax collectors. The appropriate level of digitalization of large enterprises acting as tax collectors, combined with the introduction of e-procedures, is an additional positive factor for increasing tax revenues. For large companies, digitalization allows a drastic reduction of physical travel, thus constituting a factor of reducing the administrative costs borne by taxpayers due to the physical filing of the return. Besides, it eliminates any additional cost that mainly affects companies located far from the services dedicated to their tax management. Digitalization also alleviates the difficulty for medium-sized companies to free up staff to file returns, thus removing an obstacle for these companies to collect domestic indirect taxes. Besides, e-procedures guarantee a secure date for filing returns and making payments. This is because uncertainties can arise in traditional procedures, for example, when a deadline is missed due to office closures while taxpayers are waiting or when congestion occurs as deadlines approach.

The second channel is related to the effectiveness and efficiency of the tax administration. Digitalization makes it possible to have tax data in real-time that is free of input errors made by the tax administration. Indeed, e-procedures allow real-time transmission of information produced by taxpayers into the tax administration's information system. Also, since they avoid delays in entering information, the tax authorities can immediately concentrate their resources on checking the returns. In the absence of e-procedures, a significant portion of the tax administration's staff is dedicated to receiving and entering information contained in paper returns. The staff that performs these data entry tasks is poorly qualified. A digitalized tax administration can allocate its human resources to other tasks. To take full advantage of digitalization and e-procedures, it is essential to have a single Large Tax Unit. Moreover, e-procedures allow to increase the portfolio of Medium-Sized Units, limiting their number. Thus, it is possible to concentrate highly qualified managers in a limited number of Units.

The third channel relies on the fact that digitalization is potentially a factor reducing corruption and improving tax compliance. By reducing the need for taxpayers to travel to the tax administration's offices, e-procedures reduce the possibility of corruption. In addition, with automatic procedures it is more difficult for civil servants and/or company employees to misappropriate tax revenues. In addition, digitalization by facilitating the calculation of the amount of taxes due, and by avoiding errors, encourages taxpayers to comply with their tax obligations. E-procedures promote tax compliance based on both adherence and sanction; they should provide

an accessible and quality service to facilitate the taxpayer's obligations while detecting and sanctioning non-compliant taxpayers.

3. Data and preliminary

3.1. Data

To conduct this study, we constructed an unbalanced panel of 96 low- and middle-income countries, including 38 Upper Middle Income (UMIC), 35 Lower Middle Income (LMIC), and 23 Low-Income Countries (LIC) over the period 2005 - 2016.[6] The variables explained are the ratio of tax revenues to GDP and other components of tax revenue. This data has been extracted from the database of the International Centre for Tax and Development (ICTD). For missing values in this database, the Organization for Economic Co-operation and Development (OECD) database and West African Economic and Monetary Union (WAEMU) data are used to complete them. Excepted ICT data, all other explanatory variables (GDP per capita growth, value-added of agriculture, fishing, forestry, natural resource rents, total population, imports, and exports of goods and services) are from the World Bank's World Development Index (WDI).[7] Data on readiness and usage were collected from the Networked Readiness Index (NRI) of the World Economic Forum's Global Information Technology Report (GITR) from 2005 to 2016.8 According to the 2016 edition, the readiness sub-index was constructed with three pillars of eleven variables. As for the usage sub-index, it is also composed of three pillars with sixteen variables. The score ranges from 1 to 7, where 7 is the best score.[9]

3.2. Variable's description

3.2.1. Variables of interest

ICT readiness sub-index: The Readiness Index assesses the factors that facilitate access to ICTs. It considers the availability of infrastructure and its accessibility concerning costs and competition.

[6] Countries list in appendix A.
[7] Table C in the Appendix provides a description and sources of all variables used in the paper.
[8] Readiness and usage data were collected for each year from 2005 to 2016, except for 2011, which is not available due to the absence of the GITR in that year. This was calculated by averaging the data for the years 2010 and 2011.
[9] The estimation method is presented in the appendix (table H and table I). For more details, see Duta et al. (2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015 and 2016).

This sub-index also considers the skill needed to claim to use ICT. However, even if ICTs are available and accessible, they cannot be helpful if they are not using. Therefore, it is anticipated that the effect of readiness on tax revenue will be non-significant.

ICT usage sub-index: The usage sub-index measures the adoption of ICTs by the economy's main components for their current activities. ICT usage includes the individual usage pillar that measures the popularization of ICT among the population, the Business usage pillar that measures the use of ICT by businesses in business-to-business, business-to-customer transactions, and their procedures with the government. It also includes their ability to innovate. Finally, the government usage pillar is captured by the availability and quality of online public services, government promotion, and ICT procurement.

3.2.2. Control variables

GDP per capita growth: GDP per capita growth measures the share of GDP held by an individual (i.e., average annual income) and the development level of a country. The growth of GDP per capita should have a positive effect on tax revenues. Indeed, the increase in disposable income tends to increase the tax collection capacity and the tax paying capacity of citizens.

Agriculture, fishing, and forestry value-added: Agriculture, fishing, and forestry value-added as a proportion of GDP is used to measure the economy's sectoral structuring. In developing countries, agriculture and fisheries are predominant sectors. However, the fact that most of the fruit of these activities is for self-consumption or sold on informal markets makes taxation of the agricultural sector difficult. Therefore, the effect of value added in agriculture, fisheries and forestry on tax revenues is projected to be negative.

Total natural resource rents: Total natural resource rents are the sum of oil rents, natural gas rents, coal rents (hard and soft), mineral rents, and forest rents. Natural resources are an opportunity to raise more tax revenues through multilateral corporate taxation. Moreover, in resource-rich countries, tax revenues from natural resources represent a significant share of tax revenues. Consequently, the impact of natural resource rents on tax revenues is expected to be positive.

Imports and exports of goods and services: Imports and exports provide a measure of a country's trade openness. As regards exports, there is a suspicion that they are negatively affecting

tax revenues because they are goods and services that are not subject to domestic indirect taxation and are not subject to any export tax. As for imports, they are thought to have a positive effect on tax revenues because of the gate tax and the goods and services tax, which raise more tax revenue.

Liquid liabilities to GDP: The ratio of liquid liabilities to GDP is also known as broad money or M3. They are the sum of money and deposits with the central bank (M0), plus transferable deposits and e-money (M1), plus fixed-term and savings deposits, transferable foreign currency deposits, certificates of deposit and repos (M2), plus travelers' cheques, fixed-term foreign currency deposits, commercial paper and units in mutual funds or market funds held by residents. It is used to control the financial development and degree of monetization of a country.[10]

Total population: It measures the number of people living in the territory of a country. The total population is anticipated to have a positive effect on tax revenues, as the higher the number of inhabitants, the higher the consumption and indirect tax revenues. Also, this could have a positive effect on direct personal income tax. However, a large population increases the number of taxpayers but not necessarily tax revenues.

3.3. Descriptive statistics

The table in the appendix provides a summary of the data. On average, developing countries are just above the worst offenders.[11] Range of the index for the readiness sub-index, with an average of 3.93 and a minimum of 1.74, while the maximum is 5.7. However, they remain in the worst range according to the average usage index with a mean of 3.1 and respectively a maximum and minimum of 5.1 and 1.99.[12]

Figure 1 shows that in the first few years, the readiness index increases sharply then remains stable over the period 2007-2012. The growth in the early years can be explained by initial investments in infrastructure that increase ICT readiness. Then, the decline in 2012 can be explained by obsolescence and degradation of infrastructure, which could have a negative impact on the quality of services provided and thus reduce ICT readiness. However, there is an improvement from 2012

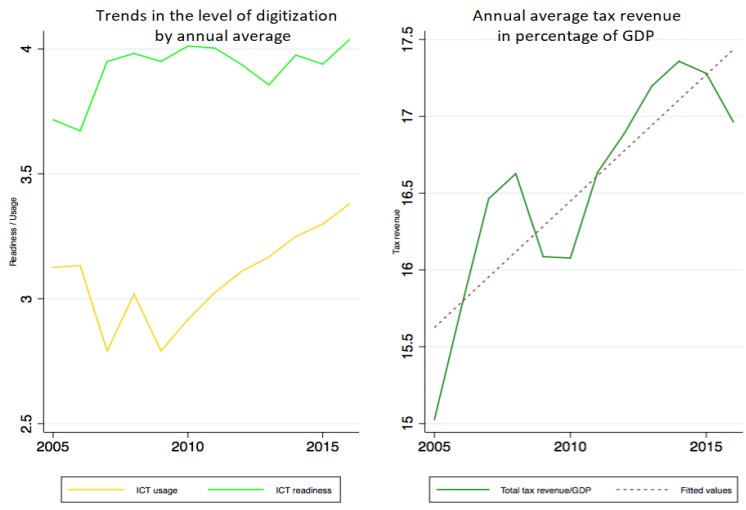
[10] About considering the degree of monetarization in explaining tax performance, see Lotz, J. R., and Morss, E. R. (1970, pp.329).
[11] According to the 2013 NRI map, the score can be classified into 5 ranges that are from the worst to the best: the first range 1-3.3, the second is 3.3-4, the third 4-5, fourth 5-5.4, and the best 5.4-7.
[12] Table B in the appendix resumes descriptive statistics.

and 2013 onwards, which could be due to improvements and innovations that could increase supply and quality. Furthermore, the readiness index remains relatively stable throughout the study period. This is since the infrastructure is a stock and is used over the long term. Therefore, they do not change much.

On the other hand, the usage index has an irregular trend until 2009. Its trend becomes stable and increases from 2010 onwards (figure 1). Unlike the readiness index, its downward trend can be caused by several factors—first, the low level of public interest in ICT in the early years. Second, the lack of skills leads to a decline in the number of people using ICT. Finally, the high-cost elasticity of demand in the early years discourages low-income people and those for whom the use of ICT is not a necessity. Over time, as ICTs become more established in daily life and through economies of scale that reduce access costs, their use increases. All these factors, combined with the adaptation of supply to needs, could explain the narrowing of the gap between readiness and usage. The gap between readiness and use shows that the full potential of ICTs is under-exploited. This gap tends to narrow over time, undoubtedly due to the popularization of the use of ICTs.

As for tax revenues, figure 1 shows that the mean of the ratios of tax revenues to GDP increased over the period considered (cf. figure1). The rising trend can be observed in two stages, with a decrease between 2008 and 2010. The first stage is from 2005 to 2008 and the second from 2010 to 2016. The decline in tax revenues between 2008 and 2010 could be explained by the effects of the financial crisis from 2008 - 2009.

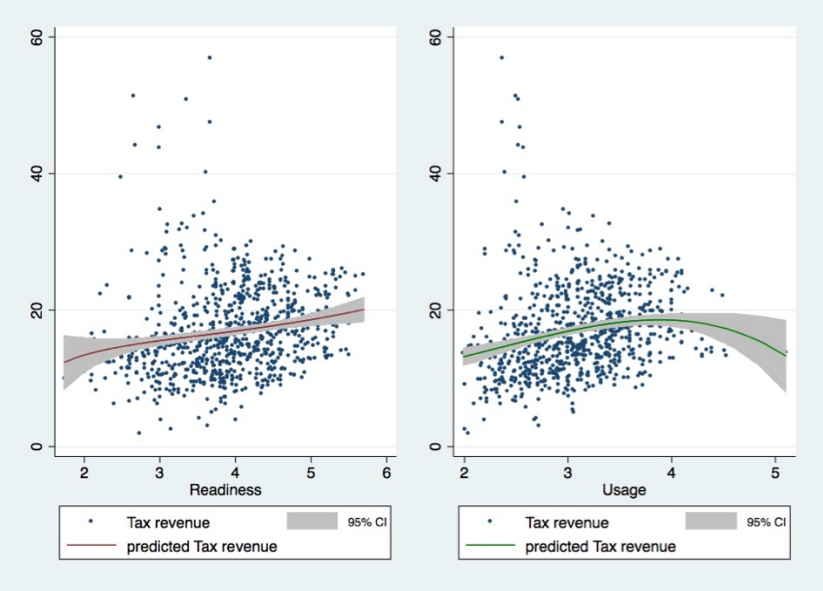
Figure 1: Trend of ICT Readiness and Usage from 2005 to 2016



Source: Author construction with GITR, ICTD, OECD, and WAEMU data

Furthermore, the scatter plot between tax revenues and ICT indices shows a positive relationship between the two variables. However, the relationship seems to be reversed for the usage index above a given threshold (figure 2). Besides, the values of the scatterplot are widely dispersed around the expected trend and that the relationship between the two phenomena is not linear. To take these observations into account, the explained variable will be set to logarithm. This technique also has several advantages as it limits the extent of asymmetry of values (Gnangnon, 2020); and could also reduce outliers' influence.

Figure 2: Scatter plot of ICT indices and tax revenues



Source: Author construction using data from GRD and GITR

4. Methodology

4.1. Model specification

According to the literature on tax mobilization (Gupta 2007, Baunsgaard, T., & Keen, M. 2010, and Clist, P., & Morrissey, O. 2011), panel fixed-effects model is specified to estimate the effect of ICT readiness and ICT use on tax resource mobilization in developing countries. The model can be written as follows:

$$\boldsymbol{log(Tax\ revenue)_{it} = \delta + \alpha ICT_{it} + \beta X_{it} + \varepsilon_{it}} \qquad \textbf{(eq1)}$$

Tax revenues is the tax revenues in the percentage of GDP. **ICT** represents the digitalization score for country i in the year j. **ICT** represents either the readiness or the use of ICT. As for the usage

components, there is the individual, business, governmental uses. X_{it} includes control variables that are determinants of revenue mobilization according to the literature on this question. These determinants are GDP per capita growth, agriculture, fisheries, and forestry value-added, total natural resource rents, trade openness (Import and export of goods and service). ε_{it} is the error-component term. Concerning $\boldsymbol{\delta}$, $\boldsymbol{\alpha}$ **and** $\boldsymbol{\beta}$ they respectively indicate the constant part of the model, the coefficient of the digitalization and the coefficients of the other control variables.

4.2. Discussing endogeneity issue and choice of instruments

Referring to the literature, a panel fixed effect (FE) model is conducted to estimate the impact of digitalization on tax revenue in developing countries. In addition, a fixed effect model with "Driscoll-Kray" standard errors (FE-DK) is estimated to deal with heteroscedasticity and autocorrelation. Driscoll & Kraay (1998) standard errors are not only relevant to control autocorrelation and heteroskedasticity, but they are also robust to temporal and cross-sectional dependence. Furthermore, it has been suspected that the readiness and usage variables may be endogenous. Indeed, they can be endogenous at three points: (i) The government can allocate part of the tax revenues collected to promote access to and use ICTs within the tax administration and at the general population level.[13] Furthermore, suppose ICTs enable the government to be efficient and to collect more resources. In that case, there will be more incentives to increase the use of ICTs in tax revenue mobilization. The more tax resources government collects through the access and use of ICTs, the greater the incentive for the government to use and promote the use of ICTs. If the tax burden is high, businesses may have an incentive to avoid taxes. To this end, they will make more use of ICT to facilitate tax avoidance and optimize taxation. In this way, tax mobilization can positively affect the readiness and usage of ICT (ii). Finally, when the tax on telecommunication time is high, the use of ICT may be affected. Indeed, individuals and businesses will prefer to use communication means that offer more considerable benefits through "free" messaging and calling applications. In this way, taxation will create a substitution effect by moving away from traditional means (fixed phones, direct calls, and messaging.) towards more

[13] In some countries, a specifics tax on telecommunication was established, and a share of this tax is used to finance ICT access and digitalization. For example, there are Burkina Faso and Côte d'Ivoire. In Burkina Faso, there is a tax rate of 2% found to access universal services and 0,5% found for research and training. In Côte d'Ivoire, there is a similar tax, but the rate is not the same. This tax resource is allocated as follows: -80% is intended for an account opened with the Directorate General of the Treasury and Public Accounts for the financing of the promotion of sport, the promotion of culture, the promotion of information and communication technologies, the equipment and modernization of the tax administration.
Source: LAW No. 037-2013/AN on the Finance Act for 2014.

sophisticated such as smartphones and the internet, which facilitate access to free calling and message applications (iii). To overcome endogeneity, instrumental variables (IV) are used in the estimations. (IV). To this end, the following four instruments have been identified to deal with endogeneity. The first is the **telecommunication investments**, which indicate annual investments in telecommunication services. In addition, there is **Computer access** which estimates the percentage of households with access to a computer at home or in the office. Moreover, **mobiles subscription,** which is the mobile-cellular subscription per 100 habitants. The last two are the primary device that is used in daily activities. The fourth is **Internet users** that is the percentage of households using the internet.[14] The rationale for choosing these indicators is that they are a useful way of improving ICT accessibility and uses.[15] For readiness, telecommunication investments, computer access, and mobile subscription are used. Regarding usage, Computer Access and Internet User were chosen because Internet use goes with the concept of computer access.[16]

5. Baseline results

5.1. Effect of ICT Readiness on tax revenues

The results in table 1 present the effects of ICTs readiness on tax revenues in the percentage of GDP. In column 1, the estimate is carried out using only the variable of interest. The results show that ICT readiness has no significant effect on tax revenues. This estimation model suffers from a bias due to omitted variables. In column 2, explanatory variables mainly used in the literature are included. The effect of ICT readiness on tax revenue remains non-significant. The result of the estimation with Driscoll-Kray standard errors (column 3) is the same as the previous results, but the significance level of some variables increases (total resource rents, total population and, export of goods and services). In column 4, the instrumental variable regression results are presented.

After instrumentation, the number of observations decreases due to missing data in instrumental variables. Besides, Anderson's canonical correlation test rejects the null hypothesis of under-identification since the p-value associated with this test (0.000) is lower than all conventional

[14] Let us know that access to the internet is different from using the internet. Being covered by the internet does not mean using it. One can have a signal on the internet but not use it for any activity. That is access to the internet.
[15] In Côte d'Ivoire, they have introduced an e-procedure for VAT declaration and refund of VAT credit. This type of procedure is underway in Burkina Faso and has been introduced in Morocco.
[16] The use of key aspects of digitalization certainly depends on the size and quality of the Internet network.

Significance thresholds. This result suggests that the instrumental variables are correlated with the endogenous variables and that these instruments are therefore appropriate. Furthermore, the Sargan–Hansen test does not reject the null hypothesis of no correlation between the instrumental variables and the error term indicating that the instruments are valid because the p-value (0.362) is higher than all convention thresholds. In addition, the first-stage results show that the instruments are valid because they explain the endogenous variables at conventional thresholds.

Table 1: Effect of ICT readiness on tax revenues

Dependant variable : Log (tax revenue in % GDP)	(1) Fixed Effects	(2) Fixed Effects	(3) Fixed Effects Driscoll-Kraay	(4) Fixed Effects - Instrumental variables
ICT Readiness index	0.0097	0.0003	0.0003	0.0185
	(0.0240)	(0.0147)	(0.0073)	(0.0304)
Liquid liabilities to GDP		-0.0002	-0.0002	-0.0008***
		(0.0006)	(0.0004)	(0.0002)
GDP per capita growth		0.0007	0.0007	0.0030**
		(0.0019)	(0.0019)	(0.0013)
Agriculture, forestry, and fishing, value added		-0.0101***	-0.0101***	-0.0051
		(0.0031)	(0.0024)	(0.0042)
Total natural resources rents		0.0064*	0.0064***	0.0084***
		(0.0035)	(0.0010)	(0.0031)
Imports of goods and services		0.0059***	0.0059***	0.0045***
		(0.0016)	(0.0007)	(0.0011)
Exports of goods and services		-0.0033**	-0.0033***	-0.0009
		(0.0015)	(0.0008)	(0.0013)
Population total		2.45e-09*	2.45e-09***	3.31e-09***
		(1.36e-09)	(5.34e-10)	(1.18e-09)
Observations	936	890	890	530
Number of groups	96	93	93	78
R-Squared	0.00	0.14	0.14	0.26
Anderson canonical cor. p-value (H0: under identification)				0.0000
Sargan-Hansen p-value				0.531

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The effects increase compared to fixed-effect estimation without instrumental variables. Moreover, the effect of readiness increases but remains non-significant. This result is because the instrumental variables corrected the bias in the previous estimates. These results suggest that readiness is not a key factor in explaining tax revenue mobilization while essential in the digitalization process. This is logical because there is no sense in carrying out the digitalization if it is not used.

5.2. Effect of ICT usage on tax revenues

As concerning ICT usage (Table 2), the fixed effect panel model (columns 1 and 2) and fixed effect with Driscoll-Kray standard errors (Column 3) show that ICT usage has a positive and significant

effect on tax revenues in developing countries, the results of both estimations are similar. However, total natural resource rents, the export of goods and services, and total population effects are more significant in DK-FE estimation.

Table 2: Effect of ICT usage on tax revenues

Dependant variable : Log (tax revenue in % GDP)	(1) Fixed Effects	(2) Fixed Effects	(3) Fixed Effects Driscoll-Kraay	(4) Fixed Effects - Instrumental variables
ICT usages	0.0771*	0.0562**	0.0562**	0.1256***
	(0.0405)	(0.0221)	(0.0222)	(0.0432)
Liquid liabilities to GDP		-0.0003	-0.0003	-0.0006
		(0.0006)	(0.0003)	(0.0004)
GDP per capita growth		0.0006	0.0006	0.0015
		(0.0019)	(0.0019)	(0.0014)
Agriculture, forestry, and fishing, value added		-0.0082***	-0.0082***	-0.0040
		(0.0029)	(0.0025)	(0.0039)
Total natural resources rents		0.0071**	0.0071***	0.0100**
		(0.0036)	(0.0013)	(0.0048)
Imports of goods and services		0.0063***	0.0063***	0.0063***
		(0.0016)	(0.0006)	(0.0016)
Exports of goods and services		-0.0034**	-0.0034***	-0.0034**
		(0.0015)	(0.0007)	(0.0015)
Population total		2.18e-09*	2.18e-09***	1.85e-09
		(1.26e-09)	(5.26e-10)	(1.22e-09)
Observations	936	890	890	821
Number of groups	96	93	93	88
R-Squared	0.02	0.15	0.15	0.17
Anderson canonical cor. p-value (H0: under identification)				0.0000
Sargan-Hansen p-value				0.124

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The results of instrumental variables estimation for ICT usage are display in column 4 of Table 2. When instrumenting the usage variable, the results of the first step show that computer access and Internet user explain ICT usage at the 5% and 1% threshold respectively.[17] The Anderson canonical correlation test (test of under-identification) indicates that the instrumental variables are correlated to the endogenous variable (ICT usage) because it rejects the null hypothesis of under-identification since the p-value associated with this test (0.000) is inferior to 1%. Finally, the p-value of the Sargan-Hansen test of overidentification is higher than the conventional thresholds (0.124). Therefore, the hypothesis of no correlation between the instrumental variables and the error term is not rejected. All these tests prove that the instruments chosen for ICT use are exogenous and relevant. After estimating with instrumental variables, the results remain the same as in the previous estimations. However, the coefficient and significance of ICT usage increases. It can be observed that the coefficient of ICT uses more than doubles (from 0.0562 to 0.1256) and the significance

[17] First-stage regression results are displayed in table D in the appendix.

level is 1%. This means that the instrumental variables correct the possible bias of endogeneity in the fixed effect model estimation.

About the other control variables, as expected, growth in GDP per capita has a positive impact on tax revenues, although this impact is not significant in all regressions. Imports are more favorable for tax revenues collection while exports have the opposite effect. A large part of the agriculture, fisheries, and forestry sector tends to slow down tax revenue collection. As anticipated, natural resource rents, as well as population size, stimulate tax revenue mobilization, although the effect of the latter remains small. As for financial development, it does not have a significant impact on tax revenue mobilization in developing countries.

These results confirm that ICT usage affects tax revenue collection in developing countries instead of ICT readiness. Although ICT readiness is at the root of digitalization, it must be accompanied by usage for the effects of digitalization to be perceived. The assumption is that ICT use is preceded by a state of readiness. Thus, the use index implicitly reflects a considerable part of the readiness. Therefore, the rest of the paper will focus on the ICT use index.

5.3. Effects of ICT usage on tax revenues: Key Taxes

The effect on direct and indirect tax revenues is now estimated, including the effects on corporate income tax (CIT), property tax (PT), personal income tax (PIT), value added tax (VAT) and excise duties. The results are presented in Table 3.

The use of ICTs improves tax revenue in developing countries for all taxes. However, the effect is not significant for property tax. Moreover, according to the p-value of the Sargan statistic (0.06), the instrumental variables are not exogenous for the property tax. This non-significant effect of digitalization on property tax, can be explained by several ways. In fact, mobilized this tax requires a lot of upstream work as it faces bottlenecks that need to be resolved first. In developing countries, there is a real problem of securing property rights and identifying owners. Taxes can therefore only be collected if the properties and owners are clearly identified and secured.

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a lot of upstream work as it faces bottlenecks that need to be resolved first. In developing countries, there is a real problem of securing property rights and identifying owners. Taxes can therefore only be collected if the properties and owners are clearly identified and secured. In addition, there is a real lack of will to collect property tax revenues. First, tax administrations are reluctant to embark on property tax collection because it will require a lot of administrative and identification effort, which could have a huge financial and administrative cost when the potential for property tax is not great. Second, there is a lack of political will. In fact, the property tax is a sensitive tax because of its local character.

Table 3: Effect of ICT usage on tax revenue components

	(1)	(2)	(3)	(4)	(5)	(7)	(8)
Dependant variables : Tax instruments in % of GDP	log (Direct tax)	log (indirect taxes)	log (CIT)	log (PIT)	log (PT)	Log (VAT)	log (Excise)
ICT usages	0.3021***	0.1414***	0.0791	0.2342***	0.4715	0.1947**	0.3804**
	(0.0879)	(0.0505)	(0.1265)	(0.0878)	(0.4411)	(0.0771)	(0.1635)
Liquid liabilities to GDP	0.0005	-0.0010*	0.0009*	0.0002	-0.0031	-0.0005	-0.0035***
	(0.0007)	(0.0005)	(0.0005)	(0.0005)	(0.0055)	(0.0005)	(0.0006)
GDP per capita growth	-0.0067**	0.0035*	0.0029	-0.0027	0.0076	0.0056*	0.0028
	(0.0027)	(0.0021)	(0.0046)	(0.0035)	(0.0119)	(0.0030)	(0.0055)
Agriculture, forestry, and fishing, value added	-0.0094	-0.0022	-0.0263**	-0.0099	0.0185	-0.0029	-0.0077
	(0.0085)	(0.0045)	(0.0122)	(0.0079)	(0.0347)	(0.0067)	(0.0149)
Total natural resources rents	0.0099	-0.0015	0.0366***	0.0280***	0.0324	0.0012	-0.0125
	(0.0062)	(0.0033)	(0.0098)	(0.0061)	(0.0430)	(0.0045)	(0.0125)
Imports of goods and services	0.0116***	0.0070***	-0.0003	0.0052	-0.0100	0.0048	-0.0075
	(0.0033)	(0.0011)	(0.0031)	(0.0036)	(0.0121)	(0.0041)	(0.0054)
Exports of goods and services	-0.0089***	-0.0039***	-0.0022	-0.0033	0.0007	-0.0025	0.0024
	(0.0034)	(0.0013)	(0.0050)	(0.0036)	(0.0122)	(0.0039)	(0.0063)
Population total	6.55e-09***	2.09e-10	6.82e-09**	5.94e-09***	1.85e-08**	-1.57e-9	6.55e-09
	(2.06e-09)	(7.77e-10)	(2.67e-09)	(1.99e-09)	(8.77e-09)	(2.31e-09)	(-2.06e-09)
Observations	681	766	582	731	439	665	633
Number of groups	80	83	64	81	53	68	67
R-Squared	0.17	0.15	0.15	0.14	0.07	0.07	0.17
Anderson canonical cor. p-value (H0: under identification)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sargan-Hansen p-value	0.518	0.944	0.703	0.27	0.06	0.561	0.518

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The politician will therefore be more reluctant to collect this tax for the purpose of securing his next electorate. Moreover, the property tax is a tax that is generally collected for the benefit of local communities because it is largely concerned with residential property taxes (the property tax on large companies is managed by the central tax administration).These communities do not have the capacity to deal with such a large number of taxpayers, whereas the tax administration, which does have the capacity, prefers to focus on the key taxes that can bring in more tax revenue. Finally, there is also the resistance of the taxpayer, who expects to receive local public services related to the payment of the property tax (Roads, household waste management, public lighting, green

spaces...). However, the lack of accountability does not encourage the taxpayer to pay property taxes. These are a series of difficulties that need to be resolved before property taxes can be collected, and digitalization is not a magic solution to all of them.

6. Robustness

6.1. Analyse of sensitivity

In this section additional control variables are introduced to control for institutional, social, or political factors (voice and accountability, government stability, efficiency of domestic revenue mobilizations, macroeconomic management, social inclusion, and change regime). As Table 4 shows, the effect of digitalization on tax revenues remains positive and significant at least at the 5% threshold. However, the results show that efficiency in revenue mobilization and social inclusion increase domestic tax revenues. Moreover, the adoption of a fixed exchange rate regime does not significantly affect tax revenues, a floating regime has a significantly negative effect at the 1% level.

Table 4: Effect of ICT usage on tax revenues: Sensitivity analysis

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependant variable : log (tax revenue in % GDP)							
ICT usage	0.1246***	0.1119**	0.2444***	0.2632***	0.2498***	0.1229***	0.1234***
	(0.0440)	(0.0463)	(0.0774)	(0.0826)	(0.0812)	(0.0435)	(0.0430)
Voice and Accountability	0.0160						
	(0.0359)						
Government Stability		0.0015					
		(0.0052)					
Domestic revenue mobilization efficiency			0.0918**				
			(0.0465)				
Macroeconomic management				0.0041			
				(0.0273)			
Social inclusion					0.0802*		
					(0.0441)		
Fix regime						-0.0272	
						(0.0255)	
Floating regime							-0.0501***
							(0.0193)
Observations	821	666	391	391	389	821	821
Number of groups	88	72	49	49	48	88	88
R-Squared	0.17	0.25	0.18	0.15	0.17	0.18	0.19
Anderson canonical cor. p-value (H0: under identification)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sargan-Hansen p-value	0.117	0.152	0.161	0.179	0.249	0.129	0.133

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

6.2. Delay in ICT usage

In practice, ICT level each year would reasonably be expected to affect tax revenues a few years later. Therefore, it would be interesting to assess the effect of digitalization on tax revenues with

delays in the digitalization index. The results in Table 5 display the effect of ICT use on tax revenues with lags of one, two and three years for the ICT usage index. When the lag times are applied, the effect of ICT use on tax revenue remains positive and significant (columns 1-3). However, the significance depends on the kind of taxes considered and the number of lags applied. Furthermore, the magnitude of the effect increases with the application of lags. This shows that the effect of ICT increases with time. Thus, experience in using ICT matters.

Table 5: Effect of ICT use on tax revenues with lags in ICT usage index.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Log(total tax revenue)	log(direct tax)	log(indirect tax)	Log(total tax revenue)	log(direct tax)	log(indirect tax)	Log(total tax revenue)	log(direct tax)	log(indirect tax)
L.(ICT usage)	0.1450**	0.2609**	0.0952						
	(0.0677)	(0.1230)	(0.0683)						
L2.(ICT usage)				0.2067**	0.3365**	0.1586*			
				(0.0824)	(0.1598)	(0.0850)			
L3.(ICT usage)							0.5380**	0.6505	0.4093*
							(0.2556)	(0.4258)	(0.2313)
Liquid liabilities to GDP	0.0009	0.0064**	0.0037***	0.0001	0.0049*	0.0034**	-0.0027	0.0013	0.0015
	(0.0020)	(0.0030)	(0.0013)	(0.0021)	(0.0027)	(0.0014)	(0.0039)	(0.0041)	(0.0025)
GDP per capita growth	0.0039***	-0.0002	0.0052**	0.0030*	-0.0037	0.0043*	0.0083**	0.0081	0.0089***
	(0.0013)	(0.0025)	(0.0021)	(0.0018)	(0.0026)	(0.0023)	(0.0036)	(0.0066)	(0.0034)
Agriculture, forestry, and fishing, value added	-0.0005	-0.0049	0.0001	0.0009	-0.0053	0.0009	0.0042	-0.0047	0.0010
	(0.0041)	(0.0083)	(0.0046)	(0.0048)	(0.0098)	(0.0054)	(0.0083)	(0.0138)	(0.0073)
Total natural resources rents	0.0111*	0.0102*	-0.0012	0.0108*	0.0104	-0.0006	0.0118**	0.0068	0.0012
	(0.0058)	(0.0059)	(0.0030)	(0.0061)	(0.0064)	(0.0033)	(0.0058)	(0.0066)	(0.0041)
Imports of goods and services	0.0071***	0.0114***	0.0065***	0.0070***	0.0107***	0.0069***	0.0091***	0.0100**	0.0078***
	(0.0015)	(0.0030)	(0.0013)	(0.0015)	(0.0030)	(0.0016)	(0.0026)	(0.0041)	(0.0023)
Exports of goods and services	-0.0034**	-0.0077***	-0.0033**	-0.0042**	-0.0090**	-0.0042**	-0.0050**	-0.0066	-0.0043*
	(0.0017)	(0.0030)	(0.0014)	(0.0017)	(0.0036)	(0.0017)	(0.0020)	(0.0041)	(0.0023)
Population total	0.0000	0.0000	-0.0000	0.0000	0.0000	-0.0000	0.0000	0.0000*	0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Observations	755	621	700	690	566	637	615	501	567
Number of groups	85	76	80	85	75	79	82	71	78
R-Squared	0.199	0.231	0.195	0.066	0.061	0.124	0.003	0.012	0.054
Anderson canonical cor. p-value (H0: under identification)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sargan-Hansen p-value	0.128	0.187	0.726	0.233	0.451	0.858	0.458	0.333	0.665

6.3. ICT usage index breakdown

Table 6 presents an estimation of ICT usage sub-components effects on tax revenues using the same instruments as previously. The results suggest that government and individual ICT usage have a positive and significant effect on tax revenue collection (columns 1 and 3). Nevertheless, statistical tests have not confirmed the validity of the instruments for business and individual usages (columns 2 and 3) as Hansen's p-value is less than the 10% threshold. Nonetheless, Business usage has no significant effect on tax revenues (column 2).

Table 6: Effect of ICT usage on tax revenues: usage components

Dependant variable : log (tax revenue in % GDP)	government	business	individual
Government usage	0.2006**		
	(0.0901)		
Business usage		-0.1796	
		(0.1260)	
Individual usage			0.0443***
			(0.0156)
Liquid liabilities to GDP	-0.0005	-0.0002	-0.0006
	(0.0004)	(0.0005)	(0.0004)
GDP per capita growth	0.0012	0.0070**	0.0030**
	(0.0016)	(0.0033)	(0.0014)
Agriculture, forestry, and fishing, value added	-0.0034	-0.0068	-0.0045
	(0.0047)	(0.0048)	(0.0039)
Total natural resources rents	0.0098*	0.0078*	0.0096**
	(0.0053)	(0.0047)	(0.0047)
Imports of goods and services	0.0064***	0.0051***	0.0061***
	(0.0015)	(0.0018)	(0.0016)
Exports of goods and services	-0.0033**	-0.0020	-0.0031**
	(0.0016)	(0.0017)	(0.0015)
Population total	9.81e-10	-9.23e-10	2.14e-09
	(1.38e-09)	(2.93e-09)	(1.34e-09)
Observations	821	821	821
Number of groups	88	88	88
R-Squared	0.01	0.02	0.16
Anderson canonical cor. p-value (H0: under identification)	0.000	0.000	0.000
Sargan-Hansen p-value	0.107	0.014	0.086

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

7. Heterogeneity analysis

7.1. Income groups

Given the sample's composition (low, lower-middle, and upper-middle-income countries), the effect is expected to be different across income groups. Indeed, the need for digitalization is undoubtedly not the same from one group to another. Hence, to assess the effect of ICT use on tax revenues for each income group, the database is divided into three income group sub-samples.

The results of the heterogeneity analysis reveal that the effect of digitalization depends on the level of the countries' development (Table 7). The effect of digitization on tax revenues is not significant for upper-middle income countries (table 7, column 3), while it is positive and significant for low- and lower-middle income countries (table 6, columns 1 and 2). In the case of low-income countries, the effect is higher than for lower-middle-income countries. This result could be explained by the fact that the latter have the least digitalized and most inefficient tax administrations in terms of tax

revenue collection. Therefore, there is a strong need for digitalization in these countries to modernize tax administration and overcome several bottlenecks.

Table 7: Effect of ICT usage on tax revenues: Income groups

Dependant variable : log (tax revenue in % GDP)	(1) Low income countries	(2) Lower middle income countries	(3) Upper middle income countries
ICT usages	0.3076**	0.1859**	-0.0148
	(0.1395)	(0.0760)	(0.0571)
Liquid liabilities to GDP	-0.0005***	0.0011	0.0011
	(0.0002)	(0.0036)	(0.0014)
GDP per capita growth	0.0046	-0.0025	0.0069***
	(0.0031)	(0.0022)	(0.0019)
Agriculture, forestry, and fishing, value added	-0.0118**	0.0001	-0.0189**
	(0.0054)	(0.0041)	(0.0095)
Total natural resources rents	0.0275***	0.0090	-0.0007
	(0.0091)	(0.0073)	(0.0049)
Imports of goods and services	0.0063***	0.0072***	0.0043***
	(0.0020)	(0.0023)	(0.0013)
Exports of goods and services	-0.0088***	-0.0036	-0.0012
	(0.0022)	(0.0026)	(0.0014)
Population total	1.81e-08***	-9.17e-10	1.67e-09
	(4.72e-09)	(1.74e-09)	(1.66e-09)
Observations	148	305	368
Number of groups	19	32	37
R-Squared	0.45	0.13	0.23
Anderson canonical cor. p-value (H0: under identification)	0.000	0.000	0.000
Sargan-Hansen p-value	0.374	0.185	0.213

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The following sections discuss the effect of ICT on tax revenues according to various factors. The hypothesis is that the effect is through improving control of corruption, government effectiveness, and tax compliance. The corruption and government effectiveness indicators are taken from the Worldwide Governance Indicators (WGI) database and the tax compliance indicator from Economic Freedom database.[18] For all these indicators, the database is divided into two groups based on the country mean of the indicator on the study period.[19] The results are presented in tables 7,8 and 9.

[18] Based on the time required to pay taxes, this index measures the cost of tax compliance. A low index means low tax compliance and vice versa. For details on calculation method, see Bennett, D. L., & Nikolaev, B. (2019) P.237.

[19] The control of corruption and government effectiveness indicator ranges from -2,5 to 2,5, while tax compliance data range from 0 to 10. When the average of the control of corruption index or the government efficiency index is less than 0, the country is considered more corrupt or less efficient, respectively. For tax compliance, we assume that a country's taxpayers are more compliant when the average is greater than seven (7) and non-compliant otherwise.

7.2. Control of corruption

In columns 1, 2 and 3 of table 8, it is found that the effect of ICT use on tax revenues is positive and significant at the 1% level for countries with a low corruption control score. The findings suggest that the effect of ICT use on tax revenue is driven by improving the capacity to control corruption.

Table 8: Effect of ICT usage on tax revenues: control of corruption

	Countries with high level of corruption			Countries that can control corruption		
Dependant variables : Tax revenue in % GDP	(1) log (tax revenue)	(2) log (direct tax)	(3) log (indirect tax)	(4) log (tax revenue)	(5) log (direct tax)	(6) log (indirect tax)
ICT usages	0.1584***	0.3614***	0.2004***	-0.0782	0.0309	-0.0934
	(0.0481)	(0.1103)	(0.0568)	(0.0769)	(0.0495)	(0.0920)
Liquid liabilities to GDP	-0.0007**	0.0003	-0.0011**	0.0028	0.0088***	0.0001
	(0.0003)	(0.0006)	(0.0005)	(0.0017)	(0.0011)	(0.0030)
GDP per capita growth	0.0017	-0.0072**	0.0038*	0.0030	-0.0050	0.0051
	(0.0015)	(0.0029)	(0.0023)	(0.0042)	(0.0050)	(0.0046)
Agriculture, forestry, and fishing, value added	-0.0014	-0.0048	0.0010	-0.0450***	-0.0714***	-0.0274*
	(0.0037)	(0.0086)	(0.0043)	(0.0142)	(0.0226)	(0.0156)
Total natural resources rents	0.0108**	0.0103*	-0.0007	-0.0013	0.0068	-0.0047
	(0.0051)	(0.0062)	(0.0032)	(0.0090)	(0.0050)	(0.0177)
Imports of goods and services	0.0058***	0.0139***	0.0060***	0.0059	-0.0015	0.0105**
	(0.0019)	(0.0036)	(0.0010)	(0.0037)	(0.0026)	(0.0044)
Exports of goods and services	-0.0036**	-0.0102***	-0.0037**	-0.0009	0.0003	-0.0041
	(0.0018)	(0.0039)	(0.0015)	(0.0023)	(0.0033)	(0.0030)
Population total	1.94e-09	6.85e-09***	3.20e-10	- 6.01e-9	-1.69e-08***	-2.02e-9
	(1.25e-09)	(2.09e-09)	(7.18e-10)	(5.15e-09)	(6.09e-09)	(4.20e-09)
Observations	703	575	655	118	106	111
Number of groups	76	68	71	12	12	12
R-Squared	0.14	0.17	0.08	0.37	0.53	0.29
Anderson canonical cor. p-value (H0: under identification)	0.000	0.000	0.000	0.000	0.000	0.000
Sargan-Hansen p-value	0.0203	0.224	0.723	0.887	0.849	0.902

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

7.3. Government effectiveness

Looking at government effectiveness (Table 9), the use of ICT has a positive and significant effect on tax revenue in countries with low government effectiveness (columns 1, 2 and 3), whereas it does not for those with high effectiveness. This means that the use of ICT improves tax revenue by increasing government effectiveness.

Table 9: Effect of ICT usage on tax revenues: government effectiveness

	Non-effective governments			Effective governments		
Dependant variables : Tax in % GDP	(1)	(2)	(3)	(4)	(5)	(6)
	log (tax revenue)	log (direct tax)	log (indirect tax)	log (tax revenue)	log (direct tax)	log (indirect tax)
ICT usages	0.1388***	0.3964***	0.1636***	0.1152	0.0077	0.0191
	(0.0474)	(0.1176)	(0.0576)	(0.1538)	(0.1239)	(0.1184)
Liquid liabilities to GDP	-0.0007**	0.0007	-0.0011**	0.0002	0.0024	0.0014
	(0.0003)	(0.0007)	(0.0005)	(0.0028)	(0.0020)	(0.0016)
GDP per capita growth	0.0014	-0.0064**	0.0030	-0.0063	0.0070*	0.0033
	(0.0016)	(0.0033)	(0.0025)	(0.0060)	(0.0038)	(0.0041)
Agriculture, forestry, and fishing, value added	-0.0028	-0.0090	-0.0011	-0.0154	-0.0104	-0.0153
	(0.0037)	(0.0084)	(0.0043)	(0.0408)	(0.0179)	(0.0216)
Total natural resources rents	0.0108**	0.0096	-0.0013	0.0119	-0.0045	0.0019
	(0.0052)	(0.0064)	(0.0031)	(0.0094)	(0.0153)	(0.0108)
Imports of goods and services	0.0063***	0.0130***	0.0071***	0.0081***	0.0060***	0.0058***
	(0.0020)	(0.0041)	(0.0014)	(0.0028)	(0.0016)	(0.0018)
Exports of goods and services	-0.0039*	-0.0102**	-0.0038**	-0.0046	-0.0027	-0.0010
	(0.0020)	(0.0046)	(0.0016)	(0.0034)	(0.0022)	(0.0019)
Population total	2.82e-10	7.36e-09***	-4.04e-10	7.33e-09*	-8.95e-10	2.52e-09
	(1.41e-09)	(2.80e-09)	(9.38e-10)	(3.78e-09)	(1.82e-09)	(2.12e-09)
Observations	622	494	574	187	192	199
Number of groups	70	62	65	18	18	18
R-Squared	0.18	0.16	0.15	0.24	0.24	0.30
Anderson canonical cor. p-value (H0: under identification)	0.000	0.000	0.000	0.000	0.000	0.000
Sargan-Hansen p-value	0.089	0.258	0.927	0.47	0.444	0.878

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

7.4. Tax compliance

Table 10: Effect of ICT usage on tax revenues: tax compliance

	Low compliance countries			High compliance countries		
Dependant variables : Tax in % GDP	(1)	(2)	(3)	(4)	(5)	(6)
	log (tax revenue)	log (direct tax)	log (indirect tax)	log (tax revenue)	log (direct tax)	log (indirect tax)
ICT usages	0.2659**	0.1036*	0.1185**	0.1518*	0.3557***	0.1131
	(0.1199)	(0.0568)	(0.0577)	(0.0795)	(0.1357)	(0.0850)
Liquid liabilities to GDP	0.0014	0.0014	-0.0016	-0.0005	0.0001	-0.0011**
	(0.0029)	(0.0016)	(0.0020)	(0.0004)	(0.0007)	(0.0005)
GDP per capita growth	-0.0020	0.0025	0.0010	0.0020	-0.0108***	0.0059*
	(0.0035)	(0.0028)	(0.0018)	(0.0026)	(0.0039)	(0.0032)
Agriculture, forestry, and fishing, value added	-0.0232*	0.0030	-0.0031	-0.0032	0.0010	-0.0053
	(0.0125)	(0.0056)	(0.0055)	(0.0064)	(0.0119)	(0.0075)
Total natural resources rents	0.0027	-0.0013	0.0079	0.0143**	0.0296***	0.0024
	(0.0055)	(0.0036)	(0.0059)	(0.0056)	(0.0099)	(0.0063)
Imports of goods and services	0.0098**	0.0067***	0.0057***	0.0067***	0.0123***	0.0060***
	(0.0039)	(0.0024)	(0.0018)	(0.0022)	(0.0041)	(0.0010)
Exports of goods and services	-0.0095*	-0.0044***	-0.0019	-0.0041**	-0.0078**	-0.0029*
	(0.0055)	(0.0017)	(0.0021)	(0.0020)	(0.0037)	(0.0016)
Population total	5.47e-09*	--7.20e-10	2.59e-09	1.71e-09	6.24e-09**	--4.80e-10
	(3.27e-09)	(1.41e-09)	(2.22e-09)	(1.56e-09)	(3.03e-09)	(7.51e-10)
Observations	367	424	445	376	314	342
Number of groups	44	46	47	41	36	37
R-Squared	0.19	0.13	0.10	0.25	0.20	0.23
Anderson canonical cor. p-value (H0: under identification)	0.000	0.000	0.000	0.000	0.000	0.000
Sargan-Hansen p-value	0.275	0.725	0.236	0.376	0.663	0.268

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

As for tax compliance, the results in Table 10 suggest that ICTs usage positively impacts tax resource mobilization regardless of the degree of tax compliance of the country's taxpayers. In the columns from 1 to 3, a positive and significant effect of ICT use on tax revenues, direct taxes and indirect taxes can be seen in the countries with a low level of compliance. The effect remains the same for the group with a higher level of tax compliance. At the same time, it is not significant for

indirect tax revenues. Nevertheless, the effect is relatively higher for the first group according to the tax revenues (0.2659>0.1518) and more significant (5% and 10%) for the first group compared to the second. These results suggest that ICT affects tax revenues by enhancing compliance.[20]

7.5. Two time periods heterogeneity

Over 12 years, several shocks can occur in an economy. Moreover, the digitalization process may take place in several phases over several years. It is, therefore, necessary to take these aspects into account in the analysis. As indicated above, ICT use has evolved in two phases. Based on the trend in ICT use, to address this question the data is divided into two subgroups: Before 2011 (2005 to 2010) and after 2010 (2011 to 2016).

Table 11: Effect of ICT usage on tax revenues: Two periods heterogeneity

	First period (2005 - 2010)			Second period (2011- 2016)		
Dependant variables : Tax in % GDP	(1)	(2)	(3)	(4)	(5)	(6)
	log (tax revenue)	log (direct tax)	log (indirect tax)	log (tax revenue)	log (direct tax)	log (indirect tax)
ICT usages	-0.2027	-0.8067	0.2253	0.2084***	0.2341***	0.1379**
	(0.4391)	(0.5194)	(0.3534)	(0.0731)	(0.0812)	(0.0700)
Liquid liabilities to GDP	0.0001	0.0020***	-0.0013***	-0.0017	-0.0008	0.0047**
	(0.0004)	(0.0007)	(0.0003)	(0.0022)	(0.0034)	(0.0023)
GDP per capita growth	0.0045	0.0066	-0.0016	0.0023	0.0032	0.0058*
	(0.0058)	(0.0092)	(0.0047)	(0.0022)	(0.0027)	(0.0035)
Agriculture, forestry, and fishing, value added	-0.0053	-0.0168	-0.0041	0.0026	-0.0138	0.0028
	(0.0064)	(0.0169)	(0.0065)	(0.0097)	(0.0122)	(0.0068)
Total natural resources rents	0.0070	0.0040	-0.0001	0.0119	-0.0037	0.0021
	(0.0043)	(0.0094)	(0.0038)	(0.0075)	(0.0045)	(0.0047)
Imports of goods and services	0.0037*	0.0036	0.0073***	0.0050***	0.0039	0.0069***
	(0.0019)	(0.0038)	(0.0024)	(0.0018)	(0.0027)	(0.0021)
Exports of goods and services	0.0006	-0.0021	-0.0052	-0.0040	0.0006	-0.0063*
	(0.0030)	(0.0053)	(0.0034)	(0.0029)	(0.0039)	(0.0034)
Population total	-1.15e-09	-1.54e-09	7.76e-10	8.68e-10	4.15e-09	-4.81e-9
	(2.81e-09)	(3.95e-09)	(2.56e-09)	(2.74e-09)	(3.83e-09)	(3.52e-09)
Observations	385	327	358	436	354	408
Number of groups	80	71	75	83	71	77
R-Squared	0.002	0.02	0.17	0.09	0.08	0.16
Anderson canonical cor. p-value (H0: under identification)	0.000	0.000	0.000	0.000	0.000	0.000
Sargan-Hansen p-value	0.638	0.903	0.866	0.966	0.197	0.828

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

In Table 11, the results in columns 1, 2, and 3 suggest that the use of ICTs does not significantly affect tax revenue in developing countries from 2005 to 2010. However, from 2011 to 2016, the effect becomes positive and significant (columns 4, 5, and 6). Appendices F show the effects of

[20] When assessing the effect of each type of ICT use on tax revenue, it appears that only the individual and government uses have a positive and significant effect for countries with high corruption and low government effectiveness, while individual use has a significant effect only in countries with low tax compliance. These results are consistent with those in table 8. This means that the digitalization of public administration and society improves tax revenue mobilization, while the digitalization of businesses does not have a significant effect. The results are presented in Appendix E.

ICT usage on the components of tax revenue for both periods. They confirm that the effect is only significant in the second period and passes through indirect taxes (excise duties and VAT) and personal income tax. The results on the second period are conform to the main results of the 12 years (table 2 and table 3).[21] This effect can be explained by several factors. In the first period, the level of digitalization may not have been sufficient to have a significant impact on tax revenues mobilization. Moreover, taxpayers had not enough confidence in the digital system and preferred to pay their taxes through traditional means rather than through ICT. This was true for many developing countries that have only recently begun to use ICT for tax revenue collection. However, over time, trust in ICTs gradually rose. Despite lack of skills and well-trained human capital to take better advantage of ICT in tax revenue collection, staff of the tax Departments became more familiar with the system through daily use and training. Finally, administrations were also able to improve the technical system to make it more efficient.

8. Transmission channels: Tax compliance, control of corruption, government effectiveness

As highlighted in section 2 on transmission channels and section 7 on heterogeneity, tax compliance, control of corruption and government effectiveness are potential channels through which digitalization can affect tax revenues positively.

Therefore, if tax compliance, control of corruption and government effectiveness can be considered as transmission channels to increase tax revenues, it is expected that digitalization will positively affect these three factors. Accordingly, the paper explores these three channels by running a panel probit regression on tax compliance, corruption control and government effectiveness. To this end, digitalization, tax compliance, corruption control and government effectiveness variables have been transformed. The four variables take a value of 1 when the index is higher than the median value of the sample and zero otherwise. The results presented respectively in the columns 1, 2 and 3 of Table 12, suggest that the likelihood of high tax compliance, good control of corruption (and thus lower levels of corruption) and government effectiveness increases with the level of ICT use.

[21] The effect of three types of ICT use has a positive and significant effect on tax revenues in the second period (Appendix G).

Table 12: Probit estimation: transmission channel of ICT usage on tax revenue

	Tax compliance	Control of corruption	Government effectiveness
ICT Usage	0.5942**	0.4481*	0.6637**
	(0.2475)	(0.2598)	(0.2643)
Liquid liabilities to GDP	0.0419***	0.0000	0.0073**
	(0.0142)	(0.0021)	(0.0030)
GDP per capita growth	-0.0180	0.0046	0.0527**
	(0.0189)	(0.0147)	(0.0239)
Agriculture, forestry, and fishing, value added	0.0157	-0.0952**	-0.1374***
	(0.0282)	(0.0379)	(0.0389)
Total natural resources rents	0.0046	-0.0502*	-0.1326***
	(0.0224)	(0.0300)	(0.0248)
Imports of goods and services	-0.0179*	0.0093	-0.0133
	(0.0107)	(0.0150)	(0.0170)
Exports of goods and services	-0.0022	-0.0036	0.0406*
	(0.0139)	(0.0229)	(0.0242)
Population total	-0.0000	0.0000	0.0000*
	(0.0000)	(0.0000)	(0.0000)
Observations	1081	1081	1081
Number of groups	95	95	95
Log pseudolikelihood	-397.175	-280.076	-319.229
Pseudo-R2	0.146	0.112	0.187

9. Conclusion

This paper discusses the effect of ICT accessibility and ICT usage on tax revenues in developing countries. The analysis relies on a fixed-effect panel data approach on a dataset of 96 developing countries from 2005 to 2016.

The research concluded that ICT readiness does not have a significant effect on tax revenues. Nevertheless, the use of ICT has a positive and significant effect on tax revenue mobilization. In fact, the use of ICTs increases direct tax revenues through personal income tax, and indirect tax revenues through VAT and excises. Moreover, the effect of ICTs on taxes is channeled through increasing government effectiveness, control of corruption, and tax compliance.

The results imply that ICT readiness and ICT usage are relevant for public revenue mobilization in terms of policy implications. Indeed, it positively impacts public revenue mobilization through fiscal discipline, control of corruption, and improving administration effectiveness. Therefore,

developing countries need to build and improve infrastructures related to new technologies and modernize their tax administration. However, to take full advantage of ICTs, they also must adopt the best tax legislation practices.

Appendix

Table A: Countries list

COUNTRY	REGION	INCOME GROUP	COUNTRY	REGION	INCOME GROUP
Albania	Europe & Central Asia	Upper middle income	Lesotho	Sub-Saharan Africa	Lower middle income
Algeria	Middle East & North Africa	Upper middle income	Liberia	Sub-Saharan Africa	Low income
Angola	Sub-Saharan Africa	Lower middle income	Libya	Middle East & North Africa	Upper middle income
Argentina	Latin America & Caribbean	Upper middle income	Macedonia	Europe & Central Asia	Upper middle income
Armenia	Europe & Central Asia	Upper middle income	Madagascar	Sub-Saharan Africa	Low income
Azerbaijan	Europe & Central Asia	Upper middle income	Malawi	Sub-Saharan Africa	Low income
Bangladesh	South Asia	Lower middle income	Malaysia	East Asia & Pacific	Upper middle income
Benin	Sub-Saharan Africa	Low income	Mali	Sub-Saharan Africa	Low income
Bhutan	South Asia	Lower middle income	Mauritania	Sub-Saharan Africa	Lower middle income
Bolivia	Latin America & Caribbean	Lower middle income	Mauritius	Sub-Saharan Africa	Upper middle income
Bosnia and Herzegovina	Europe & Central Asia	Upper middle income	Mexico	Latin America & Caribbean	Upper middle income
Botswana	Sub-Saharan Africa	Upper middle income	Moldova	Europe & Central Asia	Lower middle income
Brazil	Latin America & Caribbean	Upper middle income	Mongolia	East Asia & Pacific	Lower middle income
Bulgaria	Europe & Central Asia	Upper middle income	Montenegro	Europe & Central Asia	Upper middle income
Burkina Faso	Sub-Saharan Africa	Low income	Morocco	Middle East & North Africa	Lower middle income
Burundi	Sub-Saharan Africa	Low income	Mozambique	Sub-Saharan Africa	Low income
Cambodia	East Asia & Pacific	Lower middle income	Myanmar	East Asia & Pacific	Lower middle income
Cameroon	Sub-Saharan Africa	Lower middle income	Namibia	Sub-Saharan Africa	Upper middle income
Cape Verde	Sub-Saharan Africa	Lower middle income	Nepal	South Asia	Low income
Chad	Sub-Saharan Africa	Low income	Nicaragua	Latin America & Caribbean	Lower middle income
China	East Asia & Pacific	Upper middle income	Nigeria	Sub-Saharan Africa	Lower middle income
Colombia	Latin America & Caribbean	Upper middle income	Pakistan	South Asia	Lower middle income
Costa Rica	Latin America & Caribbean	Upper middle income	Paraguay	Latin America & Caribbean	Upper middle income
Cote d'Ivoire	Sub-Saharan Africa	Lower middle income	Peru	Latin America & Caribbean	Upper middle income
Dominican Republic	Latin America & Caribbean	Upper middle income	Philippines	East Asia & Pacific	Lower middle income
Ecuador	Latin America & Caribbean	Upper middle income	Romania	Europe & Central Asia	Upper middle income
Egypt, Arab Rep.	Middle East & North Africa	Lower middle income	Russian Federation	Europe & Central Asia	Upper middle income
El Salvador	Latin America & Caribbean	Lower middle income	Rwanda	Sub-Saharan Africa	Low income
Ethiopia	Sub-Saharan Africa	Low income	Senegal	Sub-Saharan Africa	Low income
Gabon	Sub-Saharan Africa	Upper middle income	Serbia	Europe & Central Asia	Upper middle income
Gambia, The	Sub-Saharan Africa	Low income	Sierra Leone	Sub-Saharan Africa	Low income
Georgia	Europe & Central Asia	Lower middle income	South Africa	Sub-Saharan Africa	Upper middle income
Ghana	Sub-Saharan Africa	Lower middle income	Sri Lanka	South Asia	Lower middle income
Guatemala	Latin America & Caribbean	Upper middle income	Suriname	Latin America & Caribbean	Upper middle income
Guinea	Sub-Saharan Africa	Low income	Swaziland	Sub-Saharan Africa	Lower middle income
Guyana	Latin America & Caribbean	Upper middle income	Syrian Arab Republic	Middle East & North Africa	Low income
Haiti	Latin America & Caribbean	Low income	Tajikistan	Europe & Central Asia	Low income
Honduras	Latin America & Caribbean	Lower middle income	Tanzania	Sub-Saharan Africa	Low income
India	South Asia	Lower middle income	Thailand	East Asia & Pacific	Upper middle income
Indonesia	East Asia & Pacific	Lower middle income	Timor-Leste	East Asia & Pacific	Lower middle income
Iran, Islamic Rep.	Middle East & North Africa	Upper middle income	Tunisia	Middle East & North Africa	Lower middle income
Jamaica	Latin America & Caribbean	Upper middle income	Turkey	Europe & Central Asia	Upper middle income
Jordan	Middle East & North Africa	Upper middle income	Uganda	Sub-Saharan Africa	Low income
Kazakhstan	Europe & Central Asia	Upper middle income	Ukraine	Europe & Central Asia	Lower middle income
Kenya	Sub-Saharan Africa	Lower middle income	Venezuela, RB	Latin America & Caribbean	Upper middle income
Kyrgyz Republic	Europe & Central Asia	Lower middle income	Vietnam	East Asia & Pacific	Lower middle income
Lao PDR	East Asia & Pacific	Lower middle income	Yemen, Rep.	Middle East & North Africa	Low income
Lebanon	Middle East & North Africa	Upper middle income	Zambia	Sub-Saharan Africa	Lower middle income

Table B: Variable descriptions

Variables	Description	Source
ICT readiness	Measures the extent to which a country has in place the infrastructure, skills and other factors to support the uptake of ICTs.	The Global Information Technology Report from 2005 to 2016
ICT usage (overall)	Assesses the level of ICT adoption by a society's main stakeholders: government, businesses, and individuals.	
Individual ICT usage	Measures the level of diffusion of selected ICTs among a country's population. It take nto account social networks uses	
Business ICT usage	Captures the extent to which businesses in a country use the Internet for business-to-business (B2B) and business-to-consumer (B2C) operations, as well as their efforts to integrate ICTs in their operations. It also includ internet uses for Businesss-to-government operations.	
Government ICT usage	Assesses the leadership and success of the government in developing and implementing strategies for ICT development, as well as in using ICTs, as measured by the availability and quality of government online services	
Total tax revenue	Total direct taxes, excluding social contributions and resource taxes. Includes non-resource taxes on income, profits and capitals gains, taxes on payroll and workforce and taxes on property.	ICTD / UNU-WIDER Government Revenue Dataset 2019
Value add tax	Value-added tax	
Excise	Total excise taxes	
Direct tax revenue	Direct taxes excluding social contributions and resource revenue	
Indirect tax revenue	Total Indirect Taxes. Includes taxes on goods and services, taxes on international trade and other taxes.	
Property tax	Total taxes on property	
Personal income tax	Taxes on income, profits, and capital gains	
Corporate income tax	Total income and profit taxes on corporations, including taxes on resource firms.	
liquid liability	Absolute value of liquid liabilities in percentage of GDP. For Eurocurrenycy area countries, liquid liabilities are estimated by summing IFS items 34A, 34B and 35, or alternatively FDSBC, FDSBT, FDSBO).	IMF's International Financial Statistics, August 2019
GDP per capita growth annual	GDP per capita growth (annual %)	World Bank's World Development Indicators 2019 (WDI)
Agriculture rents	Agriculture, forestry, and fishing, value added (% of GDP)	
Total natural resources rents	Total natural resources rents (% of GDP)	
Exports of goods and services	Exports of goods and services (% of GDP)	
Imports of goods and services	Imports of goods and services	
Total population	Population, total	
Internet user	Internet users (% population)	International Telecommunication Union (ITU)
Computer access	proportion of households with a computer	
TCS investment	Annual investment in telecommunication services	
Control of corruption	It captures the extent to which public power is exercised for private purposes, including both petty and grand forms of corruption, as well as the "capture" of the state by elites and private interests.	The Worldwide Governance Indicators (WGI)
Government effectiveness	It measures the quality of public services, the quality of the public service and its degree of independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to these policies.	
Voice and accountability	It coptures the perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media.	
Tax compliance	Based on the time required to pay taxes (World Bank, Doing Business), this index measures the cost of tax compliance. A low index means low tax compliance and vice versa.	Fraser institute's economic freedom dataset
Government stability	Captures Government's ability to carry out its declared program(s), and its ability to stay in office. It consists of Government unity, Popular support, Legislative stength.	International Country Risk Guide (ICRG)
Macroeconomic management	Macroeconomic management assesses the monetary, exchange rate, and aggregate demand policy framework.	World Bank Group, CPIA database
Social inclusion	The policies for social inclusion and equity cluster includes gender equality, equity of public resource use, building human resources, social protection and labor, and policies and institutions for environmental sustainability.	
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
Floating regime	Floating regime is a dummy variable taking 1 if country adopted floating regime and zero if not	

Table C: Descriptive statistics

Variables	Observations	Mean	Std. Dev.	Min.	Max.
liquid liability	1,126	47.368	55.703	3.304	903.803
Total tax revenue	1,065	16.508	6.710	1.193	56.916
Value add tax	833	0.054	0.029	0.000	0.189
Excise	797	1.940	1.282	0.000	8.141
Direct tax revenue	902	5.028	2.626	0.038	17.442
Indirect tax revenue	999	10.581	4.814	0.608	45.403
Property tax	708	0.263	0.382	0.000	1.894
Personal income tax	928	5.309	2.798	0.000	18.008
Corporate income tax	737	2.649	1.522	0.000	9.495
GDP per capita growth annual	1,153	3.034	6.076	-62.378	121.780
Agriculture rents	1,134	15.264	11.414	1.828	66.033
Total natural resources rents	1,164	10.003	11.656	0.001	74.132
Exports of goods and services	1,126	34.677	17.184	0.099	112.899
Imports of goods and services	1,126	44.304	21.493	0.065	236.391
Total population	1,164	56571359	1.851e+08	463032.000	1.379e+09
Internet user	1,12	21.345	18.722	0.065	78.788
Computer access	1,065	19.875	18.384	0.130	78.090
TCS investment	669	7.976e+11	6.652e+12	0.000	1.075e+14
ICT readiness	1,014	3.926	0.757	1.740	5.700
ICT usage (overall)	1,014	3.090	0.532	1.990	5.100
Individual ICT usage	1,014	2.451	0.905	1.000	5.300
Business ICT usage	1,014	3.340	0.644	2.060	5.651
Government ICT usage	1,014	3.479	0.655	1.800	5.867
Control of corruption	1,164	-0.5560031	.5299543	-1.672876	1.280399
Government effectiveness	1,164	-0.4639487	.5461085	-2.062993	1.267115
Voice and accountability	1,164	-0.4177901	.6854389	-2.233271	1.1515
Tax compliance	973	6.168256	2.245297	0	9.159301
Government stability	915	7.823046	1.485988	4.583333	11
Macroeconomic management	605	3.775207	0.6509393	1	5.5
Social inclusion	600	3.420833	0.4436711	1.5	4.3
Fixed regime	1,164	.2989691	.458003	0	1
Floating regime	1,164	.3582474	.4796915	0	1

Table D: First stage regression

	ICT usage
Liquid liabilities to GDP	0.0006879
	(0.0004473)
GDP per capita growth	0.010485
	(0.0032516)
Agriculture, forestry, and fishing, value added	-0.0122854
	(0.0068407)
Total natural resources rents	-0.0049449
	(0.0041999)
Imports of goods and services	-0.0034394
	(0.0017501)
Exports of goods and services	0.0031101
	(0.0021233)
Population total	-3.29e-9
	(2.77e-09)
Computer access	**0.004527****
	(0.002233)
Internet user	**0.010891*****
	(0.0021417)
Observations	821
Number of groups	88
R-Squared	0.39

Table E: Effect of ICT usage component on tax revenue in low quality of institutions countries

Dependant variables : Tax revenue/GDP	Countries with high corruption			Weakly effective government			Lower tax compliance countries		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Government usage	**0.2872****			**0.2453****			**0.1582**		
	(0.1271)			**(0.1149)**			**(0.0992)**		
Individual usage		**0.0556*****			**0.0506*****			**0.0483****	
		(0.0167)			**(0.0175)**			**(0.0228)**	
Business usage			**-0.3627**			**-0.1504**			**-0.8239**
			(0.2242)			**(0.2007)**			**(0.9805)**
Liquid liabilities to GDP	-0.0005	-0.0006*	0.0001	-0.0006	-0.0006*	-0.0003	-0.0016	-0.0017	-0.0038
	(0.0004)	(0.0003)	(0.0006)	(0.0004)	(0.0003)	(0.0005)	(0.0026)	(0.0018)	(0.0047)
GDP per capita growth	0.0009	0.0035**	0.0123*	0.0008	0.0030*	0.0057	-0.0002	0.0029*	0.0280
	(0.0020)	(0.0015)	(0.0066)	(0.0019)	(0.0017)	(0.0058)	(0.0025)	(0.0016)	(0.0316)
Agriculture, forestry, and fishing, value added	-0.0008	-0.0019	-0.0044	-0.0022	-0.0031	-0.0059	-0.0013	-0.0018	0.0283
	(0.0051)	(0.0037)	(0.0061)	(0.0048)	(0.0038)	(0.0050)	(0.0059)	(0.0059)	(0.0418)
Total natural resources rents	0.0106*	0.0105**	0.0091	0.0107*	0.0107**	0.0096*	0.0071	0.0082	0.0123
	(0.0059)	(0.0049)	(0.0057)	(0.0059)	(0.0051)	(0.0054)	(0.0065)	(0.0058)	(0.0115)
Imports of goods and services	0.0061***	0.0055***	0.0046**	0.0065***	0.0060***	0.0050**	0.0063***	0.0053***	0.0027
	(0.0019)	(0.0019)	(0.0023)	(0.0020)	(0.0021)	(0.0023)	(0.0022)	(0.0018)	(0.0051)
Exports of goods and services	-0.0033	-0.0034*	-0.0022	-0.0039*	-0.0037*	-0.0032	-0.0014	-0.0017	0.0010
	(0.0022)	(0.0018)	(0.0023)	(0.0023)	(0.0020)	(0.0022)	(0.0024)	(0.0020)	(0.0047)
Population total	2.05e-09	8.99e-10	-4.16e-9	4.26e-10	-7.93e-10	-1.85e-09	2.71e-09	2.06e-09	-4.77e-09
	(1.61e-09)	(1.41e-09)	(4.98e-09)	(2.27e-09)	(1.39e-09)	(4.52e-09)	(2.68e-09)	(2.07e-09)	(1.05e-08)
Observations	703	703	703	622	622	622	445	445	445
Number of groups	76	76	76	70	70	70	47	47	47
R-Squared	0.0145	0.0079	0.0009	0.05	0.157	0.011	0.002	0.10	0.007
Anderson canonical cor. p-value (H0: under identification)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sargan-Hansen p-value	0.1784	0.0079	0.0516	0.2892	0.0487	0.0125	0.1636	0.3071	0.978

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table F: Effect of ICT usage on the components of tax revenue in both periods

	First period (2005 - 2010)					Second period (2011-2016)				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dependant variables : Tax instruments/GDP	log (CIT)	log (PIT)	log (PT)	Log (VAT)	log (Excise)	log (CIT)	log (PIT)	log (PT)	Log (VAT)	log (Excise)
ICT usages	0.4545	-1.0486	-5.4654	-0.3750	-1.2418	0.2236	0.2067***	0.7901	0.1769**	0.6695**
	(1.2875)	(0.9104)	(6.6180)	(0.4960)	(1.3408)	(0.1714)	(0.0712)	(0.6889)	(0.0815)	(0.3288)
Liquid liabilities to GDP	0.0017**	0.0021**	0.0213	-0.0002	-0.0012	-0.0042	0.0011	-0.0221	0.0038	-0.0073
	(0.0009)	(0.0009)	(0.0400)	(0.0004)	(0.0015)	(0.0035)	(0.0026)	(0.0148)	(0.0042)	(0.0094)
GDP per capita growth	-0.0032	0.0122	0.0671	0.0046	0.0037	0.0093*	0.0041*	0.0023	0.0112***	0.0049
	(0.0105)	(0.0115)	(0.0625)	(0.0057)	(0.0115)	(0.0055)	(0.0023)	(0.0218)	(0.0037)	(0.0060)
Agriculture, forestry, and fishing, value added	-0.0175	-0.0146	0.0715	-0.0038	0.0062	-0.0291	-0.0138	-0.0206	0.0069	0.0058
	(0.0271)	(0.0171)	(0.0965)	(0.0089)	(0.0259)	(0.0179)	(0.0102)	(0.0643)	(0.0180)	(0.0388)
Total natural resources rents	0.0447***	0.0151	0.1124	0.0025	-0.0106	0.0122	0.0079*	-0.0789	0.0054	-0.0075
	(0.0167)	(0.0152)	(0.0802)	(0.0048)	(0.0162)	(0.0127)	(0.0045)	(0.0718)	(0.0073)	(0.0132)
Imports of goods and services	0.0065	-0.0025	-0.0184	0.0062**	0.0041	-0.0018	0.0036	-0.0020	0.0116***	-0.0008
	(0.0065)	(0.0046)	(0.0197)	(0.0025)	(0.0059)	(0.0046)	(0.0025)	(0.0247)	(0.0025)	(0.0096)
Exports of goods and services	-0.0116	0.0054	0.0067	-0.0040	-0.0022	0.0074	0.0004	-0.0004	-0.0103***	0.0103
	(0.0125)	(0.0081)	(0.0214)	(0.0032)	(0.0098)	(0.0059)	(0.0034)	(0.0200)	(0.0040)	(0.0130)
Population total	7.01e-09	-3.95e-09	-2.66e-8	-3.34e-9	-2.35e-08**	7.69e-09	3.56e-09	1.77e-09	(-6.29e-09**)	3.37e-09
	(7.48e-09)	(5.87e-09)	(3.96e-08)	(5.22e-09)	(9.54e-09)	(5.37e-09)	(3.54e-09)	(1.67e-08)	(2.85e-09)	(1.10e-08)
Observations	273	344	219	298	301	309	387	220	367	332
Number of groups	60	74	50	61	61	57	74	44	67	62
R-Squared	0.048	0.009	0.01	0.003	0.003	0.07	0.08	0.11	0.21	0.02
Anderson canonical cor. p-value (H0: under identification)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sargan-Hansen p-value	0.939	0.573	0.781	0.879	0.941	0.102	0.97	0.192	0.351	0.107

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table G: Table E: Effect of ICT usage component on tax revenue in low quality of institutions countries after 2010

Dependant variables : Tax revenue/GDP	Countries with high corruption			Weakly effective government			Lower tax compliance countries		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Government usage	**0.4066****			**0.3413****			**0.3347***		
	(0.1691)			**(0.1633)**			**(0.1722)**		
Individual usage		**0.0556*****			**0.1727****			**0.1652****	
		(0.0167)			**(0.0688)**			**(0.0773)**	
Business usage			**0.3820*****			**0.3237*****			**0.3065****
			(0.1062)			**(0.1116)**			**(0.1409)**
Liquid liabilities to GDP	-0.0018	-0.0006*	-0.0010	-0.0017	-0.0042	-0.0001	-0.0038	-0.0036	-0.0017
	(0.0030)	(0.0003)	(0.0021)	(0.0037)	(0.0034)	(0.0025)	(0.0044)	(0.0039)	(0.0032)
GDP per capita growth	0.0021	0.0035**	0.0011	0.0002	0.0011	0.0001	0.0000	0.0010	-0.0023
	(0.0037)	(0.0015)	(0.0028)	(0.0037)	(0.0028)	(0.0029)	(0.0047)	(0.0031)	(0.0038)
Agriculture, forestry, and fishing, value added	-0.0053	-0.0019	0.0077	-0.0056	-0.0014	0.0055	0.0154	0.0229*	0.0201
	(0.0125)	(0.0037)	(0.0107)	(0.0120)	(0.0096)	(0.0106)	(0.0157)	(0.0118)	(0.0124)
Total natural resources rents	0.0105	0.0105**	0.0136*	0.0126	0.0148*	0.0148*	0.0125	0.0170	0.0149
	(0.0092)	(0.0049)	(0.0076)	(0.0091)	(0.0078)	(0.0077)	(0.0121)	(0.0109)	(0.0108)
Imports of goods and services	0.0038**	0.0055***	0.0054***	0.0048**	0.0064***	0.0062***	0.0048	0.0050	0.0058
	(0.0019)	(0.0019)	(0.0021)	(0.0019)	(0.0023)	(0.0020)	(0.0036)	(0.0037)	(0.0037)
Exports of goods and services	-0.0035	-0.0034*	-0.0035	-0.0069*	-0.0069*	-0.0067*	-0.0044	-0.0068	-0.0044
	(0.0037)	(0.0018)	(0.0034)	(0.0036)	(0.0038)	(0.0035)	(0.0069)	(0.0068)	(0.0068)
Population total	-1.85e-09	8.99e-10	4.72e-10	-4.75e-09	-1.58e-09	-7.81e-09	1.71e-09	8.21e-10	2.05e-09
	(3.98e-09)	(1.41e-09)	(4.04e-09)	(6.59e-09)	(5.75e-09)	(5.54e-09)	(4.37e-09)	(3.73e-09)	(4.37e-09)
Observations	368	703	368	331	331	331	230	230	230
Number of groups	71	76	71	65	65	65	44	44	44
R-Squared	0.0021	0.1462	0.0004	0.0272	0.0948	0.0732	0.0291	0.1011	0.0869
Anderson canonical cor. p-value (H0: under identification)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sargan-Hansen p-value	0.4089	0.0079	0.9821	0.5381	0.6933	0.9199	0.4749	0.404	0.3200

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table H: Digitalization of the tax administration in WAEMU member countries

Benin: Since March 2018, the DGI has been gradually implementing e-procedures: 2018 for large companies and 2019 for medium-sized companies. The DGI can rely on various improvements (i) updating the national taxpayer file and the current segmentation, (ii) strengthening the deposit, collection, and control modules in SIGTAS. The digitalization of tax functions has helped to improve the monitoring of reporting obligations and the control of outstanding amounts to be recovered. The efforts made in terms of digitalization facilitate the compliance of taxpayers with their tax obligations.

Burkina Faso: Since 2017, e-procedures have been offered to large and medium-sized companies, and since May 2019, taxpayers can submit online applications for VAT credit refunds, tax status certificates, and turnover certificates. The payment of taxes by mobile money has been introduced. In May 2019, 950 taxpayers had joined the e-procedures, and more than 60% of DGI tax revenues were declared online.

Ivory Coast: Since 2018, a tax e-portal has been set up with the obligation for large and medium-sized companies (turnover over 200 million FCFA) to declare their taxes online and transmit their financial statements online ("e-liasse"). Companies then submit a transfer order to their bank to pay their taxes. All the tax documents of member companies are available in their personal space.

Mali: Despite the terrorist threats, a test phase for the implementation of remote procedures was launched at the end of March 2019 with the adhesion of 26 companies, starting with large companies.

Senegal: Tax revenues in Senegal are up 16.3% at the end of 2018. The excellent performance of both direct and indirect taxes can be attributed in part to the generalization of e-procedures, including the development of applications such as "my personal space" e-tax and m-tax dedicated to improving the fiscal citizenship of the leading business segments, e-VAT during implementation to improve the control of VAT invoice.

Source: Authors construction

Chapter II: Does the adoption of peer-to-government mobile payments improve tax revenue mobilization in developing countries?

This chapter is a collaboration with Fayçal SAWADOGO and Jesse LASTUNEN.

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Abstract: 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) mobile phone payments, adopted in several developing countries since the early 2000s. This study assesses the causal effect of P2G adoption on tax revenue using propensity score matching (PSM). 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 by low levels of urbanization and domestic credit to the private sector. 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.

Key words: mobile money, P2G, direct tax revenue, propensity score matching, developing countries

JEL classification : H2, O1, O3

Résumé : Les pays en développement doivent lever des recettes fiscales suffisantes pour financer le développement. La mobilisation des recettes est souvent entravée par une conformité fiscale limitée, des institutions faibles et des problèmes techniques de collecte des impôts. Une solution à ces défis est le paiement par téléphone mobile de personne à gouvernement (P2G), adopté dans plusieurs pays en développement depuis le début des années 2000. Cette étude évalue l'effet causal de l'adoption du P2G sur les recettes fiscales en utilisant la méthode du PSM. Selon les estimations de l'appariement, 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 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 control

fonction, 2SLS et la méthode de GMM. Les effets moyens du traitement sont les plus importants 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. Les résultats suggèrent que les pays en développement, en particulier ceux qui ont des institutions médiocres et de faibles niveaux d'inclusion financière, devraient promouvoir l'adoption et l'utilisation des services d'argent mobile pour les transactions fiscales.

Mots-clés : mobile money, P2G, recettes fiscales directes, appariement par score de propension, pays en développement

Classification JEL: H2, O1, O3

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 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 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,[22] 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 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

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

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).[23] 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 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

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

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.

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.

As for different transmission channels, P2G adoption is more effective for tax mobilization for countries characterized by an ineffective bureaucracy, extensive informality, and low levels of financial inclusion. 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.

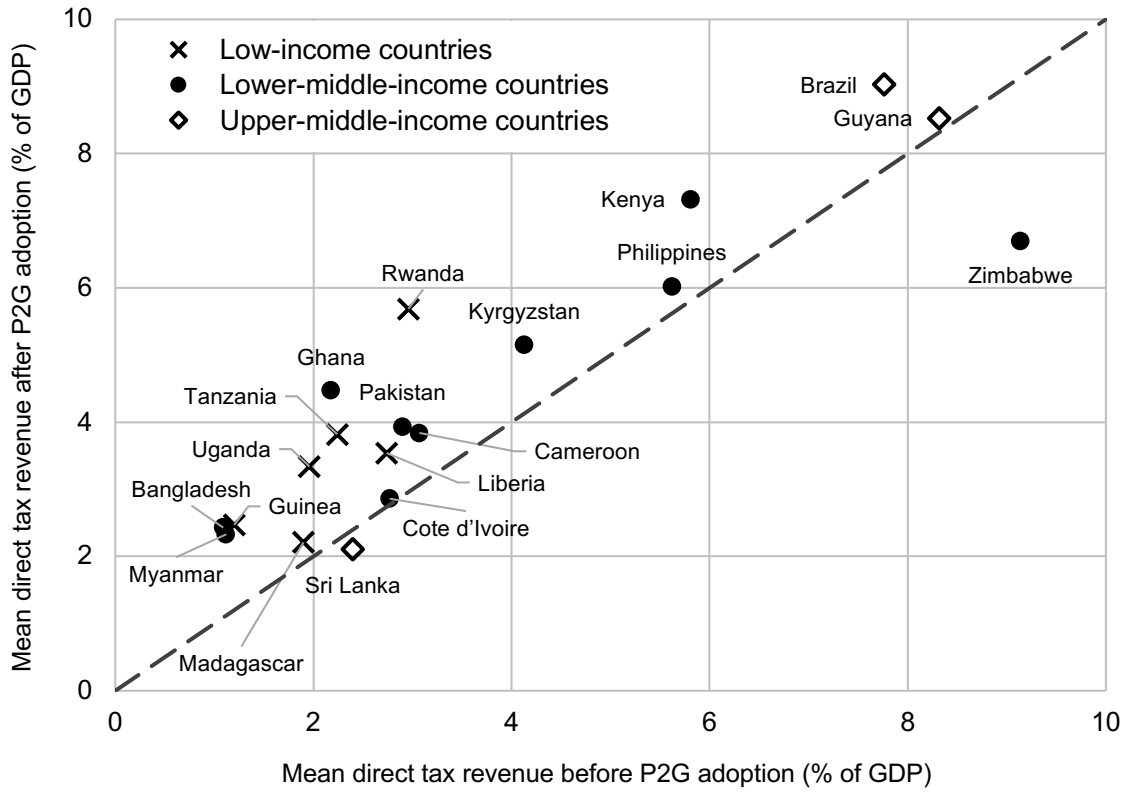
The treatment effects are also positive and significant for countries with low levels of development assistance and resource rents—potentially incentivizing tax collection reforms—and countries with high rates of labour force participation and school enrolment—indicating that reaping benefits from P2G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

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



Note: the ratio of mean direct tax revenue to GDP is calculated either from all available years before P2G adoption (X axis) or from 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 the WDI and GRD.

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). 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).

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).[24]

2.2. Methodology

PSM is used 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 (see 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 the 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). Suitable for this study, PSM 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, the average treatment effect on the treated (ATT) is estimated using various matching methods.

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

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

[24] 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.

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:

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

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:

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

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:

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

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).[25]

[25] 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.

3. Results

3.1. Propensity score estimation

PS are estimated using a probit model, where the probability of adopting P2G services is dependent 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; Morrisey et al., 2010; 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.

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 Penicaud (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.

***Table 1**: Probit estimation of propensity scores*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Population growth	0.44***	0.47***	0.44***	0.61***	0.48***	0.51***	0.51***	0.50***	0.45***	0.47***	0.42***	0.44***
	(0.06)	(0.06)	(0.05)	(0.12)	(0.07)	(0.08)	(0.08)	(0.11)	(0.07)	(0.07)	(0.07)	(0.08)
Mobile phone penetration	0.02***	0.02***	0.01***	0.02***	0.02***	0.02***	0.02***	0.01***	0.02***	0.02***	0.01***	0.02***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
GDP per capita growth	0.07***	0.07***	0.07***	0.06**	0.08***	0.07***	0.08***	0.04	0.07***	0.07***	0.06**	0.032
	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)	(0.03)	(0.03)	(0.03)	(0.02)	(0.02)	(0.03)	(0.02)
Domestic credit	−0.01***	−0.02***	−0.02***	−0.02***	−0.01***	−0.02***	−0.02***	−0.00	−0.02***	−0.01***	−0.02***	−0.01***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
Inflation	−0.03***	−0.02***	−0.02*	−0.02*	−0.03*	−0.03***	−0.00	−0.03*	−0.03***	−0.02	−0.04***	−0.04***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)
Control of corruption	−1.25***			−1.34***	−1.03***	−1.55***	−1.29***	−1.42***	−1.21***	−1.28***	−1.32***	−1.29***
	(0.16)			(0.20)	(0.18)	(0.21)	(0.19)	(0.30)	(0.17)	(0.15)	(0.20)	(0.17)
Agriculture value added	−0.01	−0.00	−0.01	−0.02**	−0.01	0.01	−0.01	−0.04***	−0.00	−0.02**	−0.01*	−0.05***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Trade openness	−0.02***	−0.02***	−0.02***	−0.02***	−0.02***	−0.01***	−0.02***	−0.03***	−0.02***	−0.02***	−0.02***	−0.02***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Resource rents	−0.08***	−0.08***	−0.08***	−0.09***	−0.08***	−0.09***	−0.07***	−0.05***	−0.08***	−0.09***	−0.08***	−0.06***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Rule of law		−0.58***										
		(0.13)										
Government effectiveness			−0.40***									
			(0.15)									
School enrolment				0.02***								
				(0.01)								
Social conditions					−0.13**							
					(0.06)							
Bureaucracy quality						0.51***						
						(0.11)						
Tax compliance							0.18***					
							(0.05)					
Public admin. quality								0.15				
								(0.30)				
Net ODA									−0.03			
									(0.02)			
Labour force participation										0.03***		
										(0.01)		
Paying taxes: score											0.01***	
											(0.00)	
Urban population												-0.04***
												(0.01)
Constant	−2.08***	−1.62***	−1.38***	−3.88***	−1.80***	−3.89***	−3.60***	−1.51	−2.07***	−4.13***	−1.52***	0.37
	(0.29)	(0.26)	(0.25)	(0.66)	(0.49)	(0.49)	(0.45)	(1.23)	(0.30)	(0.56)	(0.44)	(0.38)
Observations	1,320	1,322	1,320	1,097	918	918	826	514	1,297	1,281	845	1,320
Pseudo R2	0.35	0.29	0.28	0.37	0.33	0.36	0.34	0.36	0.34	0.37	0.37	0.43

Note: robust standard errors in brackets; *p<0.10, **p<0.05, and ***p<0.01; ODA refers to official development assistance.

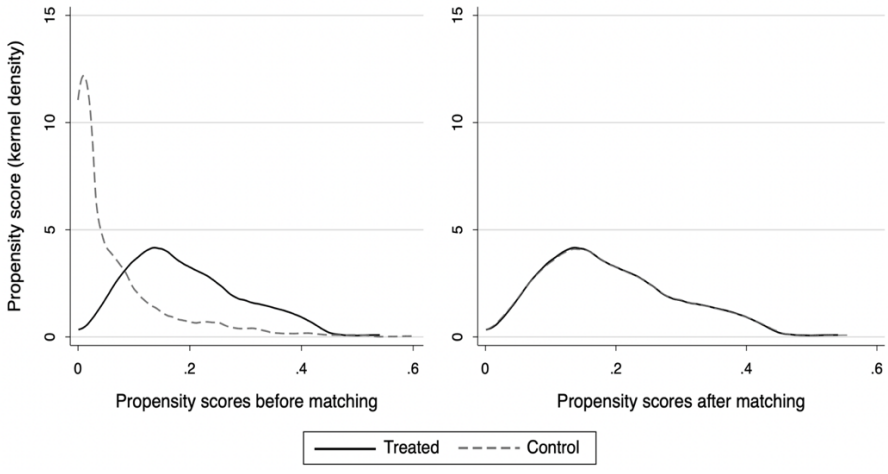
Source: authors' elaboration

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.[26] 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.

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

3.2. Matching results

Table 2 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.[27] 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.[28]

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 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.[29] The estimated ATTs also remain positive, significant, and comparable to the main estimates after

[27] 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.
[28] 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.
[29] The standard deviation of direct tax revenue is 2.71, as reported in Table B2 in Appendix B.

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 2).

Table 2: Matching results for the effect of P2G on direct taxes

Treatment variable: P2G	1-nearest neighbour matching	2-nearest neighbour matching	3-nearest neighbour matching	Radius matching			Local linear	Kernel matching
				r=0.005	*r=0.01*	*r=0.05*		
				Dependent variable: Direct taxes as percentage points of GDP				
ATT	1.28***	1.21***	1.32***	1.26***	1.29***	1.25***	1.25***	1.27***
	(0.30)	(0.27)	(0.28)	(0.25)	(0.23)	(0.23)	(0.23)	(0.23)
				Quality of the matching				
Pseudo R2	0.025	0.021	0.022	0.013	0.013	0.012	0.025	0.012
Standardized bias (p-value)	0.53	0.65	0.61	0.88	0.9	0.91	0.53	0.91
Rosenbaum upper bound sensitivity test	2.4	2.4	2.7	2.7	2.6	2.5	2.4	2.5
ATT:				***Sensitivity analysis of the main results***				
[1] Controlling for rule of law	1.21***	1.18***	1.16***	1.12***	1.10***	0.98***	0.96***	0.99***
[2] Controlling for government effectiveness	1.14***	1.07***	1.10***	1.08***	1.01***	0.96***	0.94***	0.96***
[3] Controlling for school enrolment	1.03***	1.08***	1.05***	0.75***	0.82***	0.82***	0.80***	0.83***
[4] Controlling for social conditions	1.35***	1.34***	1.43***	1.40***	1.36***	1.24***	1.20***	1.25***
[5] Controlling for bureaucracy quality	1.10***	1.13***	1.15***	1.04***	1.23***	1.15***	1.07***	1.16***
[6] Controlling for tax compliance	1.39***	1.53***	1.48***	1.40***	1.48***	1.42***	1.42***	1.43***
[7] Controlling for public administration quality	1.33***	1.20***	1.15***	0.91***	0.98***	1.16***	1.21***	1.16***
[8] Controlling for ODA	1.05***	1.14***	1.21***	1.17***	1.28***	1.26***	1.24***	1.26***
[9] Controlling for labour force participation rate	1.41***	1.43***	1.38***	1.12***	1.11***	1.11***	1.12***	1.12***
[10] Controlling for taxpaying score	1.26***	0.97***	1.03***	0.93***	1.03***	1.06***	1.05***	1.05***
[11] Controlling for urban population	1.02***	1.22***	1.19***	1.27***	1.10***	1.32***	1.33***	1.31***
ATT:				***ATT by type of direct tax***				
CIT	0.46**	0.60***	0.56***	0.50***	0.50***	0.44***	0.45***	0.44***
	(0.22)	(0.19)	(0.17)	(0.15)	(0.13)	(0.13)	(0.11)	(0.12)
PIT	0.68***	0.79***	0.76***	0.76***	0.85***	0.82***	0.82***	0.82***
	(0.24)	(0.22)	(0.2)	(0.18)	(0.18)	(0.17)	(0.16)	(0.16)

Note: for each model, there are 1,326 observations, 103 of which are treated; Standard errors in brackets; *p<0.10, **p<0.05, and ***p<0.01; 500 bootstrap replications.

Source: authors' elaboration.

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.

3.3. 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 3 demonstrate how different country characteristics mediate the impact of P2G adoption on direct tax revenue.

Table 3: Heterogeneity analysis of the effect of P2G adoption on direct taxes

	No control	Self-selectivity	Adoption preconditions	Experience	Income level			Control of corruption		Tax compliance		Paying taxes: score		Public admin. quality	
					LIC	*LMIC*	*UMIC*	*Low*	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**	**(13)**	**(14)**	**(15)**
P2G	−0.22	0.86***	−0.68**	−0.34	0.32	1.65***	−1.26	1.33***	−0.31	2.03***	0.31	1.43***	−0.12	0.81*	0.48
	(0.20)	(0.24)	(0.31)	(0.43)	(0.21)	(0.35)	(1.48)	(0.24)	(0.59)	(0.45)	(0.34)	(0.40)	(0.32)	(0.48)	(0.30)
PSCORE		−4.66***	−6.13***	−5.00***	−0.91*	−5.01***	−5.85***	−0.80*	−5.73***	−6.74***	−4.63***	−5.74***	−4.15***	0.13	−3.77***
		(0.46)	(0.50)	(0.49)	(0.47)	(0.85)	(0.77)	(0.46)	(1.03)	(1.02)	(0.87)	(0.71)	(0.80)	(0.99)	(0.57)
P2G*(PS-$\overline{PS}$)			8.80***												
			(1.20)												
P2G*time				0.24***											
				(0.06)											
Constant	4.64***	4.92***	5.00***	4.94***	3.16***	4.82***	5.70***	3.43***	5.91***	4.84***	5.21***	5.43***	5.65***	3.13***	4.97***
	(0.08)	(0.09)	(0.09)	(0.09)	(0.13)	(0.13)	(0.15)	(0.11)	(0.12)	(0.17)	(0.16)	(0.20)	(0.14)	(0.21)	(0.15)
Observations	1,32	1,32	1,32	1,32	276	487	557	653	667	295	531	363	482	138	376
R2	0.0005	0.04	0.062	0.048	0.008	0.059	0.040	0.041	0.027	0.078	0.038	0.082	0.062	0.026	0.057

	Agriculture VA		School enrolment		Domestic credit		Resource rents		Net ODA		Labour force		Urbanization 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	0.44	1.47***	0.23	0.60*	1.31***	−0.27	0.92***	0.43	0.83***	0.40	0.45	1.14***	1.35***	0.55
	(0.33)	(0.31)	(0.34)	(0.33)	(0.24)	(0.52)	(0.28)	(0.41)	(0.29)	(0.38)	(0.30)	(0.38)	(0.27)	(0.48)
PSCORE	−4.98***	−1.84***	−4.20***	−5.35***	−2.62***	−5.21***	−5.67***	−3.82***	−5.32***	−3.45***	−5.44***	−4.05***	−2.75***	−6.10***
	(0.68)	(0.47)	(0.58)	(0.86)	(0.48)	(0.95)	(0.50)	(1.40)	(0.59)	(0.63)	(0.57)	(0.72)	(0.65)	(0.58)
Constant	5.72***	3.22***	4.40***	5.29***	3.88***	6.10***	5.41***	3.74***	5.30***	3.92***	4.89***	4.97***	3.88***	5.80***
	(0.11)	(0.11)	(0.13)	(0.13)	(0.107)	(0.14)	(0.11)	(0.15)	(0.11)	(0.14)	(0.1342)	(0.13)	(0.11)	(0.13)
Observations	845	475	428	669	767	553	978	342	956	341	657	624	650	670
R2	0.039	0.054	0.064	0.035	0.032	0.038	0.071	0.015	0.051	0.032	0.058	0.031	0.035	0.063

Note: robust standard errors in brackets; *p<0.10, **p<0.05, and ***p<0.01; in Columns 8–29, the mean of each variable is used to divide the sample into two groups, countries with low values and high values respectively. LIC, LMIC, and UMIC refer to low-income, lower-middle-income, and upper-middle-income countries, respectively.

Source: authors' elaboration.

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 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.[30]

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.[31]

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

[30] 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.

[31] 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.

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.

3.4. 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 4. 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.

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.

Table 4: 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	1.834*	1.661*	1.889*	0.448*			
	(0.998)	(0.962)	(1.019)	(0.234)			
Agriculture value added	0.017	0.020*	0.026**	0.067	−0.005**	−0.005**	−0.005**
	(0.011)	(0.010)	(0.011)	(0.053)	(0.002)	(0.002)	(0.002)
Domestic credit	0.022***	0.021***	0.021***	0.024**	−0.002***	−0.002***	−0.002***
	(0.004)	(0.004)	(0.004)	(0.010)	(0.001)	(0.001)	(0.001)
Trade openness	0.008***	0.010***	0.008***	0.001	−0.001*	−0.001**	−0.001*
	(0.002)	(0.003)	(0.002)	(0.004)	(0.000)	(0.000)	(0.000)
GDP per capita (log)	1.048***	1.088***	1.103***	0.492	0.038	0.037	0.038
	(0.270)	(0.265)	(0.268)	(0.534)	(0.048)	(0.048)	(0.0491)
Inflation	0.002	0.002*	0.002	0.007	0.0002	0.0002	0.0002
	(0.001)	(0.001)	(0.001)	(0.010)	(0.000)	(0.000)	(0.000)
Total population (log)	1.843***	1.971***	1.778***	−0.046	0.409***	0.401***	0.404***
	(0.622)	(0.605)	(0.643)	(0.078)	(0.084)	(0.084)	(0.085)
School enrolment	−0.005	−0.005*	−0.006**	0.007**	−0.001	−0.001	−0.001
	(0.003)	(0.003)	(0.003)	(0.004)	(0.001)	(0.001)	(0.001)
Resource rents		−0.010	−0.010	0.001		−0.0005	−0.0005
		(0.008)	(0.008)	(0.009)		(0.001)	(0.001)
FDI			0.032***	−0.020			−0.001
			(0.009)	(0.040)			(0.001)
Lag (direct tax revenue)				0.779***			
				(0.075)			
Mobile phone penetration					0.0005***	0.0005***	0.0005***
					(0.000)	(0.000)	(0.000)
Neighbours with P2G					0.304***	0.301***	0.297***
					(0.099)	(0.099)	(0.099)
Observations	1,305	1,296	1,291	1,040	1,305	1,296	1,291
Countries	96	96	96	92	96	96	96
R2 centred	0.23	0.26	0.24				
Kleibergen-Paap LM under-identification 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***			
				(1.071)			

Note: *p<0.10, **p<0.05, and ***p<0.01; robust standard errors in brackets; in the system-GMM estimation (Column 4), the two-step estimator is used with Windmeijer's (2005) standard errors; P2G is instrumented with its first- and second-order lagged values and the two retained external instruments; the lagged dependent variable is instrumented with its first- and second-order lagged values; the instruments included in the system-GMM estimation are the first- and second-order lagged FDI, resource rents, total trade, GDP per capita, total population (log), and school enrolment; the set of instruments has been collapsed to overcome instrument proliferation (Roodman, 2009); the standard error of the long-run P2G coefficient is determined using the delta method (Greene 2003).

Source: authors' elaboration.

4. 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.

In light of 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.

Appendix

Appendix A: Adoption of P2G services

Table A1 shows the year of P2G adoption by country for low-income, lower-middle-income, and upper-middle-income countries, and mean direct tax revenues before and after adoption.

Table A1: P2G adopter countries, year of adoption, and direct tax revenues before and after adoption

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 WDI, GRD and GSMA Mobile money deployment 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 UNU-WIDER	Direct tax revenue	Total direct tax revenues excluding social contributions and resource revenues
GRD/UNU-WIDER	PIT	Taxes on income, profits, and capital gains
GRD/UNU-WIDER	CIT	Corporate and other business tax revenues
Authors' construction using GSMA mobile money deployment 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%)
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 considers 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 jobseekers
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 GRD, GSMA mobile money deployment tracker, WDI, ITU, WGI, ICRG, Economic Freedom database, World Bank Group, CPIA database, International Labour Organization's ILOSTAT database, and World Bank's Doing Business project

Table B2: Descriptive statistics

Variable	Observations	Mean	St. Dev.	Min.	Max.
Direct tax revenues	1,326	4.62	2.712	0.15	17.44
PIT	1,000	2.08	1.82	0	10.25
CIT	982	2.41	1.54	0	13.79
P2G	1,326	0.08	0.27	0	1
Agriculture value added	1,326	16.28	12.10	0.89	79.04
Domestic credit to the private sector	1,326	34.99	30.51	0	160.1
GDP per capita	1,313	3,500	3.17	221.1	20.53
GDP per capita growth	1,326	2.48	4.15	−31.33	50.24
Trade openness	1,326	77.23	38.25	0.27	311.4
Resource rents	1,326	7.27	10.53	0	81.95
Inflation	1,326	7.08	16.43	−18.11	513.9
Population growth rate	1,326	1.64	1.17	−2.17	6.57
School enrolment	1,101	103.0	17.20	29.01	151.8
Net ODA	1,303	5.27	7.79	−0.48	92.14
Urban population share	1,326	47.55	19.91	7.41	90.98
Total market penetration	1,320	61.02	48.18	0	207.8
CCE: control of corruption	1,326	−0.49	0.59	−1.77	1.65
GEE: government effectiveness	1,326	−0.44	0.58	−2.27	1.27
RLE: Rule of law	1,326	−0.50	0.58	−1.91	0.93
Social conditions	921	4.36	1.74	0	10.29
Bureaucracy quality	921	1.67	0.77	0	3
Tax compliance	826	6.07	2.10	0	9.05
Public administration quality	519	3.05	0.50	2	4
Labour force participation rate	1,287	65.52	11.40	41.53	90.34
Paying taxes: score	851	61.09	23.66	0	95.83
Neighbour	1,326	0.05	0.13	0	1
Number of countries	96	96	96	96	96

Source: authors' elaboration based on data from the GRD, GSMA mobile money deployment tracker, WDI, ITU, WGI, ICRG, Economic Freedom database, World Bank Group, CPIA database, International Labour Organization's ILOSTAT database, and World Bank's Doing Business project.

PART II: DIGITALIZATION, EFFECTIVENESS AND EFFICIENCY

Chapter III: Does digitalization improve government effectiveness? Evidence from developing and developed countries

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Abdoul-Akim Wandaogo (2022) Does digitalization improve government effectiveness? Evidence from developing and developed countries, Applied Economics, DOI: 10.1080/00036846.2021.2016590

Abstract: This study aims to analyze the effect of digitalization on government effectiveness in developing and developed countries. It uses a panel methodology with data from 138 countries between 2006 and 2016. The results suggest that a government's use of information and communication technologies (ICT) improves its effectiveness in both developing and developed countries. However, this effect is stronger in developed than in developing countries. Moreover, we find that the effect of aggregate ICT use by individuals, businesses, and government on overall government effectiveness is greater than that of individual use by each individually. The results are robust after several tests (reverse causality, dynamic effect, sensitivity analysis, heterogeneities, and alternative measurements). These results highlight the fact that governments could fully benefit from digitalization by adopting policies that promote access to and use of ICT at all levels of the economy, that is, the government itself, businesses, and individuals.

Keywords: Digitalization, government effectiveness, developed countries, developing countries

JEL Codes : H1, H4, H7, O3, O5

Résumé : Cette étude vise à analyser l'effet de la digitalisation sur l'efficacité du gouvernement dans les pays en développement et les pays développés. Elle utilise une méthodologie de panel avec des données provenant de 138 pays entre 2006 et 2016. Les résultats suggèrent que l'utilisation des technologies de l'information et de la communication (TIC) par un gouvernement améliore son efficacité tant dans les pays en développement que dans les pays développés. Cependant, cet effet est plus fort dans les pays développés que dans les pays en développement. De plus, nous constatons que l'effet de l'utilisation agrégée des TIC par les particuliers, les entreprises et le gouvernement sur l'efficacité globale du gouvernement est plus important que celui de l'utilisation individuelle de chacun d'entre eux. Les résultats sont robustes après plusieurs tests (causalité inverse, effet dynamique, analyse de sensibilité, hétérogénéités et mesures alternatives). Ces résultats soulignent le fait que les gouvernements pourraient profiter pleinement de la numérisation en adoptant des politiques qui favorisent l'accès et l'utilisation des TIC à tous les niveaux de l'économie, c'est-à-dire le gouvernement lui-même, les entreprises et les individus.

Mots-clés : Digitalisation, efficacité du gouvernement, pays développés, pays en développement.

Codes JEL : H1, H4, H7, O3, O5

1. Introduction

The economic literature shows that governance is a key factor in economic growth, poverty reduction, and economic development (Khan, 2009; Kaufmann et al., 2009; Kraay & Kaufmann, 2002; Scully, 1988; Barro, 1996; Knack & Keefer, 1995; Mauro, 1995). However, if governance is so important for economic development, then the question of how to foster effective governance arises. In this sense, Montes et al. (2019), Garcia-Sanchez et al. (2013), Adsera et al. (2003), and Al-Marhubi (2004) analyzed the determinants of government effectiveness. These studies reveal a set of factors that are important in explaining the effectiveness of a government. These include natural resources, per capita income, population, and political and social conditions.

However, digitalization is an essential factor of good governance. Effah & Nuhu (2017) and Janssen & Estevez (2013) define digitalization as the transition from a traditional management of procedures, bureaucracy, and paperwork to management via digital platforms. Irani et al. (2008) argued that digitalization represents an advanced level of e-government procedures, which allows governments to improve their effectiveness and efficiency. More broadly, digital transformation or digitalization is the integration and promotion of information and communication technologies (ICT) in daily activities. Thus, many researchers argue that the use of ICT by companies, public administrations, and individuals promotes productivity gains (Brambilla & Tortarolo, 2018; Colombo et al. 2013; Dedrick et al. 2013). For example, for several years many public administrations have been offering services that can be accessed from a telephone or a computer, which allows them to better manage their tasks and improve the quality of their service offer, as well as to improve the well-being of citizens. This trend is part of the digitalization of public administration. It would therefore be meaningless to talk about governance today without mentioning the role of digital transformation.

There are several ways in which digitalization can promote government effectiveness. First, it facilitates internal and external collaboration between different segments of administration (Islam et al., 2016). For example, the transmission and treatment of documents and reports can be performed instantaneously, whereas in a non-digitalized context, it will require a longer transmission time with risks of loss. Second, digitalizing offers a higher storage capacity for documents and archives, allowing more effective facility of action insofar as the storage remains centralized (Fichman et al., 2014). Third, digitalization allows the administration to improve and facilitate its interaction and engagement with individuals and companies while modernizing,

thereby promoting transparency, democracy, and freedom of action (Falk et al., 2017). Furthermore, since the 2000s, ICT has taken an important place in the lives of individuals as well as in the functioning of different economies (Evangelista, 2014; Van Reenen et al., 2010; Davison et al., 2000). This could be due to the diversity of services offered and their usefulness to its users, including individuals, enterprises, and public administrations. Through mobile phones, tablets, the Internet, and social media, the way citizens interact with each other and their administrations, and the way they take part in their country's governance, has changed significantly (Smorgunov, 2019; Bird & Zolt, 2008; Fleming, 2002). Governments are realizing the power and key roles of ICTs, in general, in advancing and transforming the public sector and improving the quality of public service delivery and governance (Cordella & Bonina, 2012; Ndou, 2004; Davison et al., 2000). In this regard, the United Nations (UN) encourages the development of e-government for accountable, effective, efficient, and equitable delivery of public services to all citizens. The UN argues that this enhances public confidence and ensures a transparent, participatory, and collaborative development process.

Digital transformation in the mode of governance is topical in public debates, among researchers and in international institutions such as the UN, the World Bank (WB), and regional institutions. Most of the existing studies on this issue focus on the link between ICTs and corruption or transparency (Bhattacherjee & Shrivastava, 2018; Sturges, 2004). Dobrolyubova et al. (2019) find that there is a positive correlation between government digitalization and the quality of public administration in 19 European and Central Asian countries. Others are more interested in the effect of the Internet on corruption (Kanyam et al, 2017; Elbahnasawy, 2014). Nevertheless, it is important to note that ICT is not limited to the Internet. Chen & Aklikokou (2019) used cluster analysis to assess the relationship between e-government and government effectiveness. Furthermore, some studies have addressed the effect of ICTs on trust between citizens and the government (Guriev et al., 2019; Porumbescu, 2016; Gracia & Arino, 2015; Parent et al., 2005). However, the primary objective of public administration digitalization is not to increase citizens' trust, but rather to increase the supply of public services, to encourage citizen participation in decision-making, and to facilitate access to public management information. It is the achievement of these objectives that will build and increase trust in government. As such, Welch et al. (2005) find that the use of online services increases citizens' satisfaction, which in turn increases their trust in government. Tolbert & Mossberger (2006) explain that the effect of e-government on trust in government is through improved interactions with citizens and perceived responsiveness.

Given the existing literature, the objective of this paper is, with a more exhaustive measure of digitalization, to study the effect of digitalization on government effectiveness using data on 138 developing and developed countries over the period 2006 to 2016. This study contributes to the literature on government effectiveness in several ways. First, it investigates the effect of digitalization on government effectiveness, providing an empirical analysis of the influence of digital transformation on governance, which differs from the approach used by Dobrolyubova et al. (2019).[32] Second, unlike many studies on digitalization, it uses a different measure of digitalization extracted from Global Information Technology Reports (GITR). This index is a comprehensive measure of digital transformation, considering several variables related to ICT access and use. The advantage of using an index that includes many indicators is that it captures all digitalization dimensions and makes the index more exhaustive. In fact, the GITR allows for measures of digitalization according to the use that is made of it. This allows us to capture government usage, which is more appropriate for assessing the effect of ICTs on government effectiveness. In addition, unlike Dobrolyubova et al. (2019),[33] the government ICT usage from GITR takes into consideration aspects such as the importance of ICT to government vision of the future, government prioritization and its success in ICT promotion, which makes this index more relevant. Third, there are heterogeneities according to several factors regarding digitalization and governance.

Using the panel fixed-effects methodology, we find that digitalization improves the effectiveness of government. Moreover, this effect is greater in developed countries. Moreover, the overall use of ICT affects government effectiveness more than individual, business, or government usage separately. These results are robust to alternative measures of digitalization, additional control variables, and endogeneity concerns.

[32] To analyze the effect of government digitalization on the quality of governance, Dobrolyubova et al. (2019) first performed a correlation test and then a Granger causality test. The limitations of this approach are that first, correlation does not necessarily explain the existence of an effect or causality. This is confirmed by the causality test carried out by the author, which shows an absence of causality between digitalization and the quality of governance. Correlation measures the strength of the link between the variables. Furthermore, Granger causality does not test for a true cause-and-effect relationship; it tests the order of arrival of one variable relative to another in the time series. Thus, Granger causality does not necessarily imply a causal relationship in the real sense. Finally, although these two methods allow the identification of a possible correlation as well as a causal link, it is impossible to determine the extent of the effect of a factor on another. Therefore, despite having the same objective as our study, this study is limited by the methodologies used.

[33] It should also be noted that Dobrolyubova et al. (2019) also consider the government digitalization, using E-government development, Online Service, and E-participation indexes, along with the proportion of citizens using the Internet to submit completed forms via government websites.

The remainder of this paper proceeds as follows. In Section 2, the data and identification strategies are described. The main results are presented in section 3. Section 4 focuses on further analysis and robustness checks of the results. Finally, in Section 5, we present our conclusions and the policy implications.

2. Data and methodology

2.1. Variables and data description

To assess the effect of digitalization on government effectiveness, this study uses data from 138 countries, including 88 developing (low-income countries, lower-middle-income countries, and upper-middle-income countries) and 50 developed (high-income countries) countries based on the World Bank income group for 2019-2020[34] over 11 years from 2006 to 2016. The dependent variable is government effectiveness according to the Worldwide Governance Indicators (WGI), and the main explanatory variable is the government use of ICT collected from the Global Information Technology Report (GITR).[35] The time period and countries were chosen based on the availability of digitalization and government effectiveness data. Following the existing literature on the determinants of government effectiveness (Duho et al., 2020; Montes & Paschoal, 2016; Garcia-Sanchez & Cuadrado-Ballesteros, 2016, 2013; La Porta, 1999), a set of control variables (GDP per capita, population size, stability, and absence of violence) are applied. The institutional variables used in this study are taken from the International Country Risk Guide (ICRG) and the WGI, while the other variables are mainly from the World Development Index 2020 (WDI).

Government effectiveness: According to Kraay et al. (2010), it refers to the perception of the quality of public services, the quality of the civil service and its degree of independence from political pressure, the quality of policy formulation and implementation, and finally, the credibility of the government's commitment to these policies. The values of the indicator range from -2.5 to 2.5 (-2.5 meaning the country is very ineffective, while 2.5 meaning it is very effective).

ICT usage: ICT usage is a subindex of the network readiness index (NRI) from the GITR. The NRI measures the ability of countries to profit from ICTs to increase their competitiveness and

[34] A list of countries with income group is provided in Appendix A.
[35] Dutta et al. (2007, 2008, 2009, 2010, 2011, 2012, 2015, 2016) ; Bilbao-Osorio et al. (2013, 2014). The report was published with a one-year delay before 2012. However, from 2012 onwards, each report covers the year of its publication. Because of the lack of data for 2011, we have estimated it by using the average of 2010 and 2012.

well-being, but also the trends in innovation in recent years. The NRI is an indicator composed mainly of four subindexes (the environment for ICT, the readiness of a society to use ICT, the actual use of all key stakeholders, and, finally, the impacts that ICT generates in the economy and society). Each subindex is composed of pillars constructed using indicators. The ICT usage subindex includes the individual, government, and business usage pillars.[36] The indexes,' subindexes,' and pillar's values are ranked from 0 to 7, with 7 being the best score. This study focuses on the pillars of ICT use by governments. The research hypothesis is that the use of ICT by the government has a positive effect on its effectiveness.

GDP per capita: This is the ratio of annual gross domestic product divided by the number of inhabitants at midyear. It is used to capture the level of development of a country and its wealth. The more developed a country is, the more effective the government appears to be. Moreover, development tends to be accompanied by greater involvement in public management. Therefore, it is reasonable to expect a positive effect of GDP per capita on government effectiveness.

Total population: The total population estimates the number of people living legally in the territory of a country in the middle year. A large population means that more people are satisfied through the provision of public goods and services, and more work for the government. In addition, it will be difficult for it to take individual preferences into account when adjusting the supply of public goods and services. Therefore, it may be difficult for it to satisfy an abundant population. Otherwise, when the population increases, the government will find it difficult to be effective. Nevertheless, large populations can motivate policymakers to improve the supply and quality of services and simplify procedures, which will improve their effectiveness. Therefore, it is not evident to anticipate this variable effect on government effectiveness.

Political Stability and Absence of Violence/Terrorism: It reflects the degree of stability and the absence of insecurity and violence in a country. Indeed, in a country plagued by violence and instability, development efforts are doomed to fail. Adsera et al. (2003) also argue that the ineffectiveness of government increases with political instability. Therefore, the priority will be to create a climate of peace and stability. Political stability and peace are prerequisites for economic

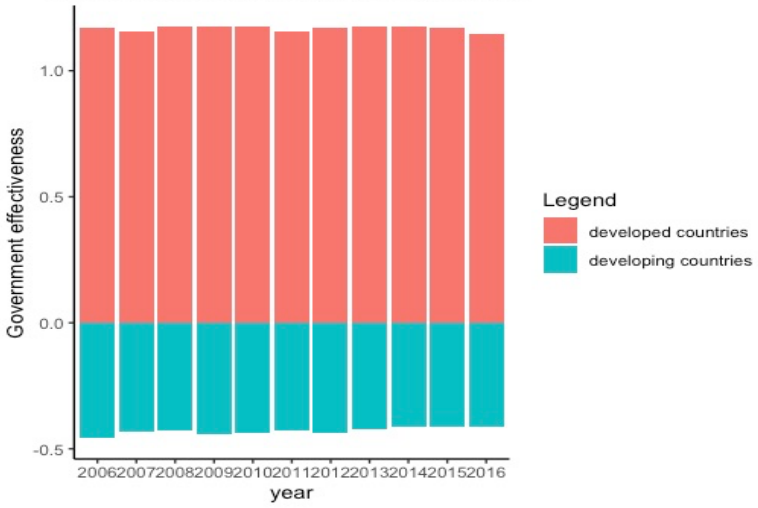
[36] Appendix B.1 presents the ICT variables uses for each usage sub-index.

development. It is only under such conditions that the government can be economically effective. Therefore, this variable is expected to have a positive effect on the effectiveness of a government.[37]

2.2. Representation of information

Figure 1 shows the evolution and level of government effectiveness for developed and developing countries during the research period. This indicates that government effectiveness is negative in developing countries. In contrast, in developed countries, the level of effectiveness is better when the index is greater than zero. The graph also indicates that the gap between government effectiveness in developed and developing countries is remarkably high. However, this gap tends to narrow over time as the level of effectiveness in developing countries gradually improves.

Figure 1: Average effectiveness by country group



Source: Author construction with WGI data

The descriptive analysis also showed that the level of effectiveness is a matter of development. The high-income countries had the highest effectiveness scores. On average, these countries have an effectiveness index of 1.75, while they are negative for countries in other groups (-0.116, -0.563, and -0.823, respectively).

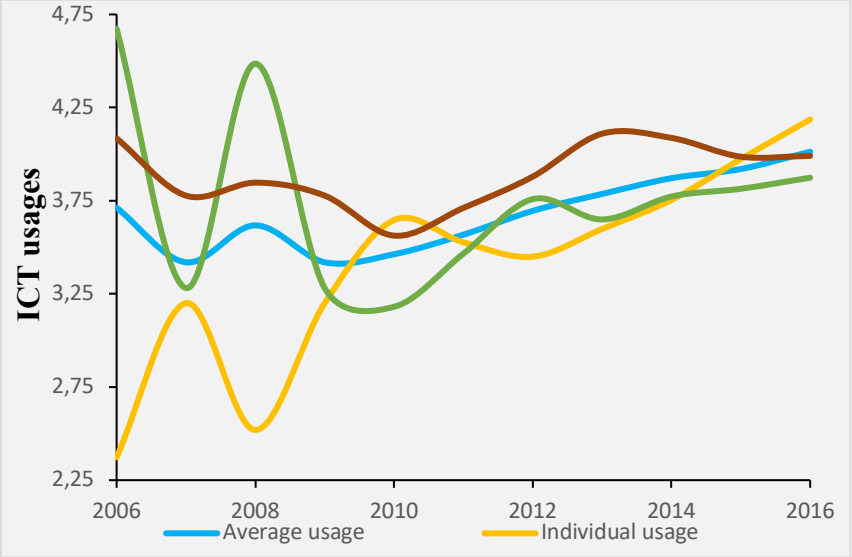
Regarding digitalization, a trend graph of ICT use and its sub-indices was constructed (Figure 2). In general, the overall use of ICT and its sub-indexes is increasing. However, government and

[37] Appendix B.2 presents definitions and sources of all variables used in this study, while Appendix B.3 gives summary statistics.

business ICT use was higher in the early years of the study. In recent years individual use has exceeded business and government use.

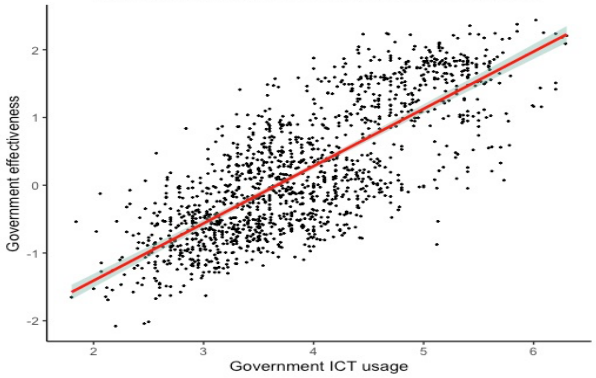
When analyzing government ICT usage by income group, we found that digitalization correlates to income level. Indeed, we observe that the higher the income level, the higher the average ICT usage score. In fact, the average score is 4.57 for high-income countries, 3.64 for upper-middle income countries, while it is 3.43 and 3.21 respectively for lower-middle and low-income countries, respectively.

Figure 2: Trend of ICT usage by component from 2006 to 2016



Source: Author construction using data from GITR

Figure 3: Scatter plot between ICT usage and government effectiveness

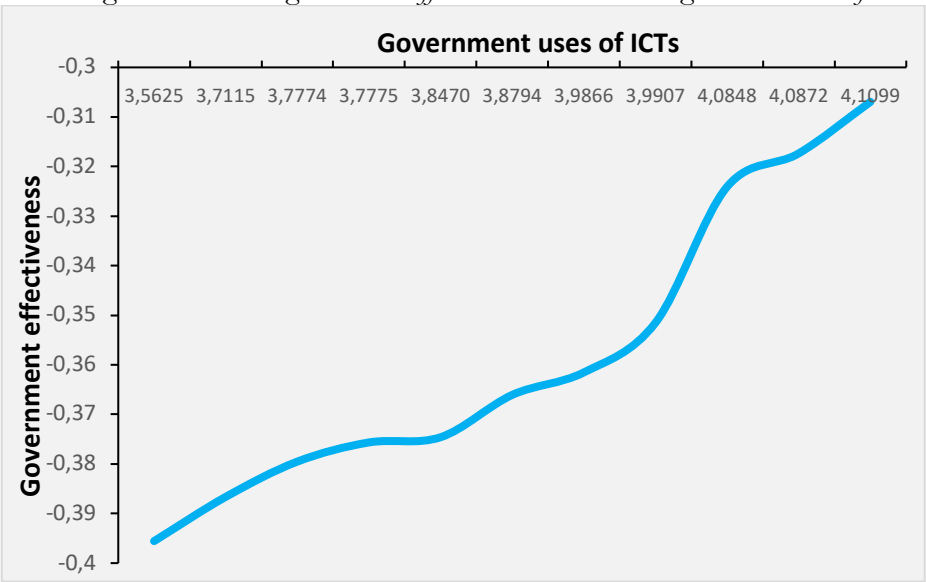


Source: Author construction using data from WGI and GITR

In figure 3, the scatter plot and the correlation line between ICT use by governments and their effectiveness are presented. There is a positive correlation between digitalization and government effectiveness. Furthermore, Figure 4 shows a positive relationship between the average level of ICT use and the average effectiveness of government. Therefore, a positive effect of ICT use on

government effectiveness can be expected. However, this graph does not confirm this because correlation does not necessarily indicate a significant effect.

Figure 4: Trend in government effectiveness in relation to government use of ICT



Source: Author construction using data from WGI and GITR

2.3. Identification strategy

To assess the effect of ICT usage on government effectiveness in developed and developing countries, a panel model with fixed effects was specified. The model is presented in equation (eq.1) below, where GEE is government effectiveness. In the right size, ICT_{it} indicates government digitalization for country i in year t. In addition, α_i, γ_t, X_{it}, and ε_{it} refer to country-and time-fixed effects, set of control variables, and error term, respectively. Moreover, φ is the constant term of the model and δ represents the coefficient of ICT usage.

$$GEE_{it} = \varphi + \delta ICT_{it} + \beta X_{it} + \alpha_i + \gamma_t + \varepsilon_{it} \qquad \text{(eq.1)}$$

3. Empirical results

Table 1 presents the impact of digitalization on government effectiveness. In column 1, we estimated the effect using only the government's use of ICT as an explanatory variable. The results show a positive and significant effect of digitalization on government effectiveness at the one percent level. However, this specification suffers from an omission variable bias. We then iterated the model using additional explanatory variables that may affect government effectiveness based

on the literature. The random-effects results in column 2 show a positive effect of digitalization on government effectiveness. Nevertheless, since each country has its own individual characteristics that may or may not influence the predictors, we added country fixed effects to control for this. In addition, we applied the time-fixed effect. The effect of digitalization on government effectiveness remains positive and significant at the conventional level (columns 3 & 4).

To choose the best estimation strategy, we proceeded with specification tests. First, the Hausman specification test (Hausman, 1978) allowed us to determine the appropriate model by comparing the random effects model (column 2) and the fixed effects model (column 3). Second, for the time fixed effects (columns 4 & 5), we used a parametric test for time-fixed effects to determine whether it is necessary to consider the time-fixed effects.

The probability of the Hausman specification test (Prob > chi2 = 0.0000) was less than one percent. Therefore, the null hypothesis of no correlation between errors and regressors is rejected. The fixed-effect model is preferred over the random-effect model. The time fixed effects test is a joint test that assesses whether the dummy variables for all years are equal to zero. If they are zero, the time fixed effect is not required; otherwise, they are relevant to the model. The probability value (Prob > F = 0.0069) of the test was below the conventional levels. Therefore, H0 is rejected, and we cannot confirm that the year dummies are jointly equal to zero. Therefore, the time-fixed effect is preferred[38] and we retain the specifications in column 5 which includes country and time-fixed effects.

The results in column 5 indicate that, on average, for the countries in the sample, an increase in digitalization level by one-point leads to an improvement of government effectiveness by 0.1 points. These results can be explained by the fact that digitalization facilitates access to certain public services as well as the interaction between citizens and the government. Moreover, by enabling good management of tasks and the acceleration of procedures, digitalization can save time, considerably reduce costs, and therefore improve effectiveness.

The coefficient of political stability and absence of violence and/or terrorism is positive and significant at the one percent level. This indicates that stability and the absence of violence are determinants of a government's effectiveness. The results show that if stability increases by one point, government effectiveness will be improved by approximately 0.093-points. We also found

[38] See Torres-Reyna. (2007) for more details about the Hausman test and the time fixed effect test.

that GDP per capita positively and significantly influenced government effectiveness. An increase in GDP per capita of one percent is associated with an improvement in effectiveness of 0.0021 points.[39] GDP per capita is generally used as a measure of a country's level of development and economic stability. Economic stability allows for a better selection of public administration staff and the sustainability of good government policies and practices (García-Sánchez et al. 2016 and Lee & Whitford, 2009). Furthermore, it can be expected that citizens with higher incomes will be less dependent on public services (such as health, education, social aid). Therefore, these services will be more oriented towards low-income citizens. These factors can be sources of improvement in the level of effectiveness of public administrations and/or government effectiveness. As for the total population, the effect is not significant.

Since the sample includes developing and developed countries, one would assume that a specific group drives the positive and significant effect of digitalization. In addition, it would be interesting to explore heterogeneity by level of development (as measured by income level). Therefore, we have split the sample into two groups: developing and developed countries. The results are shown in Table 2.

Table 1: Effect of digitalization on government effectiveness

	1	2	3	4	5
Dependent variable: Government effectiveness					
government ICT usage	**0.1239*** **	**0.0749*** **	**0.0750*** **	**0.1095*** **	**0.1004*** **
	(0.0149)	**(0.0147)**	**(0.0152)**	**(0.0182)**	**(0.0187)**
Political Stability and Absence of Violence/Terrorism		0.1096***	0.0963***	0.0978***	0.0928***
		(0.0301)	(0.0303)	(0.0308)	(0.0296)
log (GDP per capita)		0.3927***	0.2260***	0.4166***	0.2109**
		(0.0326)	(0.0812)	(0.0332)	(0.0861)
log (Total population)		-0.0256	-0.1619	-0.0053	-0.1681
		(0.0247)	(0.1592)	(0.0242)	(0.1999)
Country fixed effect	No	No	Yes	No	Yes
Time fixed effect	No	No	No	Yes	Yes
No. of Obs.	1437	1437	1437	1437	1437
No. of countries	138	138	138	138	138
R-Squared	0.69	0.78	0.16	0.79	0.18

Note: Robust standard errors in parentheses * p < 0.10, ** p < 0.05, *** p < 0.01

[39] Here, the interpretation is done considering that the variable is taken in logarithm. An increase of the explanatory variable of 1% leads to a variation of the explanatory variable of $\beta/100$ units.

For both developing (column 1) and developed (column 2) countries, the results suggest that digitalization has a positive and significant impact on government effectiveness. However, the effect is larger in developed countries than in developing countries. Several factors may explain this result. In fact, partial digitalization and an institutional culture of paperwork are common in developing countries (Effah & Nuhu, 2017; Wiredu, 2012; Schuppan, 2009). This may limit their ability to benefit fully from the effects of digitalization. Furthermore, developed countries have more experience with digitalization. In addition, there is the issue of human capital for digitalization, which is less qualified in developing countries.

Table 2: Effect of digitalization on government effectiveness by income groups

	1 Developed Countries	**2 Developing Countries**
Dependent variable: Government effectiveness		
government ICT usage	**0.1368*** **	**0.0647*** **
	(0.0273)	**(0.0233)**
Political Stability and Absence of Violence/Terrorism	0.1352**	0.0908***
	(0.0512)	(0.0308)
log (GDP per capita)	0.2665	0.1996**
	(0.1640)	(0.0931)
log (Total population)	0.0337	-0.6417***
	(0.2467)	(0.1920)
Country fixed effect	Yes	Yes
Time Fixed effect	Yes	Yes
No. of Obs.	542	895
No. of countries	50	88
R-Squared	0.19	0.22

Note: Robust standard errors in parentheses * p < 0.10, ** p < 0.05, *** p < 0.01

4. Further analysis

4.1. Addressing reverse causality issue

First, a possible reverse causal effect between digitalization and government effectiveness was suspected. Here, we assume that digitalization impacts government effectiveness. On the other hand, an effective government will tend to increase the use of ICT to provide online services or improve its effectiveness and service quality. This is a source of reverse causality and, therefore, endogeneity. To deal with this potential reverse causality, following Datta and Agarwal (2004), we estimated one, and then two lags in the digitalization variable.

Table 3 presents the results with lags in government ICT usage. The effect of digitalization on government effectiveness remains positive and significant at the conventional level. According to Datta and Agarwal (2004), this means that the impact of digitalization on government effectiveness is not only due to two-way causality. This result also shows that the effect of the level of digitalization in a given year can extend over several more years.

Table 3: Effect of digitalization on the effectiveness with lags in digitalization

	Full sample		**Developed countries**		**Developing countries**	
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Dependent variable: Government effectiveness						
government ICT usage (t-1)	**0.065*** **		**0.089*** **		**0.033** **	
	(0.019)		**(0.031)**		**(0.015)**	
government ICT usage (t-2)		**0.047** **		**0.060***		**0.026**
		(0.020)		**(0.033)**		**(0.026)**
Political Stability and Absence of Violence/Terrorism	0.097***	0.099***	0.114**	0.110*	0.097***	0.101***
	(0.032)	(0.035)	(0.054)	(0.057)	(0.015)	(0.038)
Log (GDP per capita)	0.260***	0.341***	0.320*	0.436**	0.276***	0.311***
	(0.088)	(0.091)	(0.187)	(0.210)	(0.063)	(0.103)
Log (Total population)	-0.218	-0.269	0.023	-0.049	-0.683***	-0.639**
	(0.226)	(0.203)	(0.308)	(0.302)	(0.126)	(0.252)
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
No. of Obs.	1308	1174	495	446	813	728
No. of group	138	138	50	50		88
R-Squared	0.150	0.151	0.116	0.099	0.206	0.206

Note: Robust standard errors in parentheses * p < 0.10, ** p < 0.05, *** p < 0.01

Second, reverse causality could arise from wealth and the absence of political violence and/or terrorism. Indeed, an effective government is expected to be able to avoid political crises and social tensions and enable wealth creation. In addition, government efficiency is expected to improve the supply and quality of healthcare services. This could lead to a decrease in mortality rates (infant, maternal, and total) and an increase in life expectancy, thus affecting the population size. Therefore, we assumed a possible endogeneity for all control variables and to addresses this endogeneity issue, we utilized a two-step system GMM (Blundell and Bond, 1998).[40] The collapse option was applied to overcome instrument proliferation bias (Roodman, 2009). To correct the finite sample bias, we used Windmeijer's (2005) standard errors.

[40] We also consider digitalization and the lag of dependent variables as endogenous in the system GMM.

Third, government effectiveness also tends to be persistent since the country's current effectiveness may depend on the previous year's effectiveness. If this consideration is not considered, the regressions may suffer from the serious problem of a lack of relevant explanatory variables. Therefore, in line with the literature on the dynamic model, we included the one-period lagged value of the dependent variable as an explanatory variable to deal with the potential dynamic issue of government effectiveness. Therefore, the model can be written as follows:

$$GEE_{it} = \varphi + \rho GEE_{i,t-1} + \delta ICT_{it} + \beta X_{it} + \alpha_i + \gamma_t + \varepsilon_{it} \quad \text{(eq.2)}$$

The results of the GMM estimation are presented in Table 4. The AR(2) and the Hansen test p-values support the validity of the results as the p-values are higher than all conventional levels. Furthermore, the high and significant coefficient on the lagged dependent variable validates the relevance of the specified system GMM model and confirms that government effectiveness is persistent. This result suggests the existence of a dynamic in government effectiveness. Therefore, a given government's effectiveness level can be explained by that of previous years. As for the effect of digitalization, it remains positive and significant at the conventional level (Table 4, columns 1 to 3).

Table 4: Two-step system GMM estimation results

	1 **Full sample**	**2** **Developed countries**	**3** **Developing countries**
Dependent variable: Government effectiveness			
Government effectiveness (t-1)	**0.832*** **	**0.819*** **	**0.812*** **
	(0.034)	**(0.085)**	**(0.051)**
Government ICT usage	**0.039** **	**0.054***	**0.047***
	(0.019)	(0.029)	(0.025)
Political Stability and Absence of Violence/Terrorism	0.098***	0.078*	0.072**
	(0.022)	(0.040)	(0.028)
Log (GDP per capita)	0.045***	0.054	0.042***
	(0.014)	(0.039)	(0.012)
Log (Total population)	0.032**	0.009	0.024
	(0.014)	(0.006)	(0.019)
Time fixed effect	Yes	Yes	Yes
No. of Obs.	1287	496	795
No. of countries	138	50	88
Instruments	33	42	53
AR1-pvalue	0.000	0.000	0.000
AR2-pvalue	0.478	0.838	0.455
Hansen-P-value	0.13	0.35	0.14

Note: Robust standard errors in parentheses * p < 0.10, ** p < 0.05, *** p < 0.01

4.2. Sensitivity analysis

To test the sensitivity of the results, we added more variables to explain government effectiveness. They are education, control of corruption, the rule of law, representation and accountability, regulatory quality, stability, government size, and the proportion of women in parliament.[41] After adding these new variables (Table 5, columns 1 to 9), the effect of digitalization on government effectiveness remains positive and significant at the one percent level, confirming the robustness of the results. Regarding additional variables, the results suggest that better control of corruption, rule of law, regulatory quality (columns 2 to 4), and government stability (column 6) all improve government effectiveness. The effect of these variables on government effectiveness was positive and significant. This indicates that the quality of institutions is an important contributor to the explanation of government effectiveness. As for education (column 1), voice and accountability (column 5), the size of government, and the proportion of women in parliament (columns 8 and 9), their effects on government effectiveness are not significant at conventional levels.

In addition, greater natural resource revenue negatively impacted government effectiveness (column 7). This negative effect of natural resources on government effectiveness is consistent with the results of Isham et al. (2005), Bulte et al. (2005), and Sala-i-Martin and Subramanian (2003). This can be explained by the "natural resource curse." Indeed, Clark (1997) and Gause (1995) explained that governments, through revenues from natural resources, can finance security in order to undermine people's aspirations for quality government institutions and services. Following Busse and Gröning (2013), the negative effect of resource revenues can also be explained mainly through three channels. First, with abundant resource revenues, the government will tend to tax taxpayers less than necessary. Second, resource revenues can be used to ease tensions and sow corruption among the population. Finally, these funds can be used to prevent the creation of pressure groups that defend the rights of the population. Thus, without pressure groups or with a repressed population, aspirations for democracy, governance, and quality institutions will be undermined. In addition, a low-taxed population will have a low demand for international quality and public goods. In addition to these explanations, abundant natural resource revenues can be wasteful through excessive, inappropriate, inefficient, and ineffective spending. [42]

[41] To capture the size of government, the final consumption of government relative to GDP Is used, while the proportion of women in parliament is used to capture the gender composition of government.
[42] For more details on the literature on the effect of natural resources on the quality of governance and institutions, see Busse and Gröning (2013).

Table 5: Sensitivity analysis

	1	2	3	4	5	6	7	8	9
Dependent variable: Government effectiveness									
Government ICT usage	**0.0744*** **	**0.0823*** **	**0.0741*** **	**0.0768*** **	**0.1003*** **	**0.1077*** **	**0.0994*** **	**0.0990*** **	**0.0975*** **
	(0.0199)	**(0.0178)**	**(0.0158)**	**(0.0169)**	**(0.0184)**	**(0.0192)**	**(0.0187)**	**(0.0192)**	**(0.0191)**
Political Stability and Absence of Violence/Terrorism	0.0991***	0.0787***	0.0351	0.0575**	0.0933***	0.0683**	0.0906**	0.1056***	0.0938***
	(0.0337)	(0.0292)	(0.0264)	(0.0270)	(0.0295)	(0.0302)	(0.0383)	(0.0347)	(0.0305)
Log (GDP per capita)	0.3032***	0.1372*	0.1080	0.0642	0.2135**	0.1627*	0.1704*	0.2508***	0.2374***
	(0.0950)	(0.0817)	(0.0714)	(0.0810)	(0.0856)	(0.0874)	(0.0899)	(0.0950)	(0.0903)
Log (Total population)	-0.4671***	0.1303	0.1479	0.1729	0.1710	0.1512	-0.1895	-0.1732	-0.1624
	(0.1572)	(0.1735)	(0.1556)	(0.1679)	(0.2002)	(0.2100)	(0.2134)	(0.2104)	(0.2061)
log (Education)	0.0109								
	(0.0373)								
Control of Corruption		0.2622***							
		(0.0496)							
Rule of Law			0.4340***						
			(0.0473)						
Regulatory Quality				0.3153***					
				(0.0534)					
Voice and Accountability					0.0290				
					(0.0712)				
Government Stability						0.0247***			
						(0.0051)			
Natural resources revenue							-0.0045***		
							(0.0015)		
Government size								0.0043	
								(0.0035)	
Women in parliament									0.0015
									(0.0013)
Country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of Obs.	1099	1437	1437	1437	1437	1261	1310	1369	1373
No. of countries	128	138	138	138	138	120	130	133	133
R-Squared	0.19	0.24	0.30	0.26	0.18	0.21	0.16	0.18	0.19

Note: Robust standard errors in parentheses * p < 0.10, ** p < 0.05, *** p < 0.01

4.3. Heterogeneity

We also performed heterogeneity analyses to test whether the effect of digitalization on government effectiveness differs across geographic regions or effectiveness levels. For this purpose, we divided the database into sub-samples according to each country's continent[43] or government effectiveness score.

[43] For African and European countries, the geographical grouping has been assigned according to the football confederation to which they are affiliated. This allows to easily classify countries that straddle two continents or belong to a region different from their continent. There are two countries in Oceania (namely Australia and New Zealand) that are not considered in this heterogeneity analysis due to the small number of observations. However, the result does not change if they are added to the group of Asian countries.

4.3.1. By geographic region

In this section, we analyze the effect of digitalization by geographical group. The results displayed in Table 6 show that digitalization positively and significantly affects government effectiveness in African (column 1), Asian, and European countries (columns 3 and 4). However, the effect is not significant for American countries, although it is positive (column 3).[44] The coefficient is highest for European countries (column 4), suggesting that European countries benefit most from digitization.[45]

Table 6: Geographical heterogeneity

	1	2	3	4
	Africa	America	Asia	Europa
Dependent variable: Government effectiveness				
Government ICT usage	**0.1043*** **	**0.0312**	**0.0915** **	**0.1155*** **
	(0.0345)	**(0.0384)**	**(0.0347)**	**(0.0328)**
Political Stability and Absence of Violence/Terrorism	0.1363***	0.0989**	0.0363	0.0526
	(0.0369)	(0.0450)	(0.0478)	(0.0648)
Log (GDP per capita)	0.0441	0.5773**	0.4096**	0.4386**
	(0.1769)	(0.2292)	(0.1566)	(0.1651)
Log (Total population)	0.4304	0.5459	0.3515	-1.2000***
	(0.5100)	(0.6587)	(0.2723)	(0.4145)
Country fixed effect	Yes	Yes	Yes	Yes
Time Fixed effect	Yes	Yes	Yes	Yes
No. of Obs.	365	273	318	459
No. of countries	37	26	31	42
R-Squared	0.32	0.26	0.20	0.29

Note: Robust standard errors in parentheses * p < 0.10, ** p < 0.05, *** p < 0.01

4.3.2. By level of effectiveness

To constitute the effectiveness subgroups, we calculated the average effectiveness rate per country. Next, this value was compared to the median effectiveness value of the entire sample. Countries with an average effectiveness below the median are considered the least effective; otherwise, they are effective.

The results in Table 7 suggest that government effectiveness is positively and significantly affected by digitalization, regardless of the level of effectiveness. The results imply that an additional

[44] When disaggregating South and North American countries, the effect remains positive and non-significant for North American countries (there are 15 countries and islands, including the USA and Canada), while it becomes significant for South American countries. Therefore, it is likely that the non-significant effect comes from North American countries.

[45] We perform an additional geographic analysis based on the WB region groups. The results are presented in the Appendix C

increase in digitalization of one unit has an average impact on government effectiveness of 0.048 for the least effective group (column 1) and 0.145 for the most effective group (column 2). This result is explained by the same reasons as for developed and developing countries (i.e., experience, technological advancement, and quality of human capital in ICT are higher in developed countries) because the group of least effective countries is mostly composed of developing countries.

Table 7: Heterogeneity by effectiveness level

	1 Low effectiveness	**2 High effectiveness**
Dependent variable: Government effectiveness		
Government ICT usage	**0.0484***	**0.1447*****
	(0.0254)	**(0.0239)**
Political Stability and Absence of Violence/Terrorism	0.0731**	0.1685***
	(0.0322)	(0.0489)
log (GDP per capita)	0.2474**	0.2415**
	(0.1211)	(0.1189)
log (Total population)	-0.6167**	-0.0765
	(0.2332)	(0.2449)
Country fixed effect	Yes	Yes
Time fixed effect	Yes	Yes
No. of Obs.	702	735
No. of countries	70	68
R-Squared	0.20	0.23

Note: Robust standard errors in parentheses * p < 0.10, ** p < 0.05, *** p < 0.01

4.4. Additional ICT usage Indexes

While there is evidence that government digitalization has a positive effect on government effectiveness, this effect appears to be only partial. Indeed, ICT use by the government alone could only affect its internal effectiveness, particularly in terms of management and current activities. However, the use of ICT by other actors, such as individuals and businesses, can also improve government effectiveness. For example, suppose that the government makes it possible for individuals to conduct their administrative procedures online to reduce delays and ease procedures. However, some individuals do not use this alternative or do not have access to a connection device or the Internet and prefer physical procedures. Therefore, we believe that this is only possible if everyone (government, business, and individuals) has access to and use ICT. To investigate this question, we evaluate the effect of ICT use by individuals, businesses, and the entire society on the effectiveness of the government.

The results displayed in Table 8 suggest that use of ICT by individuals (column 1), businesses (column 2), and overall (column 3) increases government effectiveness. In addition, the effect of ICT use in society is higher, with a coefficient of 0.166, while that of business use is 0.04, and that of individual use is 0.065 (note that the coefficient of government use is around 0.1). This underlines the importance of facilitating access to ICT for all and promoting their use to make the most of digitalization. The effects of these variables on government effectiveness for both developed and developing countries were also compared. The impact is still positive and significant for both groups, except for business usage in developed countries. This result supports the baseline results, as the effect is larger in developed countries than in developing countries. The effect of overall usage remains higher for each group, suggesting that it is more helpful in promoting digitalization at all levels.[46]

Table 8: Effect of other type of ICT usage on government effectiveness

	1	2	3
Dependent variable: Government effectiveness			
Individual ICT usage	**0.0652*** **		
	(0.0182)		
business ICT usage		**0.0404** **	
		(0.0201)	
Overall usage			**0.1655*** **
			(0.0301)
Political Stability and Absence of Violence/Terrorism	0.1113***	0.1047***	0.0968***
	(0.0305)	(0.0295)	(0.0288)
Log (GDP per capita)	0.3102***	0.2836***	0.2545***
	(0.0829)	(0.0864)	(0.0837)
Log (Total population)	-0.0797	-0.1157	-0.1368
	(0.1839)	(0.2035)	(0.1713)
Country fixed effect	Yes	Yes	Yes
Time Fixed effect	Yes	Yes	Yes
No. of Obs.	1437	1437	1437
No. of countries	138	138	138
R-Squared	0.1516	0.1309	0.1855

Note: Robust standard errors in parentheses * p < 0.10, ** p < 0.05, *** p < 0.01

4.5. Alternative measurements

We now consider alternative measures of digitalization according to the E-Government Development Index (EGDI) from the United Nations e-Government Survey. The EGDI is a composite indicator that consists of the online services index, telecommunications index, and

[46] The results are displays in appendix D.1 and D.2, for developed and developing countries, respectively.

human capital index. The e-participation index is also considered.[47] These indices are equally weighted and cover a wide range of topics relevant to e-government.[48]

Table 9: Alternative digitalization indexes effect on government effectiveness

	1	2	3
Dependent variable: Government effectiveness			
E-Government	**0.4706*** **		
	(0.1752)		
E-Participation		**0.1347** **	
		(0.0531)	
Online Service			**0.1899** **
			(0.0847)
Political Stability and Absence of Violence/Terrorism	0.1001***	0.0991***	0.0984***
	(0.0302)	(0.0303)	(0.0305)
Log (GDP per capita)	0.3543***	0.3376***	0.3364***
	(0.0903)	(0.0921)	(0.0937)
Log (Total population)	-0.1123	-0.1075	-0.1400
	(0.1929)	(0.1917)	(0.1953)
Country fixed effect	Yes	Yes	Yes
Time Fixed effect	Yes	Yes	Yes
No. of Obs.	1492	1489	1492
No. of countries	136	136	136
R-Squared	0.1603	0.1533	0.1536

Note: Robust standard errors in parentheses * p < 0.10, ** p < 0.05, *** p < 0.01

The results displayed in Table 9, columns 1 to 3, show that all considered indicators positively and significantly affect government effectiveness. They suggest that the increase in government effectiveness following ICT usage does not change with the ICT measures. The results for both groups are presented in Appendices E.1 and E.2. They reveal that e-government, e-participation, and online services positively affect government effectiveness. Nevertheless, this effect is not significant for developing countries.[49]

[47] A definition of these indicators is given in appendix B.2.
[48] As EGDI is available over two years, we replaced data for gap year by the mean of the year after and the year before.
[49] Several reasons may explain this effect in developing countries. First, most of these countries are in the beginning stages of using these services (e-government, e-services, and e-participation), therefore it takes time for users to adapt and take full advantage of them. Furthermore, Jacobin et al. (2019) and Brun et al. (2019) explain that experience matters in the use of digital services. Second, the implementation of these services needs to be supported by policies to promote and sustain them, and thus by political will. Third, most developing countries face either technical difficulties and/or user reluctance. Thus, even if the services exist, the expected effects will not be achieved. Finally, Dobrolyubova et al. (2017) argue that the insignificant effect of EGID indices can be explained by the fact that in addition to not reflecting the actual level of digitalization, they do not capture all dimensions of digitalization.

5. Conclusion

This study investigates the impact of digitalization on government effectiveness using panel data methodology. It considered a dataset of 88 developing and 50 developed countries from 2006 to 2016. The results suggest that digitalization has a significant and positive effect on government effectiveness. This effect is greater for developed countries than for developing countries. This effect is more important when considering the overall use of ICT. It remains relevant when sensitivity to several political, institutional, and macroeconomic conditions is tested. Furthermore, it appears that the average effect by geographical group remains significant and positive, apart from the American countries where the effect is non-significant.

The findings of this study highlight how country governments can improve their effectiveness through digital transformation, especially in developing countries. In addition, to reap the full benefits of digitalization, they should adopt policies that would promote the use of ICT at all levels of the economy, that is, the government itself, businesses, and individuals. These policies should focus more on increasing the coverage of ICT and the Internet among the population and in all sectors of activity. This could include building and improving the technological infrastructure, particularly in developing countries. They should also adopt policy reforms to modernize public administration. Furthermore, they could offer more online services and dematerialize most administrative procedures as much as possible. They should also promote engagement and collaboration through participatory governance via ICT. Beyond all these policy recommendations, there is a need for a strong political will from policymakers to promote digitalization and to be more effective.

Appendix

Appendix A: Countries list

No.	Country	Region	Income group	No.	Country	Region	Income group
1	Australia	Oceania	High income	70	Cambodia	Asia	Lower middle income
2	Austria	Europe	High income	71	Cameroon	Africa	Lower middle income
3	Bahrain	Asia	High income	72	Cape Verde	Africa	Lower middle income
4	Barbados	North America	High income	73	Cote d'Ivoire	Africa	Lower middle income
5	Belgium	Europe	High income	74	Egypt, Arab Rep.	Africa	Lower middle income
6	Brunei Darussalam	Asia	High income	75	El Salvador	North America	Lower middle income
7	Canada	North America	High income	76	Ghana	Africa	Lower middle income
8	Chile	South America	High income	77	Honduras	North America	Lower middle income
9	Croatia	Europe	High income	78	India	Asia	Lower middle income
10	Cyprus	Asia	High income	79	Indonesia	Asia	Lower middle income
11	Czech Republic	Europe	High income	80	Kenya	Africa	Lower middle income
12	Denmark	Europe	High income	81	Kyrgyz Republic	Asia	Lower middle income
13	Estonia	Europe	High income	82	Lesotho	Africa	Lower middle income
14	Finland	Europe	High income	83	Mauritania	Africa	Lower middle income
15	France	Europe	High income	84	Moldova	Europe	Lower middle income
16	Germany	Europe	High income	85	Mongolia	Asia	Lower middle income
17	Greece	Europe	High income	86	Morocco	Africa	Lower middle income
18	Hong Kong	Asia	High income	87	Nicaragua	North America	Lower middle income
19	Hungary	Europe	High income	88	Nigeria	Africa	Lower middle income
20	Iceland	Europe	High income	89	Pakistan	Asia	Lower middle income
21	Ireland	Europe	High income	90	Philippines	Asia	Lower middle income
22	Israel	Asia	High income	91	Senegal	Africa	Lower middle income
23	Italy	Europe	High income	92	Swaziland	Africa	Lower middle income
24	Japan	Asia	High income	93	Timor-Leste	Asia	Lower middle income
25	Kuwait	Asia	High income	94	Tunisia	Africa	Lower middle income
26	Latvia	Europe	High income	95	Ukraine	Europe	Lower middle income
27	Lithuania	Europe	High income	96	Vietnam	Asia	Lower middle income
28	Luxembourg	Europe	High income	97	Zambia	Africa	Lower middle income
29	Malta	Europe	High income	98	Zimbabwe	Africa	Lower middle income
30	Netherlands	Europe	High income	99	Albania	Europe	Upper middle income
31	New Zealand	Oceania	High income	100	Algeria	Africa	Upper middle income
32	Norway	Europe	High income	101	Argentina	South America	Upper middle income
33	Oman	Asia	High income	102	Armenia	Europe	Upper middle income
34	Panama	North America	High income	103	Azerbaijan	Europe	Upper middle income
35	Poland	Europe	High income	104	Bosnia and Herzegovina	Europe	Upper middle income

36	Portugal	Europe	High income
37	Puerto Rico	North America	High income
38	Qatar	Asia	High income
39	Saudi Arabia	Asia	High income
40	Singapore	Asia	High income
41	Slovak Republic	Europe	High income
42	Slovenia	Europe	High income
43	Spain	Europe	High income
44	Sweden	Europe	High income
45	Switzerland	Europe	High income
46	Trinidad and Tobago	North America	High income
47	United Arab Emirates	Asia	High income
48	United Kingdom	Europe	High income
49	United States	North America	High income
50	Uruguay	South America	High income
51	Benin	Africa	Low income
52	Burkina Faso	Africa	Low income
53	Burundi	Africa	Low income
54	Chad	Africa	Low income
55	Ethiopia	Africa	Low income
56	Gambia, The	Africa	Low income
57	Guinea	Africa	Low income
58	Haiti	North America	Low income
59	Madagascar	Africa	Low income
60	Malawi	Africa	Low income
61	Mali	Africa	Low income
62	Mozambique	Africa	Low income
63	Rwanda	Africa	Low income
64	Tajikistan	Asia	Low income
65	Tanzania	Africa	Low income
66	Uganda	Africa	Low income
67	Yemen, Rep.	Asia	Low income
68	Angola	Africa	Lower middle income
69	Bangladesh	Asia	Lower middle income
105	Botswana	Africa	Upper middle income
106	Brazil	South America	Upper middle income
107	Bulgaria	Europe	Upper middle income
108	China	Asia	Upper middle income
109	Colombia	South America	Upper middle income
110	Costa Rica	North America	Upper middle income
111	Dominican Republic	North America	Upper middle income
112	Ecuador	South America	Upper middle income
113	Gabon	Africa	Upper middle income
114	Georgia	Europe	Upper middle income
115	Guatemala	North America	Upper middle income
116	Guyana	South America	Upper middle income
117	Iran, Islamic Rep.	Asia	Upper middle income
118	Jamaica	North America	Upper middle income
119	Jordan	Asia	Upper middle income
120	Kazakhstan	Europe	Upper middle income
121	Lebanon	Asia	Upper middle income
122	Libya	Africa	Upper middle income
123	Malaysia	Asia	Upper middle income
124	Mauritius	Africa	Upper middle income
125	Mexico	North America	Upper middle income
126	Montenegro	Europe	Upper middle income
127	Namibia	Africa	Upper middle income
128	Paraguay	South America	Upper middle income
129	Peru	South America	Upper middle income
130	Romania	Europe	Upper middle income
131	Russian Federation	Europe	Upper middle income
132	Serbia	Europe	Upper middle income
133	South Africa	Africa	Upper middle income
134	Sri Lanka	Asia	Upper middle income
135	Suriname	South America	Upper middle income
136	Thailand	Asia	Upper middle income
137	Turkey	Europe	Upper middle income
138	Venezuela, RB	South America	Upper middle income

Appendix B.1: List of variables for ICT usage indexes

Government Usage index	**Individual usage index**	**Business usage index**
Importance of ICT to government vision of the future	Mobile phone subscription	Firm-level technology absorption
Government prioritization of ICT	Individual using internet	Capacity for innovation
Government success in ICT promotion	Household with personal computer	Patent Cooperation Treaty (PCT) application
E-Participation Index	Household with internet access	ICT impact on new services and products
Government online services	Fixed broadband internet subscription	ICT impact on new organizational models
	Mobile broadband subscription	High-tech export
	Cellular subscription with data	Prevalence of foreign technology licensing
	Internet access in school	Business-to-business internet uses
	Uses of virtual social network (e.g., Facebook, Twitter, LinkedIn)	Business-to-consumer internet uses
		Extent of staff training

Appendix B.2: Variable descriptions

Variables	Description	Source
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.	Worldwide Governance Indicators (WGI) by World Bank
Political Stability and Absence of Violence/Terrorism	Perceptions of the likelihood that the government will be destabilized or overthrown by unconstitutional or violent means, including politically motivated violence and terrorism.	
Voice and Accountability	Perceptions of the extent to which a country's citizens can participate in selecting their government, as well as freedom of expression, freedom of association, and a free media."	
Regulatory Quality	"Perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development.	
Rule of Law	Perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence.	
Control of Corruption	Perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests.	
Government Stability	The assessment is both an evaluation of the government's ability to carry out its programmed(s) as declared and its ability to stay in office.	the International Country Risk Guide (ICRG)
GDP per capita (constant 2010 USD)	GDP per capita is the gross domestic product divided by the mid-year population. It is used to measure a country's level of wealth, and also its level of development.	World Development Indicators (WDI)
Population, total	It represents all residents regardless of their legal status or citizenship, estimated at mid-year.	
Government size	They include all current expenditure by the general government on purchasing goods and services and compensation of employees. They also include most national defense and security expenditure but exclude general government military expenditure.	
Women in parliament	It measures the percentage of parliamentary seats held by women in a single or lower house.	
School enrolment, secondary (% gross)	Ratio of total enrolment, regardless of age, to the population of the age group that officially corresponds to the level of education shown.	
Total Resource Revenue (% GDP)	Tax revenues from natural resources	The International Centre for Tax and Development (ICTD)
E-Government Index	The E-Government Development Index presents the state of E-Government Development of the United Nations Member States. Along with an assessment of the website development patterns in a country, the E-Government Development index incorporates the access characteristics, such as the infrastructure and educational levels, to reflect how a country is using information technologies to promote access and inclusion of its people.	UN E-Government Survey 2020 - United Nations
E-Participation Index	The e-Participation Index (EPI) focuses on the use of online services to facilitate the provision of information by governments to citizens (e-information Sharing), interaction with stakeholders (e-Consultation), and participation in decision-making processes (e-Decision-making).	
Online Service Index	The Online Services Index assesses the availability and the quality of online government service delivery.	
ICT usage (overall)	Assesses the level of ICT adoption by a society's main stakeholders: government, businesses, and individuals.	Global Information Technology Report (GITR)
Individual ICT usage	Measures the extend of selected ICTs diffusion among a country's population. It considers social networks uses	
Business ICT usage	Captures the extent to which businesses in a country use the internet for business-to-business (B2B) and business-to-consumer (B2C) operations and their efforts to integrate ICTs in their operations. It also includes internet uses for Business-to-government operations.	
Government ICT usage	Assesses the leadership and success of the government in developing and implementing strategies for ICT development, as well as in using ICTs, as measured by the availability and quality of online government services	

Source: Author construction with data from GITR, ICTD, ICRG, WDI, WGI, and UN

Appendix B.3: Summary statistics

Variables	Number of Observations.	Mean	Stdard Deviation	Min	Max
Government effectiveness	1437	0.1931506	0.9464555	-2.078492	2.436975
Political Stability and Absence of Violence/Terrorism	1437	-0.0285954	0.9020166	-2.810035	1.525453
Voice and Accountability	1437	0.0924449	0.9188504	-1.951152	1.737975
Regulatory Quality	1437	0.2410341	0.8979762	-2.232313	2.260543
Rule of Law	1437	0.1189995	0.9757775	-1.916324	2.100273
Control of Corruption	1437	0.0992537	1.025483	-1.616931	2.469991
Government Stability	1261	7.746897	1.48141	4.041667	11.5
GDP per capita	1437	16027.71	20181.22	219.9615	111968.3
Population, total	1437	4.89e+07	1.63e+08	277477	1.38e+09
Government size	1373	20.00763	11.01528	0	63.75
Women in parliament	1369	15.76746	5.330143	2.047121	41.88798
School enrollment, secondary	1099	85.21118	27.6707	14.13834	163.9347
Total Resource Revenue	1310	3.824984	10.09095	0	72.35043
E-Government Index	1415	0.5160066	0.1948272	0	0.91928
E-Participation Index	1412	0.3363908	0.2640916	0	1
Online Service Index	1415	0.4609137	0.2318458	0	1
Overall ICT usage	1437	3.68309	0.9697118	1.99	6.07
Individual ICT usage	1437	3.417053	1.511046	1	6.9
Business ICT usage	1437	3.740884	0.9306428	2.06	6.22
Government ICT usage	1437	3.893114	0.8617827	1.8	6.3

Appendix C: Geographic heterogeneity: WB region groups

	1 Europe & Central Asia	2 Sub-Saharan Africa	3 Latin America & Caribbean	4 Middle East & North Africa	5 East Asia & Pacific	6 South Asia	7 North America
Dependent variable: Government effectiveness							
Government ICT usage	**0.1137*** **	**0.0680***	**0.0447**	**0.1531*** **	**0.0875** **	**0.0358**	**0.0450**
	(0.0355)	**(0.0381)**	**(0.0425)**	**(0.0431)**	**(0.0347)**	**(0.0648)**	**(.)**
Political Stability and Absence of Violence/Terrorism	0.0323	0.1145***	0.0946**	0.1247*	0.1470**	0.1242	-0.1629
	(0.0638)	(0.0380)	(0.0447)	(0.0638)	(0.0635)	(0.1546)	(.)
Log (GDP per capita)	0.5462***	0.2689	0.5363**	0.0819	0.1948	0.9914	-1.8627
	(0.1454)	(0.3007)	(0.2425)	(0.2029)	(0.1343)	(0.9896)	(.)
Log (Total population)	-1.1019***	0.2411	0.5477	0.2383	-1.6963***	2.5731	5.9094
	(0.3258)	(0.5568)	(0.6713)	(0.2603)	(0.5511)	(5.4723)	(.)
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	457	314	251	167	160	44	22
Number of countries	42	32	24	17	15	4	2
R-Squared	0.28	0.21	0.27	0.42	0.44	0.60	0.90

Note: Robust standard errors in parentheses * p < 0.10, ** p < 0.05, *** p < 0.01

Appendix D.1: Effect of other types of ICT usage on government effectiveness: developed countries

	1	2	3
Dependent variable: Government effectiveness			
Individual ICT usage	**0.0633****		
	(0.0254)		
business ICT usage		**0.0088**	
		(0.0282)	
Overall usage			**0.2031*****
			(0.0503)
Political Stability and Absence of Violence/Terrorism	0.1301**	0.1220**	0.1307**
	(0.0551)	(0.0543)	(0.0545)
Log (GDP per capita)	0.3642**	0.3812**	0.2903*
	(0.1595)	(0.1587)	(0.1582)
Log (Total population)	0.1414	0.2358	-0.0061
	(0.2261)	(0.2286)	(0.2239)
Country fixed effect	Yes	Yes	Yes
Time Fixed effect	Yes	Yes	Yes
No. of Obs.	542	542	542
No. of countries	50	50	50
R-Squared	0.1063	0.0828	0.1658

Note: Robust standard errors in parentheses * p < 0.10, ** p < 0.05, *** p < 0.01

Appendix D.2: Effect of other types of ICT usage on government effectiveness: developing countries

	1	2	3
Dependent variable: Government effectiveness			
Individual ICT usage	**0.0481***		
	(0.0279)		
business ICT usage		**0.0657****	
		(0.0297)	
Overall usage			**0.1305*****
			(0.0414)
Political Stability and Absence of Violence/Terrorism	0.1057***	0.0958***	0.0943***
	(0.0324)	(0.0302)	(0.0307)
Log (GDP per capita)	0.2651***	0.2428**	0.2114**
	(0.0899)	(0.0964)	(0.0891)
Log (Total population)	-0.5484**	-0.6973***	-0.5325***
	(0.2149)	(0.1897)	(0.2000)
Country fixed effect	Yes	Yes	Yes
Time Fixed effect	Yes	Yes	Yes
No. of Obs.	895	895	895
No. of countries	88	88	88
R-Squared	0.213	0.213	0.233

Note: Robust standard errors in parentheses * p < 0.10, ** p < 0.05, *** p < 0.01

Appendix E.1: Effect of alternative ICT indexes on government effectiveness in developed countries

	1	2	3
Dependent variable: Government effectiveness			
E-Government	**0.7093****		
	(0.2663)		
E-Participation		**0.1682****	
		(0.0691)	
Online Service			**0.3246*****
			(0.1036)
Political Stability and Absence of Violence/Terrorism	0.1528***	0.1569***	0.1458***
	(0.0520)	(0.0550)	(0.0474)
Log (GDP per capita)	0.3374**	0.3333**	0.3501**
	(0.1670)	(0.1627)	(0.1631)
Log (Total population)	0.1085	0.1612	0.1180
	(0.2360)	(0.2147)	(0.2206)
Country fixed effect	Yes	Yes	Yes
Time Fixed effect	Yes	Yes	Yes
No. of Obs.	528	528	528
No. of countries	48	48	48
R-Squared	0.1237	0.1144	0.1307

Note: Robust standard errors in parentheses * p < 0.10, ** p < 0.05, *** p < 0.01

Appendix E.2: Effect of alternative ICT indexes on government effectiveness in developing countries

	1	2	3
Dependent variable: Government effectiveness			
E-Government	**0.2704**		
	(0.2168)		
E-Participation		**0.0321**	
		(0.0744)	
Online Service			**0.0671**
			(0.1172)
Political Stability and Absence of Violence/Terrorism	0.0878***	0.0868***	0.0867***
	(0.0325)	(0.0328)	(0.0327)
Log (GDP per capita)	0.3949***	0.3966***	0.3904***
	(0.1148)	(0.1196)	(0.1220)
Log (Total population)	-0.5549***	-0.5967***	-0.6060***
	(0.1894)	(0.1936)	(0.1855)
Country fixed effect	Yes	Yes	Yes
Time Fixed effect	Yes	Yes	Yes
No. of Obs.	964	961	964
No. of countries	88	88	88
R-Squared	0.2181	0.2123	0.2134

Note: Robust standard errors in parentheses * p < 0.10, ** p < 0.05, *** p < 0.01

Chap IV: Effect of ICT investment on efficiency of health and education spending in developing countries

Abstract: This paper analyses the importance of ICT investment in explaining the efficiency of public spending. We focused on health and education sectors. The study covers 43 developing countries between 2000 and 2015. We use DEA model to measure efficiency scores. For the analysis of the effects of environmental variables on technical efficiencies, we use the Tobit model. The results showed that low and middle-income countries can increase their efficiency level by 7% without changing the level of spending. We also found that the less developed a country is, the less efficient it is in allocating resources. Furthermore, African countries are the least efficient. However, the study showed that investment in ICT has a positive effect on technical efficiency. Although the effect depends on income level, it does not depend on geographic location. Finally, while total tax revenues do not have a significant effect, natural resource revenues have positive effects on the technical efficiency of public spending in developing countries.

Keywords: ICT investments, efficiency, Education, health, public expenditures.

JEL Codes : O30, C14, H51, H52, E62

Résumé : Ce document analyse l'importance des investissements en TIC pour expliquer l'efficience des dépenses publiques. Nous nous sommes intéressés aux secteurs de la santé et de l'éducation. L'étude couvre 43 pays en développement entre 2000 et 2015. Nous utilisons le modèle DEA pour estimer les scores d'efficience. Pour l'analyse des effets des variables environnementales sur les efficiences techniques, nous utilisons le modèle Tobit. Les résultats ont montré que les pays à revenu faible et intermédiaire peuvent augmenter leur niveau d'efficience de 7 % sans modifier le niveau des dépenses. Nous avons également constaté que moins un pays est développé, moins il est efficient dans l'allocation des ressources. En outre, les pays africains sont les moins efficients. Cependant, l'investissement dans les TIC a un effet positif sur l'efficacité technique. Bien que l'effet dépende du niveau de revenu, il ne dépend pas de la situation géographique. Enfin, si les recettes fiscales totales n'ont pas d'effet significatif, les recettes provenant des ressources naturelles ont des effets positifs sur l'efficacité technique des dépenses publiques dans les pays en développement.

Mots-clés : Investissements en TIC, efficacité, Éducation, santé, dépenses publiques.

Codes JEL : O30, C14, H51, H52, E62

1. Introduction

In the beguining of years 2000, the United Nations organization adopted eight Millennium Development Goals (MDGs). Fifteen years later, under the MDGs, seventeen sustainable development goals (SDGs) have been adopted. All of them aimed to fight against poverty and inequality, and to increase the level of development. About inequality, Maurin (2018)[50] suggests addressing the problem at its source to remedy it. The main source of inequality, he says, is in the provision of health and education services.

From the MDGs to the SDGs, the issue of health and education is essential. Indeed, in the MDGs, education comes second and 3 of the goals are directly linked to the issue of health. In the MDGs, health and education come just after the fight against poverty and hunger. In addition, the human capital theory has long demonstrated the importance of education in explaining economies' productivity (Becker, 1985). Lucas (1988) also sees education as the engine of economic growth, and shows that public spending on education, through the increase in human capital, has an impact on economic growth. More recently, Zagler and Dürnecker (2003) have argued that public spending on health and education has a long-term effect on economies.

The literature shows that education and health are important factors in the development issue. The least developed countries should, therefore, increase the supply of education and health, however, these countries are facing a chronic lack of resources for this purpose. In this sense, Duret (2005) shows that in African countries, current spending in education fluctuates between 1% and 9% of gross domestic product (GDP) or 5 to 31% of States' resources. Furthermore, according to 2019 data from World Bank, education spending in developing countries represented 4% of GDP in 2016, with an average annual growth rate of 1.02%. As for health spending, WHO et al. (2018) report estimated it at about 6.3% of GDP for the same year for developing countries. Meanwhile, in contrast to education, they increased sharply between 2000 and 2016, with an average annual growth rate of 6%.

The question, then, is how to increase supply in the social sectors with so few available resources? To address this question, some studies have focused on the efficiency of public spending in the social

[50] Louis Maurin, the Director of the "*Observatoire des inégalités",* France

sectors. Indeed, technical efficiency is the efficiency with which a decisionmaking unit (DMU) uses a given set of inputs to produce outputs. A DMU is technically efficient if it produces the maximum output possiblle from the minimum amount of inputs possible, such as labour, capital, technology, or any other resources. The studies on the subject indicate that developing countries have low efficiencies in public spending compared to others. These studies show that several factors[51] explain the efficiency level of public spending. But excepted Machado De Freitas et al. (2014) that analyze the impact of having a computer on the efficiency of education spending in OECD countries, all previous studies have tended to omit an importance factor which is the Information and communication technologies (ICT), in explaining the efficiency of education and health sectors. This study concludes the absence of a significant link between having a computer and efficiency in the education sector. In addition, Sung (2007) discusses the role of ICT on performances of Korean local government throgh efficiency and productivity analysis. The results show positive effects of ICT on the efficiency and productivity of Korea's public sectors. But the paper does not address the case of health and education.

Nowadays, ICTs have more than ever become a part of our daily lives as they intervene in almost every sector including health and education, and help to overcome some difficulties and facilitate access to many services. The most recent evidence of the major importance of ICTs in the efficiency of these two sectors is the role they played during the COVID-19 pandemic. In this particular situation, many countries used ICTs for the management of the health crisis. In fact, Internet, mega-data, artificial intelligence and cloud computing have been used to monitor the evolution of the pandemic, to track patients, to alert the population on measures and barrier actions to prevent the disease and also in the process of treating patients. ICTs have also enabled the rational management of the production and distribution of medical supplies. In the same context, some developing countries were looking for medical technologies to deal with the pandemic. Apart from health, education is one of the sectors that has benefited most from the advantages of digitalization during this crisis. With the closure of educational institutions around the world, education stakeholders have therefore turned to the digital solution to ensure continuity of education. This period has seen the development of e-learning, e-classes, Visio conferencing, and the applications and platforms that accompany them. Universities

[51] In literature, explanatory variables differ according to whether the study is on education or health, but there are variables common to both. Thus, we can list Corruption, inequality, GDP per capita, population density or government revenue. To perform the study, he composed an ICT index with four variables that are: number of related meetings and plans about ICT (ICT support), investment and equipment (ICT infrastructure), human and organizational factors (ICT skills), together, usage and application (ICT usage).

distributed and/or subsidized computer tools and Internet access for students and teachers to facilitate the continuation of courses and exams. Nevertheless, developing countries have been confronted with the lack of necessary ICT resources and poor infrastructures. In this sense, some of these countries have set up exam preparation courses via television and radio for students (Côtre d'Ivore, Burkina Faso, Senegal). However, the majority of schools in developing countries have remained closed, while in developed countries, digitalization and technological advances have made it possible to ensure continuity in education. On the one hand, this pandemic context has thus highlighted how ICTs can contribute to increasing the efficiency and productivity of both sectors, and on the other hand, it has given a boost to the digitalization process in some countries. Many countries are investing in the acquisition of technological goods for health in particular. It can be said that in developed countries, ICT plays a key role in the performance of the health and education sectors. For developing countries, the question arises as to whether investment in ICT will also improve the efficiency of these two sectors. In other words, do ICTs have a significant impact on the efficiency of public spending in the education and health sectors?

This study aims to analyze the impact of ICT investments on the efficiency of public spending in the health and education sectors. Specifically, we will first determine the technical efficiency and productivity in 43 developing countries for the two sectors. Then, we will analyze their productivity and the evolution of these performances throughout our study period. Finally, we will evaluate the impact of environmental variables, including investment in ICT, on technical efficiency. Using a Data Envelopment Analysis (DEA) model in the first step and a Tobit model in the second, the results suggest that at least 7% of public spending on education and health in developing countries is wasteful. In addition, these countries and yields an average productivity gain of 0.8% per year. As for the investment in ICT, it allows to improve the technical efficiency of health and education spending in developing countries.

The rest of this paper is structured as follows: Section 3 deals with the literature review. Section 4 presents the methodologies used to estimate efficiency scores and the impact of environmental variables on technical efficiency. In Section 5, we provide the data. The results are shown in Section 6. In Section 7, we perform further analyses.

2. Literature review

Concerning studies on the efficiency of public spending, there are various methods in literature for estimating them and the results are sometimes confused. Mainly these studies identify that African in particular and developing countries in general are the least efficient in spending. To study spending efficiency and its determinants, researchers first estimate efficiency scores and then analyze the impact of environmental variables on efficiency scores. In the next sub-section, we will review some studies on the efficiency of public spending and the factors that affect it.

2.1. The efficiency of public spending

Two groups of methods are mainly used to estimate the efficiency of public sectors. These are parametric and non-parametric methods. For the parametric method, stochastic frontier analysis (SFA) is the most widely used in many efficiency studies. Using this method, Aremo and Olanubi (2016) measure the efficiency of health spending in three selected sub-Saharan African countries (Uganda, South Africa, and Nigeria) over the period 1998 - 2012, and Olanubi and Osode (2017), studied health spending in Nigeria between 1966 and 2014 in addition to Herwartz and Schley (2018); Grigoli and Kapsoli (2018).

Regarding non-parametric methods (NPM), data envelopment analysis (DEA) and Free Disposal Hull (FDH) are the main methods used. Using FDH, Gupta and Verhoeven (2001) compared the efficiency of public spending on health and education for 37 countries on different continents. Their results show that European countries are more efficient than Asian and African countries. Similarly, Afonso and Aubyn (2005) use both methods to assess the effectiveness of public spending on health and education in the context of Organisation for Economic Co-operation and Development (OECD) countries. Also regarding OECD countries, Aristovnik (2013) uses DEA methods as well as Afonso and St. Aubyn, (2006) to study the effectiveness of public education. All of these studies have shown that public spending in developing countries is the least efficient compared to developed countries. In other words, the level of efficiency is a function of income group. African countries are also the least efficient in terms of public spending. There are also a few studies that use these methods to assess efficiency in the health and education sectors (Marschall and Flessa, 2009; Kirigia et al., 2011; Abeney and Yu, 2015) but not about public spending. After analysing the level of efficiency, some researchers have

investigated external variables that may explain the efficiency level. In the following section, we will review the most commonly used variables.

2.2. Determinants of the efficiency of public spending

There are many external variables that can affect the effectiveness of the DMU. A number of studies have analyzed the effect of household income, inequality, population density, government resources, and control of corruption. But the results for some variables are inconsistent across studies. It appears that individual income has a strong impact on the effectiveness of public spending in the social sectors. Indeed, some authors show that the effectiveness of public spending is positively related to individual income. This can be explained by the fact that people with a high income are less dependent on public action in certain social sectors because they will take care of a large part of their health and education expenses themselves. Thus, public action will benefit poorer people more. Regarding this aspect, Afonso and St. Aubyn (2006) for the efficiency of education and Olanubi and Osode (2017) for health found a positive effect of household income on the technical efficiency of public spending. Herwartz and Schley (2018) found that growth in per capita income positively affects the efficiency of health spending. In contrast, for one group of researchers, the higher the household income, the more it affects the efficiency of the public sector. This was highlighted by Santiago and Gaobo (2005); Lavado and Cabanda (2009).

In addition, Hsu (2013) shows that higher population density can be expected to improve the performance and efficiency of public sectors by reducing the cost of service delivery through economies of scale and lower transmission costs. Several studies (Jafarov and Gunnarsson (2008) and Lavado and Cabanda (2009)) show that inequality has negative effects on public spending. Inequality reduces the opportunities to access public services. In this sense, some people will be rationed from the supply of public goods and services. Inequality is indeed high in health and education, mainly in developing countries. As for corruption, it is a key factor in the issue of public spending. It appears that controlling corruption can help reduce waste and embezzlement. On this point, Hauner and Kyobe (2010) do not find a significant effect of corruption control in improving public sector performance, but they show that greater government accountability is needed to improve education performance and efficiency. on the other hand, positive results were observed by Machado De Freitas

et al. (2014) for 26 OECD countries. Fonchamnyo and Sama (2016),also found a positive effect in countries in the Central African Economic and Monetary Community (CEMAC).

The effect of budget constraints is also noticeable. In some cases, inefficiency can be explained by waste due to the abundance of resources allocated. Indeed, decision makers tend to waste resources when they have plenty of them. Lavado and Cabanda (2009), on Philippine public spending on health and education, found a negative effect of the central government subsidy and the local government allocation on their spending on education and health. The more flexibility governments have with their budgets, the less efficient they are in spending. However, when their budget is limited, they are careful in their spending to avoid waste. Nonetheless, D'Inverno et al. (2018) found that budget constraint is negative for public sector efficiency. This could be explained by the fact that having a sufficient budget allows many needs to be covered and the supply of public goods and services to be increased. For this second step, most studies that adopt nonparametric methods use a Tobit model (D'Inverno et al., 2018; Abeney and Yu, 2015; Lavado and Cabanda, 2009; Afonso et al., 2006; Santiago and Gaobo, 2005). However, some use other models like Fonchamnyo and Sama, (2016) who used a fractional Logit model and (Machado De Freitas et al., 2014) who used an OLS model.

2.3. Link between ICT and Health/education

Despite the lack of econometrics studies on the link between ICT, health and education, there are many works about the importance of ICT in the outcome of both sectors. Most of them use either descriptive statistics or a literature review. So, in the case of Canada, Karsenti (2003) explains that ICT can be a good way to overcome the lack of motivation among education actors. Because introducing educative games allows students to learn while having fun. The same study showed that ICT used in education leads to more enthusiasm for students and increases their level of concentration and facilitate learning. Then, it improves their academic results. Vernadakis et al. (2005) demonstrated that ICT has a significant effect on children's cognitive, emotional, linguistic and literacy skills. Furthermore, S nchez et al. (2011) explored similarities and differences regarding ICT integration and use in Korean and Chilean curriculum. It also aimed to understand the factors that affect ICT's integration, as well as those that hinder it. Based on literature review and meta-data analysis, it shows that it is necessary to have a national strategy of education development for the long-term to integrate the vision of ICT. Perbawaningsih (2013) conducted a study based on a meta-analysis to explain the dialectical usefulness

of ICT in the learning process in higher education. It also relate that ICT usefulness will be negative. Again, about ICT use in education, some papers such as Liua et al. (2014) analyzed the positive impacts of access and use of ICT in pre-school, on the teachers' attitudes and competences.

Regarding the health sectors, Déglise et al. (2012) argues that using short message service (SMS) in the health sector for awareness and information about diseases such as malaria and cholera in developing countries can help to prevent and overcome them. This argument is based on the fact that nowadays, smartphones are widespread and because SMS is a reliable channel to convey information. Meyer and Ball (2015) highlight the capital role of assistive technologies (AT) among student with learning disabilities. This paper suggests that using AT to communicate with the patient and their parents can enhance the efficiency of the user (time management, independence, increasing of wellbeing). It adopted a theoretical analysis to obtain these results. In Ghana, at the end of the National ICT Forum for Health and Development hosted by One Million community (2016), a measure to integrate ICT in health sectors for development has been adopted. It appears from the report that they planed telemedicine, e-health and teleconsultation projects. The first two will facilitate access to health care at all times through expert instructions. The last purpose is to enable health professionals and patients to have expert advice on an urgent case or treatment. Nevertheless, they point out that the realization of these projects requires large investments in ICT devices. Also, to study the impact of patient-centric based ICT healthcare on the performance of students with learning, physical and sensory disabilities, Papanastasiou et al. (2018) used literature review, theoretical and survey statistical analyses. In addition to that, through statistical analysis, Zhang et al. (2018) show the mains role of ICT use in HIV prevention and management in Guanxi (China).

We also observed that all studies on the importance of ICT in these sectors have no empirical support. They are based on literature reviews or superficial statistical analyses. Moreover, at the time of this study, we have not seen another study that considers the impact of ICT on social sectors through the channel of efficiencies. Our study differs in that it takes into account ICT investments in explaining efficiency gains in the health and education sectors by adopting empirical methods.

3. Identification strategies

3.1. Data Envelopment Analysis

As we saw above, two groups of methods have been used in literature for estimations. there is at first, the parametric methods, and secondly, the non-parametric methods. Concerning the non-parametric methods, the most widespread is Data envelopment analysis (DEA). DEA bottom theory was developed by Farrell (1957). Then, as a part of a study about the efficiency of an American federal program of resource allocation for schools, Charnes et al. (1978) introduced a mathematical approach that they called DEA. The DEA process enables us to measure efficiency by a convex production frontier. In this process, a link is established between resources (Input) and productions (Output) of the DMUs in the sample. Thereby, the DMUs with the best Input-Output combination as considered as the most efficient. To estimate scores by DEA, it's necessary to precise the DEA model and orientation. Constant Return to Scale (CRS) model imply that the DMUs operate at their maximal performances. In other words, they can adjust their input and output. This supposes that the DMUs are in perfect competition context, wich is not the case of public sectors. The efficiency score, in this case, is called *Constant Return to Scale Technical Efficiency (CRSTE)*. Variable Return to Scale (VRS) model was introduced by Banker et al. (1984) to take account of the fact that the DMUs are not always at their maximum size. It's applied in sectors such as health, education and other social sectors in general (Or non-profit sectors). A DMU that is efficient in the CRS model is also efficient in VRS model, but the reciprocal is not true. The efficiency score is called *Variable Return to Scale Technical Efficiency (VRSTE)*. There are also two types of orientation. The input oriented assesses how much inputs the DMU can use, while maintaining its output level constant. That means the DMUs can adjust their input, or they know in advance, output that they can obtain. However, it is not the case in public sectors. The output oriented is to evaluate how much output can be obtained without changing the input. This implies that the DMUs have not control of their inputs[52]. It is also due to the fact that social sectors want to maximize their output as much as possible.

[52] SEIFORD and THRALL (1990); Lovell et al. (1994); Coelli et al. (1998); Huguenin (2013) gives more detailed about DEA efficiency methods and techniques.

The mathematical equation of DEA analysis in a CRS model is defined as follows: Suppose a DMU i with an input x_i , and an output y_i. Let δ and θ be successively the weight vectors of factors and productions of the DMU. The maximization function will be:

$$MAX_{\delta\theta}(\theta' y)$$

$$\text{S/C} \quad \delta' x_i - \theta' y_i \leq 0; i = 1 \ldots I$$

$$\delta . \theta > 0$$

If we have many DMUs in the sample, X and Y will designate the input and output for all of them. But in a VRS model, to take into account the convexity of production frontier, we will have:

$$\sum \lambda = 1$$

where λ is the weight vector.

Free disposal hull (FDH) is an extension and an alternative to DEA developed by Tulkens and Deprins (1984). This process removes the convexity condition, has a fewer assumptions and is more flexible[53]. Therefore, for a same input, different DMUs with different outputs must be declared as efficient.

3.2. Malmquist Productivity Index

With panel data, it will be interesting to perform Malmquist DEA constructed by Malmquist and Hille (1948), that allows to estimate Total Factor production (TFP), analyzes the progression of efficiency, productivity, and their causes. But Caves, D.; Christensen, L.; Diewert (1982) used the measurement of this index based on a non-parametric function in Input orientation. It allows determining the efficiency change by comparing the productivity of the period t with that of $t + 1$. According to Färe and Grosskopf (1992), the Malmquist productivity index (MPI) has two sub-indexes: efficiency change

[53] for more, see Brennan et al. (2014); Azar Dufrechou (2016)

and technical change. Fare et al. (1994) provid an output-based Malmquist index and show how to incorporate a scale efficiency change[54].

The mathematical equation of MPI for DMU i can be defined as:

$$M_i(y_{t+1}, x_{t+1}, y_t, x_t) = \frac{d_i^t(y_i^t, x_i^t)}{d_i^{t+1}(y_{t+1}, x_{t+1})} \times \frac{d_i^{t+1}(y_t, x_t) * d_i^{t+1}(y_{t+1}, x_{t+1})}{d_i^{t+1}(y_t, x_t) * d_i^t(y_{t+1}, x_{t+1})}^{1/2}$$

In the Total Factor Productivity (TFP) equation, M is TFP, d, the distance between the technology used at t period and that is used at $t+1$. It is a geometrical mean. TFP is a product of technical efficiency change ($EFFCHH$)[55] and technological change ($TECHCH$)[56].

To overcome some shortcomings of previous works, Aigner et al. (1977) and Meeusen and van Den Broeck (1977) introduced the stochastic methods to involve specification methods. Their works show that the error terms are composed of two components. Thereafter, Polachek and Yoon (1987) extends to two-tier stochastics methods. These studies intended to introduce three error component structures to take account the impact of informational inefficiencies.

Recently, several papers have been published about parametric approaches such as Baltas (2005) who adapted the method to food consumption. Also, Parmeter et al. (2014) have many articles about efficiencies methods, principally SFA.

In the first step of this work, we use a variable return to scale DEA, oriented output to estimate efficiency scores. We do not use the parametrical method because it's difficult to define the form of the production function in the health and education sectors that are more public sector. Also, in these sectors, we need to maximize the output with given inpu as public sectors are non-profit. And we will focus only on technical efficiency and MPI. However, DEA has some flaws. It does not measure absolute efficiency, is not subject to basic statistical tests, may suffer from measurement bias and does not take into account negative and null values. Although, it remain the best methods to estimate efficiency of public and social sectors.

[54] Brennan et al. (2014).
[55] first fraction of the MPI equation.
[56] second fraction of the MPI equation.

3.3. Second-step analyses

In the second step, the analysis will focus on the impact of environmental variables on efficiency scores. When the dependent variable is censored as efficiency scores, this means that it is distributed over a bounded range, using OLS will give a biased result because the model does not take into account the fact that the dependent variables are censored. In this case, it is more appropriate to estimate the effect of environmental variables with a censored dependent variable model. In light of the structure of the efficiency scores (between 0 and 1), we use the Tobit model. The estimated model can be presented as follows:

$$VRSE_{it} = \beta_i X + \alpha + \epsilon_{it}$$

When ICTs are considered in the explanations of efficiency results, the model becomes as illustrated below :

$$VRSE_{it} = \gamma ICT + \beta_i X + \alpha + \epsilon_{it}$$

Where γ is the coefficient of ICT variable, α designs a constant, β is the coefficient of explicative variables, X_{it} is determinants of technical efficiency for the country i at the t period and ϵ_{it} is the usual error term.

4. Data and descriptive statistics

The data used in this study cover 43 developing countries over a 16-year period (2000-2015). It relates to 10 low-income countries, 18 lower-middle income countries, and 15 upper-middle income countries. Based on previous studies(Gupta and Verhoeven (2001); Afonso et al. (2005); Afonso and Aubyn (2005); Fonchamnyo and Sama (2016)), public spending on health and education in percent of GDP are used as input[57] variables.[58] Table 1 presente descriptive statistics[59]. With respect to its

[57] The output variables were chosen with reference to the studies we cited in the literature review section.
[58] Taking spending as a percentage of GDP allows us to consider the difference in income levels between countries because values taken in gross terms may suggest that some developing countries have a low level of social spending, however, when put into proportion to their income, they may be quite high and the reverse for developed countries.
[59] Table xx in appendix present variables description.

definition, the student/teacher ratio variable, a lower ratio is better. So, regarding the principle of maximization in efficiency method, we use the inverse of this ratio to transform it to the teacher-pupil ratio.Concerning infant mortality rate, it has a negative connotation, so it is appropriate to take it by negative mark. Since DEA doesn't allow negative values, referring to Bowlin (1998), first, we multiply the variable by a negative sign in order to take into account the negative aspect of mortality, then we add it to a positive value in order to reverse the trend and no longer have a negative value. Thus, the variable turns into infantile survival rate. Besides, Hsu (2013)[60] proposes to take the reciprocal of the positive value for all DMUs.[61]

Figures 1 and 2 present a graphical analysis of public spending on health and education. We observe in graph 1 of figure 1 that the share of GDP allocated to the health sector has increased throughout the study period. As for education, the graphic 2 show that the share of GDP allocated to this sector has increased over the period, but this evolution is not constant. Spending on education increased by 55.23% between 2000 and 2015. Moreover, one year of increase is systematically followed by another of lower education spending.

Table 1: Summary statistics

Variable	Observations	Mean	Std. Dev.	Max	Min
Input variables					
Education spending (% GDP)	688	4.169	1.596	9.510	0.005
Health spending (% GDP)	688	2.449	1.493	9.511	0.408
Output variables					
Life expectancy at birth (LEXB)	688	65.74	8.144	79.63	45.91
Immunization, DPT (IDPT)	688	84.81	13.56	99	23
Infant mortality rate (IMRT)	688	960.3	25.84	996.9	884.7
Primary completion rate (PCR)	688	80.82	20.73	100	4.088
Pupils-Teacher ratio (PTRP)	688	3.998	1.867	11.52	1.531
Secondary general pupils (SEGP)	688	7.120	2.725	14.14	0.868
Environmental variables					
ICT goods investments (ICT)	585	5.169	3.793	24.36	0.713
Population density (POP)	688	134.803	200.803	1394.677	2.307
GDP per capita	688	6539.292	5004.256	20556	724.16
World Income Inequality (SWIID)	599	40.27	7.191	62.5	23.6
Access to electricity (ELECT)	688	69.124	32.018	100	3.207
Aid and assistance (NDAO)	666	5.20e+08	5.48e+08	3.71e+09	-4.86e+8
Government revenue (MOB)	672	5.14e+08	1.49e+09	1.37e+10	2112834

Source: Author construction with WDI, WHO, UIS, ICRG and ICTD databases 2019

[60] citing Rayp and VAN DE SIJPE (2007).
[61] In addition, the output data do not differentiate between private and public outcomes. It would therefore make sense to consider private or household spending in both sectors. However, the available data do not allow for this.

The histogram of spending by period[62] (graphic 3) confirms that total spending on education increased over the 16 years of study, but the increase is very small. According to the graph 4 on figure 2, education spending is increasing for low-income countries, remaining almost constant for low-middle-income countries, and declining for upper-middle-income countries.

Figure 1: Health spending graphics

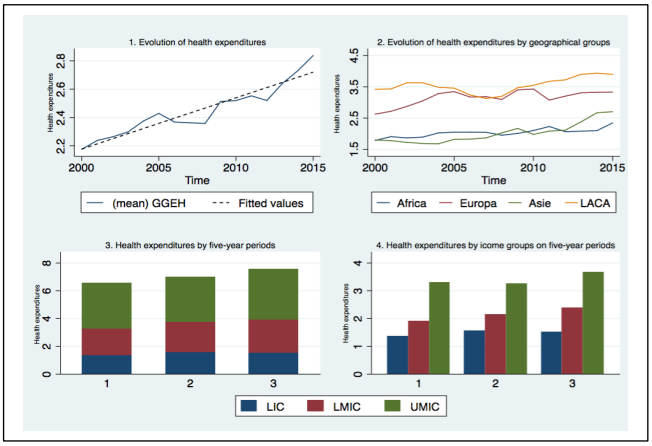
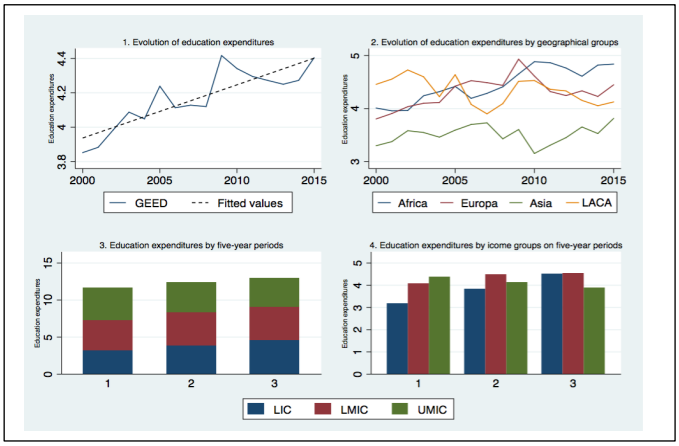


Figure 2: Education spending graphics



Source: Author construction

The import of ICT goods represents the share of ICT goods in the countries' total imports. This variable includes cell phones, computers and peripheral products, medical ICT and other electronic products. Due to lack of data, we use it as a proxy for public and private investment in ICT. Indeed, the vast majority of developing countries do not produce ICT goods. They are major importers. We can see that on average, 5.17% of the imports of the countries in the sample are ICT goods. This number can reach up to 25% of imports for some countries. The dependant variable is variable return to scale technical efficiency (VRSE).

[62]Period 1: 2000-2005; Period 2: 2006-2010; and Period 3: 2011-2015

5. Empirical results

5.1. Efficiency and productivity

A multiple input-output DEA is implemented to calculate efficiency scores. Accordingly, the inputs and outputs of both sectors were entered simultaneously.[63] The results are displayed in table 2. Overall, the efficiency results show an average score of 0.93. This means that developing countries can improve the efficiency level of their spending in social sectors by 7% while maintaining the same level of spending. Compared to the others, 10 countries (23.26% of countries in the sample) are declared to be efficient. They are Albania, Azerbaïjan, Belarus, Costa Rica, Georgia, Indonesia, Iran, Lebanon, The Maldive, and Mauritius. Among these countries, we do not have a LIC and only one LMIC is represented. The other 9 are UMICs. Based on the average per income group, we find that LIC are the least efficient. With an average score of 0.823, they are below the mean of the sample. Thus, 17.7% of public spending in the health and education sectors of these countries was a waste from 2000 to 2015. In other words, they can increase their efficiency by 0.177 points while maintaining the current level of their health and education spending. For the LMICs, they are slightly above the means with a score of 0.934. They waste 6.6% of health and education spending. UMICs is the best performing group with a waste level of 0.013 (1.3%) or an average score of 0.987. We can also observe that countries with low-efficiency scores are mainly African countries with an average of (0.857).

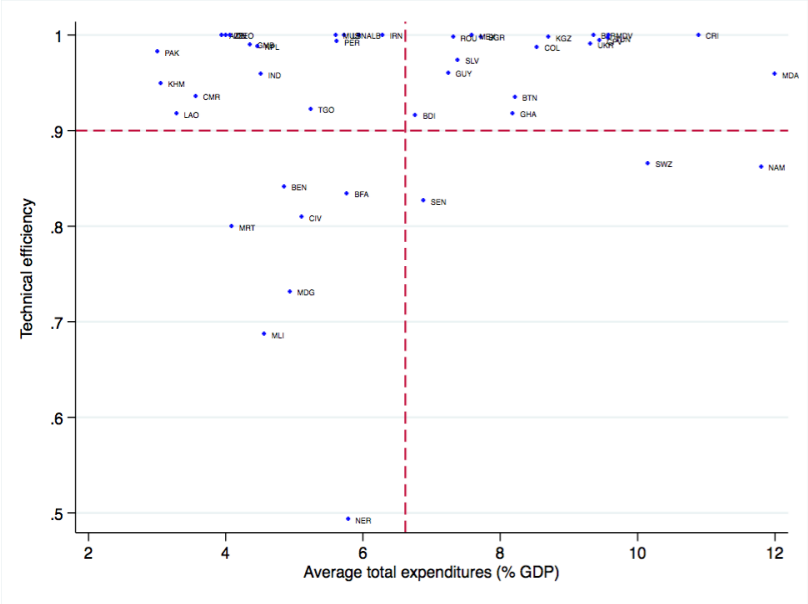
The DEA analysis shows that the level of efficiency of both sectors depends on the level of income. We observe that the higher the income level of a country, the more efficient it is in allocating spending. These results can be explained by the fact that the higher the income level of a country, the more developed the country is considered to be. And the more developed it is, the more efficiently it manages its expenditures and allocations. As the statistical description above has shown, the higher

[63] Gupta and Verhoeven (2001) argues that analyzing government spending separately does not definitively answer the question of which country is efficiently spends its public resources because a country can be efficient on some indicator or sector and weak on others The reverse may be the case in another country (Page 446). The paper then suggests combining all the outputs of education and health. In addition, it is possible that spending in a given sector can influence the output of the other, and this is the case for both sectors.

the income group of a country, the lower the share of its GDP that it allocates to social spending. But the opposite should be true, as low-income countries should rationalize their spending.

Figure 4 shows four boxes. The first shows countries with low spending and low efficiency. The second shows countries with low spending and high efficiency. The third group consists of countries with high spending and high efficiency. In the last quadrant, we find countries with high spending and low efficiency. The best situation is that of countries with low spending and high efficiency. On the other hand, the bad situation is countries with high spending but low efficiency.

Figure 4: Scatter plot of efficiency scores by level of spending



Source: Author construction

Table 3 summarizes the Malmquist Productivity Index (MPI). All averages in Malmquist index are geometric means. On average, the countries in the sample have productivity of 0.8% because the total factor productivity (TFPCH) is 1.008. In fact, TFPCH is a function of efficiency changes (EFFCH) and technological changes (TCHCH). In this case, the EFFCH is 1.000, which means that countries did not notice several increases in efficiency during the study period. And the TECHCH is 1.008 which

means that they have technological progress of 0.008 points (0.8%). Thus, we can conclude that the productivity gain is entirely due to the technological gain and not to the efficiency gain[64].

Table 2: Efficiency scores

Country	Technical efficiency	Rank	Income group	Country	Technical efficiency	Rank	Income group
Albania	1	1	Upper-middle income	Pakistan	0.982	22	Lower-middle income
Azerbaijan	1	1	Upper-middle income	El Salvador	0.974	23	Lower-middle income
Belarus	1	1	Upper-middle income	Guyana	0.960	24	Upper-middle income
Costa Rica	1	1	Upper-middle income	Moldova	0.959	25	Lower-middle income
Georgia	1	1	Lower-middle income	India	0.959	25	Lower-middle income
Iran, Islamic Rep.	1	1	Upper-middle income	Cambodia	0.949	27	Lower-middle income
Lebanon	1	1	Upper-middle income	Cameroon	0.936	28	Lower-middle income
Maldives	1	1	Upper-middle income	Bhutan	0.935	29	Lower-middle income
Mauritius	1	1	Upper-middle income	Togo	0.923	30	Low-income
Indonesia	1	1	Lower-middle income	Ghana	0.918	31	Lower-middle income
Mexico	0.999	11	Upper-middle income	Lao PDR	0.918	31	Lower-middle income
Bulgaria	0.998	12	Upper-middle income	Burundi	0.916	33	Low-income
Romania	0.998	12	Upper-middle income	Swaziland	0.866	34	Lower-middle income
Kyrgyz Republic	0.997	14	Lower-middle income	Namibia	0.862	35	Upper-middle income
Tunisia	0.997	14	Lower-middle income	Benin	0.841	36	Low-income
Cape Verde	0.994	16	Lower-middle income	Burkina Faso	0.834	37	Low-income
Peru	0.993	17	Upper-middle income	Senegal	0.826	38	Low-income
Ukraine	0.990	18	Lower-middle income	Cote d'Ivoire	0.810	39	Lower-middle income
Gambia, The	0.990	18	Low-income	Mauritania	0.799	40	Lower-middle income
Nepal	0.988	20	Low-income	Madagascar	0.731	41	Low-income
Colombia	0.987	21	Upper-middle income	Mali	0.687	42	Low-income
				Niger	0.493	43	Low-income
			Total average		0.930		
			Low income countries		0.823		
			Lower-middle income countries		0.934		
			Upper-middle income countries		0.987		

However, table 3 show that low-efficiency countries have a positive EFFCH. This shows that despite the low score, they are making progress over the years. But for most of these countries, there is a TECHCH technology loss. So, inefficient countries are confronted by technological constraints. Indeed, this technological loss is due to the low qualification of human resources according to Varela

[64] There is progress or gain when the index is greater than 1 (positive), and when it is less than 1 (negative), there is a loss or regression

et al. (2010) and the difficulties of exploiting new technologies. Moreover, Gaal et al. (2006)[65] explains that technologies in the health sector are used marginally and in urgent cases. While they should be used as a permanent health system. Again, developping countries have difficulty accessing new technologies and are slowly adapting to progress in these sectors.

Table 3: Malmquist productivity Index

Country	EFFCH	TECHCH	PECH	SECH	TFPCH	Country	EFFCH	TECHCH	PECH	SECH	TFPCH
Albania	0.992	1.001	1.000	0.992	0.993	Kyrgyz Republic	0.954	0.992	1.000	0.954	0.946
Azerbaijan	1.000	0.993	1.000	1.000	0.993	Lao PDR	1.004	1.004	1.000	1.004	1.007
Belarus	1.009	1.006	1.000	1.009	1.015	Lebanon	0.984	1.023	1.000	0.984	1.007
Benin	1.026	1.001	1.008	1.017	1.027	Madagascar	1.020	1.017	1.033	0.988	1.038
Bhutan	1.021	0.983	1.006	1.015	1.004	Maldives	0.988	1.053	1.000	0.988	1.041
Bulgaria	0.969	1.016	0.999	0.970	0.984	Mali	1.061	0.998	1.047	1.013	1.058
Burkina Faso	1.065	0.997	1.066	0.999	1.061	Mauritania	0.982	1.002	0.998	0.983	0.983
Burundi	0.970	0.995	1.006	0.964	0.966	Mauritius	0.990	0.997	1.000	0.990	0.987
Cambodia	1.022	1.017	1.013	1.008	1.038	Mexico	0.989	1.000	1.000	0.989	0.989
Cameroon	1.021	0.990	1.000	1.021	1.010	Moldova	0.966	0.999	0.995	0.971	0.965
Cape Verde	1.028	0.996	0.999	1.029	1.024	Namibia	1.008	1.035	1.000	1.008	1.043
Colombia	0.973	1.018	1.004	0.970	0.991	Nepal	1.000	0.985	1.000	1.000	0.985
Costa Rica	0.972	1.010	1.000	0.972	0.982	Niger	1.084	0.987	1.083	1.001	1.070
Cote d'Ivoire	0.999	1.001	1.008	0.991	1.000	Pakistan	1.014	1.009	1.007	1.007	1.023
El Salvador	0.958	1.026	0.998	0.960	0.983	Peru	0.983	1.009	1.000	0.983	0.992
Gambia, The	0.951	0.995	0.998	0.953	0.946	Romania	0.971	1.031	1.000	0.971	1.001
Georgia	1.000	0.995	1.000	1.000	0.995	Senegal	1.051	0.997	1.043	1.008	1.047
Ghana	0.981	0.994	1.000	0.981	0.976	Swaziland	0.986	0.990	1.006	0.979	0.975
Guyana	1.085	1.252	1.000	1.085	1.359	Togo	0.955	0.981	0.991	0.963	0.937
India	1.026	0.992	1.019	1.008	1.018	Tunisia	0.997	0.997	1.000	0.996	0.993
Indonesia	1.000	0.974	1.000	1.000	0.974	Ukraine	0.991	0.992	1.000	0.991	0.983
Iran, Islamic Rep,	0.975	1.014	1.000	0.975	0.989	**Mean**	**1.000**	**1.008**	**1.007**	**0.993**	**1.008**

5.2. Results of the Tobit Panel analysis

The results of the effect of tobit analysis are displayed in Table 4. In column 1, only ICT variable is used as the explanatory variable. The results shows that ICT investment positively affect efficiency.

[65] Cited by Hsu (2014).

But this result may suffer from omitted variables bias. In column 2, we use only variables in the literature to explain efficiency. It shows that results are in line with the literature. So, we add ICT and other variables. Column 3 show that the results do not change in terms of sign and significance.

After successively adding net official development assistance (NODA) and access to electricity (ELECT), the effect of ICT on efficiency remains significant and positive. The results in column 5 show that population density (POP) has a positive effect. POP is the number of people living per km^2. A low density means that the population is dispersed (there are few people per km). Conversely, a high density shows that the settlements are close together. Thus, public provision will benefit a larger number of people. This reduces the cost-benefit ratio for the government. In addition, it makes it easier for people to access services because they will not have to travel long distances to school or hospital. Therefore, the government will have to spend less to reach a large population. As such, population density can have a positive impact on the efficiency of public spending. Inequality index is the dispersion of income around an average considered equal. A higher value of this index indicates a high level of inequality. In fact, inequality can negatively affect access to public goods because it can be implicitly a factor of exclusion when access to health and education services is not free of charge. For the low-wage earners, it will be difficult to obtain these services if their incomes do not allow it. This will reduce their access to services (health and education in our case), thus reducing the results for these sectors and will, in turn, hurt level of performance. Hence the negative effect of inequality on the efficiency of public spending.

In this paper, we use government revenues as a budgetary constraint. Results shows that when a government mobilizes a lot of revenue, it has a positive impact on its level of efficiency. That is because they can finance more health and educational infrastructures. This increases the performances of these sectors and improves well-being of the population. Concerning the access to energy, the Results shows that access to electricity has a positive impact on the efficiency of public spending in health and education sector. In fact, access to electricity has an impact on the efficiency of health and education sector because these sectors are highly dependent on it. Because today, almost all hospitals depend on electricity to operate and to run certain machines. Ultimately, the lack of electricity leads to the unavailability of these machines and reduces the supply of care, making spending on these machines inefficient. About education, the impact depends on the need for electricity to study. This need is much greater in remote areas and limits study time available for students and teachers.

The study shows that investment in ICT goods can improve the performance of public spending on health and education. This impact can be explained on several levels. First, with the use of ICTs, public administration becomes efficient in data processing and analysis. Thereby they overcomes the difficulties of manual analysis. At the educational level, this makes it easy to follow several students, to facilitate the enrolment procedures. As we know, developing countries have overcrowded classrooms. With e-learning, which requires the availability of ICT products, this concern could be overcome by dematerializing some modules and offering distance learning. At the level of patient health, it will also be possible to have a better follow-up of the health status of patients, to reduce errors thanks to new technologies related to the health field, to have clear and detailed diagnoses and so on. Furthermore, the traceability of administrative activity through digitisation will reduce embezzlement in public services. ICT can therefore contribute to improving the accessibility and quality of supply while at the same time significantly reducing the waste of resources.

Table 4: Determinats of the efficiency of public spending on health and education

	1	2	3	4	5
ICT investment	0.0121**		0.0121**	0.00942*	0.00979**
	(2.24)		(2.43)	(1.91)	(1.99)
Log (GDP per capita)		0.103***	0.0833***	0.0243	
		(3.36)	(2.73)	(0.66)	
Population density		0.000615**	0.000613**	0.000425*	0.000411*
		(2.33)	(2.37)	(1.83)	(1.80)
Inequality		-0.00818***	-0.00854***	-0.00571*	-0.00550*
		(-2.70)	(-2.84)	(-1.93)	(-1.86)
Control of corruption		0.0306	0.0116	0.0322	0.0379
		(0.86)	(0.33)	(0.91)	(1.10)
Government revenue		0.421	0.561*	0.438	0.497*
		(1.44)	(1.94)	(1.55)	(1.86)
Log (Net aid & assistance)			0.00246	0.00323	0.00372
			(0.19)	(0.26)	(0.30)
Access to electricity				0.00249***	0.00289***
				(2.59)	(3.94)
Constant	0.975***	0.357	0.394	0.651*	0.800***
	(22.81)	(1.25)	(1.07)	(1.77)	(2.73)
Number of groups	39	39	39	39	39
Number of observations	453	453	453	453	453

t statistics in parentheses * p<0.10, ** p<0.05, *** p<0.01

6. Further analysis

In this section, we analyze the consideration of other additional parameters such as geographic location, income categories, natural resource revenues, and taxation.

For the income leve, we use World bank income group. The results in table 5 show that the effect is positive for all groups. But it is only significant for low middle-income group. This can be explained by the fact that developing countries do not have yet not only the sufficient level of digitalization to take full advantage of it, but also the question of experience counts.

Table 5: Effect of environmental variables by Income groups

	(1) Low income	(2) Low Middle-income	(3) Upper middle-income
ICT investment	0.0174	0.0296***	0.00214
	(1.41)	(4.50)	(0.65)
Log (GDP per capita)	0.837***	0.0139	-0.0146
	(3.64)	(0.30)	(-0.44)
Population density	-0.000898	0.000205	0.00117
	(-0.49)	(0.69)	(1.64)
Inequality	-0.0380***	-0.00113	-0.00460**
	(-2.78)	(-0.28)	(-2.37)
Government revenue	0.256	0.688**	-0.415**
	(0.30)	(1.99)	(-2.11)
Log (Net aid & assistance)	0.0448	-0.0300*	-0.00844
	(1.19)	(-1.76)	(-0.95)
Constant	-4.597**	1.247***	1.556***
	(-2.32)	(2.61)	(4.41)
Number of groups	9	16	14
Number of observations	106	202	179

t statistics in parentheses, * p<0.10, ** p<0.05, *** p<0.01

For the geographic analysis, we created four subsamples. These are countries in Africa, Asia, Latin America and the Caribbean (LACA), and Europe. Since we will not have enough observations if we split the database into four groups, we create dummy variables for each group. The dummy variable takes the value one when the country is ranked in the group and zero otherwise. Next, we interact each dummy variable with the ICT variable. Finally, for each group, we include the ICT variable, its interaction with the dummy variable and the dummy variable in the same equation. Table 6 presents the estimation results. The results in Table 6 show that we do not have a significant effect of ICT investment on the efficiency of public spending by geographic region, but we can see that the effects remain positive and significant for each region. These results mean that although having a positive

impact, geographic region does not matter in explaining the impact of ICT investment on the efficiency of public spending.

Table 6: Impact of ICT investment on the efficiency of public spending by geographical group

	(1) Africa	(2) Asia	(3) Europe	(4) LACA
ICT investment	0.0138**	0.0146***	0.0152***	0.0167***
	(2.18)	(2.94)	(3.04)	(2.65)
ICT investment*Africa	0.00137			
	(0.14)			
ICT investment*Asia		0.00913		
		(0.54)		
ICT investment*Europa			-0.00332	
			(-0.18)	
ICT investment*LACA				-0.00367
				(-0.36)
Africa	-0.0538			
	(-0.71)			
Asia		0.0839		
		(0.84)		
Europa			-0.0605	
			(-0.53)	
LACA				0.00944
				(0.09)
Access to electricity	0.00241**	0.00265***	0.00305***	0.00291***
	(2.57)	(3.60)	(4.00)	(3.57)
Population density	0.000451*	0.000324	0.000435*	0.000443*
	(1.93)	(1.44)	(1.81)	(1.82)
Inequality	-0.00558*	-0.00515*	-0.00717**	-0.00567*
	(-1.84)	(-1.78)	(-2.23)	(-1.72)
Government revenue	0.640**	0.725***	0.677**	0.598**
	(2.42)	(2.73)	(2.56)	(2.25)
Log (Net aid & assistance)	-0.00212	-0.00538	-0.00578	-0.00155
	(-0.16)	(-0.42)	(-0.43)	(-0.12)
Constant	0.909***	0.886***	0.983***	0.844***
	(3.02)	(3.06)	(3.13)	(2.73)
Number of groups	39	39	39	39
Number of observations	487	487	487	487

t statistics in parentheses, * p<0.10, ** p<0.05, *** p<0.01

Table 7 presents the results of the impact of ICT investments when resource revenues and taxation are included. The results suggest that resource revenues have a positive and significant effect on the

efficiency of public spending. This is because resource revenues increase the resources available to finance projects in the social sectors. This increases supply and thus improves efficiency levels. However, the opposite effect was expected because of the resource curse. As for overall tax revenues, they do not have a significant effect on the efficiency of public spending. Nevertheless, the effect of ICT remains positive and significant.

Table7:Impact of taxation and natural ressources variables on efficiency scores

	(1)	(3)	(2)
	Total tax revenue	Resource tax revenue	Total resource revenue
ICT investment	0.0139***	0.0137***	0.0156**
	(2.87)	(2.62)	(2.33)
Access to electricity	0.00293***	0.00294***	0.00355***
	(3.99)	(3.56)	(3.53)
Population density	0.000496**	0.000431*	0.000507*
	(2.03)	(1.87)	(1.66)
Inequality	-0.00510*	-0.00424	-0.00270
	(-1.73)	(-1.36)	(-0.67)
Government revenue	0.667	0.330	0.569*
	(1.37)	(1.21)	(1.69)
Log (Net aid & assistance)	-0.00284	-0.00914	-0.00160
	(-0.22)	(-0.66)	(-0.09)
Total tax revenue	-0.00150		
	(-0.27)		
Resource tax revenue		0.0311***	
		(2.75)	
Total resource revenue			0.0182***
			(2.90)
Constant	0.860***	0.970***	0.623
	(2.92)	(2.94)	(1.49)
Number of groups	39	33	23
Number of observations	479	403	252

t statistics in parentheses, * p<0.10, ** p<0.05, *** p<0.01

7. Conclusion

Lacking sufficient resources to increase the supply of health and education, developing countries must be efficient in allocating available resources. The advent of ICT is an opportunity to optimize spending in these sectors. Thus, this paper has analyzed the impact of ICT investments on the efficiency of

public spending on health and education in developing countries over the period 2000 to 2015. For this, we first used a DEA method to determine the efficiency levels of public spending on health and education. Second, using a Tobit model, we analyzed the effect of environmental variables on efficiency scores, focusing on ICT investments.

The results suggest that developing countries can increase their efficiency level by 7% without changing the level of expenditures. Compared to previous studies, this result is a sign of progress. However, LICs and African countries have the lowest efficiency levels. This indicates an estimated 17.7 percent waste of public expenditure for LICs. Moreover, the average productivity gain is only 0.8 percent. In the second stage, the results suggest that investment in ICT can help increase the efficiency of public spending. We also find that resource revenues positively affect efficiency.

Based on the results of our study, it is advisable for developing countries to invest in ICT to increase efficiency levels in the health and education sectors. LICs, on the other hand, should focus on improving access to electricity and increasing available resources. Nevertheless, access to and use of ICTs can be a way to improve their resource mobilization strategies to increase available resources.

Appendix

Table A.1: Country list

Country	Region	Income group	Country	Region	Income group
Albania	Europe	Upper-middle income	Iran, Islamic Rep.	Asia	Upper-middle income
Azerbaijan	Europe	Upper-middle income	Kyrgyz Republic	Asia	Lower-middle income
Belarus	Europe	Upper-middle income	Lao PDR	Asia	Lower-middle income
Benin	Africa	Low income	Lebanon	Asia	Upper-middle income
Bhutan	Asia	Lower-middle income	Madagascar	Africa	Low income
Bulgaria	Europe	Upper-middle income	Maldives	Asia	Upper-middle income
Burkina Faso	Africa	Low income	Mali	Africa	Low income
Burundi	Africa	Low income	Mauritania	Africa	Lower-middle income
Cambodia	Asia	Lower-middle income	Mauritius	Africa	Upper-middle income
Cameroon	Africa	Lower-middle income	Mexico	Latin America and the Caribbean	Upper-middle income
Cape Verde	Africa	Lower-middle income	Moldova	Europe	Lower-middle income
Colombia	Latin America and the Caribbean	Upper-middle income	Namibia	Africa	Upper-middle income
Costa Rica	Latin America and the Caribbean	Upper-middle income	Nepal	Asia	Low income
Cote d'Ivoire	Africa	Lower-middle income	Niger	Africa	Low income
El Salvador	Latin America and the Caribbean	Lower-middle income	Pakistan	Asia	Lower-middle income
Gambia, The	Africa	Low income	Peru	Latin America and the Caribbean	Upper-middle income
Georgia	Europe	Lower-middle income	Romania	Europe	Upper-middle income
Ghana	Africa	Lower-middle income	Senegal	Africa	Low income
Guyana	Latin America and the Caribbean	Upper-middle income	Swaziland	Africa	Lower-middle income
India	Asia	Lower-middle income	Togo	Africa	Low income
Indonesia	Asia	Lower-middle income	Tunisia	Africa	Lower-middle income
			Ukraine	Europe	Lower-middle income

Table B.1: Description of variables

VARIABLES	Description	Source
General government health spending as a percentage of GDP (GGHE)	Health spending in GDP committed at all levels of government	World health organization NHA indicators.
Domestic government spending on education as a percentage of GDP (GGEE)	Education spending in GDP committed at all levels of government	Unesco institute for statistics (UIS)
Pupils-Teacher ratio (PTRP)	Average number of pupils per primary school teacher	
Primary completion rate (PCR)	New entrants in the last grade of primary, relative to the population in age.	
Secondary general pupils (SEGP)	Secondary students in general education, including teacher training	
ICT goods Import (ICT)	ICT goods imports (% total goods imports)	World Development Indicators (WDI)
Immunization, DPT	Percentage of children ages who received DPT vaccinations before 12 months	
Infant mortality rate (IMRT)	Infants who died before the age of one	
Life expectancy at birth (LEXB)	Years that a newborn can expect to live	
Population density (POP)	Population density (people per sq. km of land area)	
GDP per capita	GDP per capita, PPP (constant 2011 international $)	
Access to electricity (ELECT)	Access to electricity (% of population)	
Aid and assistance (NDAO)	Net official development assistance and aid received (constant 2015 US$)	
Inequality index (SWIID)	Standardized World Income Inequality Database	Standardized World Income Inequality Database
Technical efficiency (VRSE)	Variable return to scale technical efficiency	Author computation
Control of corruption (COR)	Assessment of corruption within the political system	International Country Risk Guide (ICRG)
Government total revenue (MOB)	Revenue excluding grants and social contributions	ICTD / UNU- WIDER Government Revenue Dataset 2017
Resource tax revenue	Tax revenue from natural resource	
Total resource revenue	Total revenue from natural resource	
Total tax revenue	Total tax revenue excluding grant and social contribution	

Source: Author construction with 2018 data from WDI, ICRG, ICTD, WHO and UIS databases

Table C.1: Efficiency tables for all countries from 2000 to 2015

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Albania	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Azerbaijan	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Bhutan	0.908	0.855	0.828	0.947	0.868	0.959	0.963	0.947	0.96	0.921	0.895	0.948	0.979	0.982	1.000	1.000
Bulgaria	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.989	1.000	1.000	1.000	1.000	1.000	0.992	0.99
Burundi	0.855	0.812	0.819	0.906	0.803	0.875	0.928	1.000	0.908	0.934	0.966	0.96	0.96	1.000	1.000	0.934
Belarus	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Cambodia	0.821	0.688	0.893	0.811	0.975	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Cameroon	1.000	0.726	0.67	0.858	0.871	1.000	1.000	1.000	1.000	1.000	1.000	0.846	1.000	1.000	1.000	1.000
Cape Verde	1.000	0.985	1.000	1.000	0.982	0.955	0.996	0.997	1.000	1.000	1.000	1.000	1.000	1.000	0.998	0.992
Colombia	0.948	0.934	0.939	0.977	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Costa Rica	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Benin	0.884	0.805	0.8	0.88	0.803	0.785	0.773	0.932	0.844	0.826	0.856	0.74	0.84	0.777	0.915	1.000
El Salvador	1.000	0.953	0.897	0.958	0.913	0.943	0.982	1.000	0.987	0.978	1.000	1.000	1.000	1.000	1.000	0.966
Georgia	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Gambia, The	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.96	0.987	1.000	0.963	0.987	1.000	0.967	0.973
Ghana	1.000	0.81	0.867	0.908	0.93	0.823	0.819	0.935	0.921	0.934	0.934	0.896	0.949	0.96	1.000	1.000
Guyana	1.000	0.874	0.895	0.882	0.895	0.926	0.958	0.955	0.978	1.000	1.000	1.000	1.000	1.000	1.000	1.000
India	0.759	0.872	0.822	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.986	0.956	0.944	1.000	1.000	1.000
Indonesia	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Iran, Islamic Rep.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Cote d'Ivoire	0.73	0.891	0.752	0.736	0.764	0.907	0.922	0.828	0.792	0.881	1.000	0.584	0.866	0.74	0.743	0.817
Kyrgyz Republic	1.000	1.000	0.991	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.996	0.972	1.000	1.000	1.000
Lao PDR	1.000	0.698	0.683	0.718	0.906	0.794	0.881	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Lebanon	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Madagascar	0.5	0.51	0.569	0.616	0.784	0.856	0.841	0.807	0.718	0.763	0.71	0.727	0.814	0.888	0.789	0.811
Maldives	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Mali	0.332	0.426	0.58	0.597	0.628	0.744	0.747	0.677	0.742	0.797	1.000	0.681	1.000	0.745	0.637	0.658
Mauritania	0.695	1.000	0.986	0.905	0.87	0.796	0.744	0.764	0.726	0.685	0.722	0.767	0.849	0.799	0.804	0.678
Mauritius	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Mexico	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.988	1.000	1.000	1.000	1.000
Moldova	0.993	0.988	0.984	1.000	0.987	1.000	0.986	0.955	0.937	0.94	0.936	0.936	0.919	0.931	0.928	0.923
Namibia	0.907	0.933	0.919	0.922	0.844	0.844	0.829	0.831	0.791	0.834	0.808	0.826	0.848	0.877	0.869	0.912
Nepal	1.000	1.000	0.835	1.000	1.000	0.976	1.000	1.000	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Niger	0.215	0.231	0.264	0.326	0.358	0.362	0.401	0.45	0.578	0.632	0.659	0.692	0.667	0.634	0.714	0.708
Pakistan	0.897	1.000	0.917	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.953	0.947	1.000	1.000	1.000
Peru	1.000	0.979	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.975	0.981	0.959	0.995
Romania	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.988	1.000	0.985	0.996	1.000	0.992	1.000	1.000	1.000
Senegal	0.497	0.493	0.548	0.682	0.883	0.823	0.884	0.942	0.855	0.838	0.996	0.954	0.975	0.991	0.932	0.928
Swaziland	0.802	0.802	0.815	0.815	0.828	0.833	0.841	0.841	0.855	0.855	0.868	0.895	0.947	0.987	0.987	0.882
Togo	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.906	0.91	0.813	0.835	0.849	0.837	0.844	0.886	0.88
Tunisia	0.994	1.000	0.972	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.982	1.000	1.000	1.000
Ukraine	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.987	0.948	0.967	0.964	0.977	1.000	1.000	1.000
Burkina Faso	0.355	0.619	0.685	0.91	0.751	0.867	0.864	0.875	0.921	0.908	0.978	0.927	0.966	0.874	0.918	0.926

Source : Author Calculation

PART III: NEW PAYMENT METHODS AND TRADE FACILITATION: CASE OF MOBILE MONEY SERVICES

Chapter V: Mobile Money for Merchant Payments: A boost for south-south trade?

This chapter is a joint paper with Fayçal SAWADOGO

Abstract: This article investigates the effect of Mobile money for merchant payment (MPAY) on goods trade between developing countries. We use data for 120 developing countries between 1994 and 2018. The propensity score matching methodology is adopted for estimation as main strategy in addition to entropy balancing and General Moment Method (GMM). We find that trade in goods has increased by about 0.63% of GDP compared to those who have not adopted MPAY. This effect is higher for primary commodities and food products. The results of the study are not sensitive to the alternative matching method -entropy balancing- we used. Finally, when we treat the endogeneity while considering the panel structure of the data using the GMM method, the results do not change.

Keywords: Merchant payment; Goods trade; PSM; developing countries

JEL classification : F10, O23, O33, O55.

Résumé : Cette étude analyse l'effet du Mobile Money utilisé pour le paiement marchand (MPAY) sur le commerce de marchandises entre les pays en développement. Nous utilisons des données pour 120 pays en développement entre 1994 et 2018. La méthodologie d'appariement des scores de propension (PSM) est adoptée pour l'estimation comme stratégie principale en plus de entropy balancing et de la méthode des moments généraux (GMM). Nous constatons que le commerce des biens a augmenté d'environ 0,63 % du PIB par rapport à ceux qui n'ont pas adopté la MPAY. Cet effet est plus élevé pour les produits primaires et les produits alimentaires. Les résultats de l'étude ne sont pas sensibles à la méthode d'appariement alternative -l'équilibrage de l'entropie- que nous avons utilisée. Enfin, lorsque nous traitons l'endogénéïté en considérant la structure de panel des données par la méthode GMM, les résultats ne changent pas.

Mots-clés : Paiement marchand ; Commerce de marchandises ; PSM ; pays en développement

Classification JEL: F10, O23, O33, O55.

1. Introduction

Trade between developing countries, although increasing since the 1990s, still faces many obstacles. One of the main barriers to South-South Trade (SST) is related to limited market access due to the low financial development of developing countries. In fact, in most of these countries, the great majority of the population is rationed from the traditional financial system. This lack of access to financial services therefore limits market access and thus trade. Therefore, improving financial development could have a positive impact on International trade (Hajilee and Niroomand, 2019; Sun and Muganyi, 2019; Hur et al., 2006). Moreover, Niroomand et al. (2014), shows in a sample of 18 emerging countries, that financial market inclusion promotes trade openness. In addition, Demir and Dahi (2011) argue that financial development promotes SST more than South-North trade. Indeed, these studies show that financial market inclusion (financial inclusion) as well as financial development has a greater effect on international trade or trade openness in developing countries. This can be explained by two aspects. First, it may be due to the fact that financial inclusion is itself a very important aspect of financial development and leads to financial development. Second, financial inclusion has the advantage of providing to the large majority of the population rationed from the conventional banking system, financial services that are easily accessible, readily available, and at low cost. A concrete example is the Mobile Money system.

Mobile money (MM) is a payment system that allows, from a cell phone and an account, to make financial transactions. The account is debited from another phone, a bank card, or simply by cash with an agent. Introduced in 2002 by the operator Yandex in Russia, MM earned interest faster than expected, especially in developing countries. Today, MM has spread all over the world and offers a variety of services. It enables domestic transfers (P2P transfer), bill payment, transfer of people to and from the government, airtime top-up, international remittances, cash outflows and inflows or even merchant payments. In this study, we are particularly interested in merchant payment (MPAY) which is a MM service used for trade and commercial transactions. Indeed, MPAY is a MM service that allows you to make a payment from a mobile money account via a mobile money platform to a retailer or online merchant in exchange for goods or services.

2. Data and methodology

2.1. Data and description

In this study, we use data from 120 countries over the period 1999 to 2018. The choice of countries as well as the period is based on the availability of data on trade and control variables. Our main explanatory variable is MPAY, which we constructed using information collected from GSMA. MPAY is a dummy variable that takes the value 1 if there is a MPAY in the country and zero otherwise. Country list including year of MPAY adoption is presented in appendix A in appendix. The dependent variables are total goods trade, total goods imports, total goods exports, and their breakdown into types of goods, in particular primary commodities, agricultural raw materials, and food products.[66] Moreover, based on previous studies (Sawadogo and Wandaogo, 2021;) we retain a set of variables that simultaneously explain MPAY adoption and trade value. These variables include total population, GDP per capita, financial development, inflation rate, natural resources rents and monetary exchange system. Excluding exchange system which we constructed using International Monetary Fund (IMF) information on exchange rates classification, the rest of control variables are from World Bank database on World Development Indicators (WDI). We display variable descriptions and give sources in appendix B.

As we can see from appendix C, developing countries have an average total trade value of about 107 per cent of GDP over the period 1999 to 2018. This is equivalent to an average value of about $67.7 billion. China is the most important partner in the trade of goods between developing countries with a share of 1.92% ($1.303 billion) followed by India with 0.42% ($0.29 billion). The African country with the highest value of trade in goods between developing partners is South Africa in 12th position with an average total value of 65.05 billion dollars, i.e. 0.10%, while Brazil is in 6th position with 0.23%, followed by Russian federation with 0.2% of total trade value in share of GDP. In addition, we can remark that agricultural raw materials account only 2,51 % of GDP (this can be explained by the fact that most developing countries are not industrialized and

[66] Trade data are in share of GDP. We also retain them in logarithm form for interpretation purposes.

therefore do not transform raw materials into finished products) while primary commodities and food items are respectively valued at 19% and 11% of GDP.

2.2. Identification strategy

To address the causal effect of the adoption of MPAY on the volume of trade between developing countries, we apply the Propensity Score Matching (PSM) method according to Sawadogo and Wandaogo (2021), Girma, S. et al. (2003), and Wagner, J. (2002). Developed by Rosenbaum and Rubin (1983), the PSM is adapted to non-randomized studies. It permits to correct sample selection bias because there will be differences between the control group (Non adopters) and the treatment group (adopters). Implementing the PSM methods requires three steps.

First, we estimate the propensity score (PS), which measures the probability that a country will adopt MPAY given the basic characteristics (covariates) likely to influence the adoption decision and trade between developing countries. Considering Y_i as the basic characteristics of country i, MPAY the treatment variable, we can write PS as follows:

$$PS_i = P(MPAY_i = 1|Y_i) \qquad (1)$$

In fact, PS concentrates the information contained in the covariates within a single variable. In the next part of our work, we will call it $\delta(Y_i)$.

After estimating $\delta(Y_i)$, we match adoption countries with peers with similar characteristics but who have not adopted MPAY. This means that they have relatively similar $\delta(Y_i)$ values.

Finally, based on the equations below, we estimate the Average Treatment effect on Treated (ATT) which is the average difference between South-South Trade (ST) for a country *i* that adopted MPAY (ST_i^1) and those it would have if it had not adopters (ST_i^0). Equation (2) provides the mathematical expression of ATT.

$$ATT = E(ST_i^1 \big| MPAY_i = 1) - E(ST_i^0 \big| MPAY_i = 1) \qquad (2)$$

However, according to Heckman et al. (1998), Dehejia and Wahba (2002) and Lin and Ye, (2007), there will be a self-selection bias in the exposition of the treatment (MPAY adoption in our study). In fact, the MPAY adoption may not be random but correlated with a set of observable characteristics. To overcome this limitation, we replace the last term of previous equation (ST_i^0)

with ST of non-adopters MPAY countries that have similar $\delta(Y_i)$ with an adopter, because this term is not observable. We then rewrite the equation as below:

$$ATT = E\left[ST_i^1 \middle| MPAY_i = 1, \delta(Y_i)\right] - E\left[ST_i^0 \middle| MPAY_i = 0, \delta(Y_i)\right] \quad (3)$$

Indeed, to estimate ATT, we use a set of matching methods existing in the literature. We first considered nearest neighbor matching with respectively n=1, 2, and 3. This method consists in matching each MPAY adopter with the non-adopter with closest PS. We also consider radius matching (Dehejia and Wahba, 2002) with retaining a PS radius of 0.005, 0.01, and 0.05. in addition, we use Kernel estimator (Heckman et al., 1997, 1998) consisting in matching each MPAY adopter with a weighted average of all non-. Finally, we compute a local linear regression (Heckman et al.1997, 1998). According to Fan, 1993, the last one is an improvement of kernel estimator by adding a linear term in the weighting function.[67]

In addition, we implement several statistical tests to confirm the quality of the matching. The Pseudo R2 to examine the extent to which the control variables explain the probability of exposure to the treatment, which in our case is the adoption of MPAY (Sianesi, 2004). Moreover, we report the standardized bias and the bound sensitivity test to verify the hypothesis of conditional independence regarding observables and non-observables (Rosenbaum, 2002).

3. Empirical results

3.1. Propensity scores estimation

To estimate the PS, we choose a set of variables that simultaneously effect MPAY adoption and trade. We retain population, GDP per capita, financial depth, inflation rate, natural resource rents and exchange regime. Using a probit model, we estimate the probability of adopting MPAY based on the set of baseline conditions.

The PS result is presented in table 5. It suggests that High population and natural resources favorize MPAY adoption while Inflation and GDP per capita negatively affect it adoption. In fact, having

[67] see Imbens (2004), Smith and Todd (2005) and Caliendo & Kopeinig (2008) for more detail about matching methods.

many potential users for a technology would increase the likelihood of adoption due to the underlying network effect. In addition, the size of the population would reduce the cost of deploying the service, which would further encourage the introduction of the service and thus the likelihood of adoption. Regarding natural resources, they have a positive effect on the likelihood of MPAY adoption because in developing countries rich in natural resources, there is a high level of traditional and clandestine exploitation of resources by the populations. In addition to being poor and lacking access to mainstream banking services, these exploited areas are poorly served by financial services. This creates the need for an alternative that is more accessible to everyone and everywhere. As for the negative effect of inflation and GDP per capita, the first is explained by the fact that inflation reduces demand through higher prices, which could discourage the adoption of new payment methods. The other may be due to the fact that high-income individuals already have access to the mainstream banking system and therefore do not necessarily need alternative means of payment, including mobile payments, which they may consider risky for them. Finally, the results show that financial development as well as the exchange rate regime do not have significant effects on the probability of MPAY adoption. However, Sawadogo and Wandaogo (2021) had found that these two factors increase the likelihood of adoption of general mobile money services in African countries.

Table 1: Propensity scores estimation results

	mm merchant payment
log (total population)	0.1599***
	(0.0180)
log(gdp per capita)	-0.1421***
	(0.0363)
Financial depth	0.0016
	(0.0013)
inflation	-0.0271***
	(0.0059)
Natural resources rents	0.0054*
	(0.0028)
Fixed regime	-0.0555
	(0.0741)
Constant	-1.9909***
	(0.4272)
Observations	1926
Pseudo-R2	0.07

Note: Robust tandard errors are in parentheses.
* p < 0.10, ** p < 0.05, *** p < 0.01.

3.2. Matching results

The matching results are displays in table 2 to table 4. All statistical tests confirm the validity of the results of the PSM estimations. Indeed, all the Pseudo-R2 are lower than 0.01 which is according to Caliendo and Kopeinig (2008) a guarantee of a good quality matching because a good matching must have relatively low Pseudo-R2. The results in table 2 suggest that adopting Mobile Money services for trades transactions increase trade volume in developing countries that adopted it, as the ATT is positive and significant at 1% level. It shows that, on average, developing countries that have adopted the MPAY see their trade in goods rise among members by about 0.617 percent of GDP. When disaggregated by type of good, we find that food products are the most affected by the adoption of MPAY with an average effect of 0.6608. Sawadogo and Wandaogo (2021) explain that since food products are produced in rural areas by populations that are rationed from the traditional financial system, the MM would allow them to open to external partners at a lower cost. This is followed by primary commodities (0.658). These two effects are very close, even more so since the products of first necessity include a part of food products.

Table 2: Matching results for Log (Total goods trade/GDP)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treatment Variable : MPAY	**1-Nearest Neighbor Matching**	**2-Nearest Neighbor Matching**	**3-Nearest Neighbor Matching**	**Radius Matching**			**Local linear regrssion Matching**	**Kernel Matching**
				r=0.005	**r=0.01**	**r=0.05**		
				Total trade				
Average Treatment on the Treated	0.6117***	0.6180***	0.5991***	0.6058***	0.6005***	0.6344***	0.6340***	0.6295***
	(0.0862)	(0.0771)	(0.0725)	(0.0525)	(0.0476)	(0.0399)	(0.0406)	(0.0409)
Average Trearment Effect	1.5612***	1.5612***	1.5612***	1.5612***	1.5612***	1.5612***	1.5612***	1.5612***
	(0.0837)	(0.0861)	(0.0843)	(0.0875)	(0.0860)	(0.0850)	(0.0866)	(0.0855)
Observations/Treated	1925/541							
	Quality of the matching							
Pseudo_R2	0.006	0.007	0.005	0.004	0.003	0.002	0.006	0.002
Rosembaum bounds sensitivity test	2.4	3.1	3.1	3.9	4.1	4.4	4.5	4.4
Standardized bias (p-value)	0.211	0.123	0.325	0.416	0.584	0.789	0.211	0.788
	Primary commodities							
Average Treatment on the Treated	0.6225***	0.6367***	0.6299***	0.6541***	0.6539***	0.6907***	0.6948***	0.6859***
	(0.0900)	(0.0791)	(0.0676)	(0.0522)	(0.0501)	(0.0414)	(0.0431)	(0.0434)
Average Trearment Effect	1.6137***	1.6137***	1.6137***	1.6137***	1.6137***	1.6137***	1.6137***	1.6137***
	(0.0816)	(0.0824)	(0.0784)	(0.0816)	(0.0840)	(0.0828)	(0.0863)	(0.0789)
	All foods items							
Average Treatment on the Treated	0.6301***	0.6381***	0.6379***	0.6561***	0.6565***	0.6898***	0.6914***	0.6861***
	(0.0916)	(0.0787)	(0.0727)	(0.0553)	(0.0493)	(0.0440)	(0.0480)	(0.0435)
Average Trearment Effect	1.5840***	1.5840***	1.5840***	1.5840***	1.5840***	1.5840***	1.5840***	1.5840***
	(0.0818)	(0.0837)	(0.0865)	(0.0822)	(0.0793)	(0.0788)	(0.0800)	(0.0875)
	Agricultural raw materials							
Average Treatment on the Treated	0.5612***	0.6037***	0.5750***	0.5866***	0.5713***	0.6436***	0.6344***	0.6357***
	(0.1170)	(0.1054)	(0.1066)	(0.0816)	(0.0745)	(0.0629)	(0.0733)	(0.0714)
Average Trearment Effect	1.7259***	1.7259***	1.7259***	1.7259***	1.7259***	1.7259***	1.7259***	1.7259***
	(0.1027)	(0.1007)	(0.0972)	(0.1068)	(0.1028)	(0.1020)	(0.1078)	(0.1056)

Note: Standard errors are in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01.

We then analyze by trade type. That is, imports and exports. The results in Tables 3 and 4 show that the adoption of MPAY affects both imports and exports of goods because the coefficients are positive and significant at the 1% level. The ATTs are 0.65 for imports (table 3) and 0.61 for exports (table 4) respectively. The adoption of MPAY thus has a higher effect on imports than on exports of goods between developing countries. This is simply because developing countries are mostly importers of manufactured goods and exporters of raw materials. Moreover, the effect on the different components shows that the adoption of MPAY favors food imports and exports the most, followed by primary commodities and then agricultural raw materials.

Table 3: Matching results for Log (Total goods imports/GDP)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treatment Variable : MPAY	**1-Nearest Neighbor Matching**	**2-Nearest Neighbor Matching**	**3-Nearest Neighbor Matching**	**Radius Matching**			**Local linear regrssion Matching**	**Kernel Matching**
				r=0.005	**r=0.01**	**r=0.05**		
				Total imports				
Average Treatment on the Treated	0.6438***	0.6404***	0.6264***	0.6358***	0.6311***	0.6691***	0.6549***	0.6642***
	(0.0837)	(0.0776)	(0.0668)	(0.0539)	(0.0474)	(0.0415)	(0.0428)	(0.0398)
Average Trearment Effect	1.5449***	1.5449***	1.5449***	1.5449***	1.5449***	1.5449***	1.5449***	1.5449***
	(0.0826)	(0.0858)	(0.0869)	(0.0818)	(0.0831)	(0.0811)	(0.0818)	(0.0870)
Observations/Treated				1925/541				
				Quality of the matching				
Pseudo_R2	0.006	0.007	0.005	0.004	0.003	0.002	0.006	0.002
Rosembaum bounds sensitivity test	2.5	3.1	3.2	4.2	4.4	4.8	4.5	4.4
Standardized bias (p-value)	0.211	0.123	0.325	0.416	0.584	0.789	0.211	0.788
				Primary commodities				
Average Treatment on the Treated	0.5664***	0.5883***	0.5857***	0.6014***	0.6055***	0.6401***	0.6306***	0.6356***
	(0.0857)	(0.0788)	(0.0710)	(0.0520)	(0.0490)	(0.0400)	(0.0404)	(0.0432)
Average Trearment Effect	1.5103***	1.5103***	1.5103***	1.5103***	1.5103***	1.5103***	1.5103***	1.5103***
	(0.0828)	(0.0774)	(0.0855)	(0.0828)	(0.0757)	(0.0836)	(0.0806)	(0.0858)
				All foods items				
Average Treatment on the Treated	0.6048***	0.6275***	0.6271***	0.6474***	0.6553***	0.6887***	0.6890***	0.6847***
	(0.0848)	(0.0754)	(0.0659)	(0.0532)	(0.0491)	(0.0433)	(0.0414)	(0.0406)
Average Trearment Effect	1.5361***	1.5361***	1.5361***	1.5361***	1.5361***	1.5361***	1.5361***	1.5361***
	(0.0795)	(0.0786)	(0.0860)	(0.0771)	(0.0838)	(0.0794)	(0.0794)	(0.0771)
				Agricultural raw materials				
Average Treatment on the Treated	0.5006***	0.4670***	0.4461***	0.5005***	0.4965***	0.5398***	0.4927***	0.5346***
	(0.1257)	(0.1185)	(0.1046)	(0.0819)	(0.0768)	(0.0654)	(0.0630)	(0.0661)
Average Trearment Effect	1.5605***	1.5605***	1.5605***	1.5605***	1.5605***	1.5605***	1.5605***	1.5605***
	(0.1090)	(0.1072)	(0.1143)	(0.1075)	(0.1204)	(0.1095)	(0.1080)	(0.1103)

Note: Standard errors are in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01.

The Average Treatment effect ATE shows the effect that the treatment has on the whole sample (i.e., adopters and non-adopters). In the results presented above, it appears that the adoption of MPAY increases trade in goods between developing countries by an average of 1.5612%. In contrast to the ATT, the ATE shows that the adoption of MPAY affects more exports of goods with an effect of 1.7019 than imports (ATE=1.549).

Table 4: Matching results for Log (Total goods exports/GDP)

Treatment Variable : MPAY	(1) 1-Nearest Neighbor Matching	(2) 2-Nearest Neighbor Matching	(3) 3-Nearest Neighbor Matching	(4) Radius Matching r=0.005	(5) Radius Matching r=0.01	(6) Radius Matching r=0.05	(7) Local linear regrssion Matching	(8) Kernel Matching
				Total exports				
Average Treatment on the Treated	0.6015***	0.6235***	0.5983***	0.5988***	0.5907***	0.6206***	0.6493***	0.6160***
	(0.1166)	(0.0960)	(0.0935)	(0.0681)	(0.0601)	(0.0512)	(0.0523)	(0.0537)
Average Trearment Effect	1.7019***	1.7019***	1.7019***	1.7019***	1.7019***	1.7019***	1.7019***	1.7019***
	(0.0987)	(0.0983)	(0.0970)	(0.1015)	(0.1051)	(0.1033)	(0.1022)	(0.0997)
Observations/Treated				1925/541				
				Quality of the matching				
Pseudo_R2	0.006	0.007	0.005	0.004	0.003	0.002	0.006	0.002
Rosembaum bounds sensitivity test	1.85	2.35	2.4	2.75	2.8	3	3.15	2.95
Standardized bias (p-value)	0.211	0.123	0.325	0.416	0.584	0.789	0.211	0.788
				Primary commodities				
Average Treatment on the Treated	0.7698***	0.7644***	0.7689***	0.8005***	0.7892***	0.8301***	0.8483***	0.8253***
	(0.1228)	(0.1110)	(0.1002)	(0.0794)	(0.0759)	(0.0621)	(0.0685)	(0.0650)
Average Trearment Effect	1.8347***	1.8347***	1.8347***	1.8347***	1.8347***	1.8347***	1.8347***	1.8347***
	(0.0931)	(0.0955)	(0.0932)	(0.1007)	(0.0970)	(0.1013)	(0.0969)	(0.0988)
				All foods items excluding fuel				
Average Treatment on the Treated	0.8319***	0.7806***	0.8229***	0.8447***	0.8340***	0.8581***	0.8685***	0.8569***
	(0.1479)	(0.1396)	(0.1156)	(0.0875)	(0.0845)	(0.0755)	(0.0718)	(0.0744)
Average Trearment Effect	1.8566***	1.8566***	1.8566***	1.8566***	1.8566***	1.8566***	1.8566***	1.8566***
	(0.1006)	(0.1036)	(0.1019)	(0.1053)	(0.1135)	(0.0980)	(0.1091)	(0.1008)
				Agricultural raw materials				
Average Treatment on the Treated	0.6397***	0.6468***	0.6346***	0.6954***	0.6731***	0.7739***	0.8031***	0.7631***
	(0.1551)	(0.1499)	(0.1388)	(0.1089)	(0.1005)	(0.0948)	(0.0974)	(0.0928)
Average Trearment Effect	2.1027***	2.1027***	2.1027***	2.1027***	2.1027***	2.1027***	2.1027***	2.1027***
	(0.1386)	(0.1315)	(0.1303)	(0.1360)	(0.1323)	(0.1320)	(0.1321)	(0.1277)

Note: Standard errors are in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01.

4. Further analysis

4.1. Heterogeneity

As in all studies with heterogeneous samples, it is to be expected that the results may differ according to the characteristics of the different groups. Therefore, the heterogeneity analyses are also performed to test whether the effect of MPAY on goods trade differs across income groups, or geographic regions. For this purpose, the database has been divided into sub-samples according to each country's continent and to World Bank income group 2019-2020. We use for the heterogeneity analysis, a control function regression methodology (Lin and Ye, 200) developed by Wooldrige (2002). The methods consist in including the PS score firstly estimated and the MPAY variable in an Ordinary Last Square (OLS) regression.

4.1.1. By income group

The heterogeneity by income groups confirms that MPAY adoption positively and significantly effect goods trade in developing countries. The size of the effect is inversely proportional to the

level of income. In low-income countries, the adoption of MPAY has an effect of 0.91 percent on total trade in goods as a percentage of GDP. While it is 0.75 percent for lower-middle income countries and 0.57 percent for upper-middle income countries. One possible explanation for these results is that as people's income increases, they have more access to traditional financial services. Indeed, MPAY is used much more by individuals who do not have access to these services, represented more by low-income groups.

Table 5: Effect of MPAY on south)-south trade by income group

Dependant variable : log(total trade/GDP)	(1) Low income	(2) Lower middle income	(3) Upper middle income
MPAY	0.9179***	0.7509***	0.5715***
	(0.0706)	(0.0720)	(0.0616)
PSCORE	1.3654*	0.4553	2.0287*
	(0.7626)	(0.6416)	(1.0679)
Constant	6.9682***	7.3096***	6.3339***
	(0.2470)	(0.1865)	(0.2454)
Observations	425	733	767
R-Squared	0.45	0.30	0.18

Notes : Robust standard errors are in parentheses. *p<0.10, **p<0.05, ***p<0.01

4.1.2. By socio-economic indicators

Furthermore, we investigate heterogeneity through a set of socio-economic indicators. We are interested in the financial sector rate, social inclusion, and social conditions. We chose these variables as a proxy for financial inclusion.

We find that in countries with a less developed financial sector, the impact of MPAY on goods trade is greater (0.87) than countries with most developed financial sector rate (0.68). As we explained earlier, as people's income level increases, they will tend to turn to more sophisticated payment systems, and MPAY is suitable for economies with poor financial systems.

As for social inclusion, the results in table 6 columns 3 and 4, suggest that the countries with less social inclusion index know a greater effect of MPAY (0.79) adoption on goods trade than countries that are more included socially (0.74).

Regarding social conditions, the result is similar as for social inclusion and financial sector rate. MPAY adoption has greater effect on goods trade in countries with low social conditions more

than countries with higher social condition. The effect in the first group is 0.82 percent while it is 0.71 percent in the second.

These results confirm that the effect of MPAY adoption on South-South trade in goods is through financial inclusion and increasing the rate of financial sector development.

Table 6: Effect of MPAY on south-south trade by socio-economic indicators

Dependant variable : log(total trade/GDP)	(1) Low financial sectore rate	(2) High finacial sectore rate	(3) Low social inclusion	(4) High social inclusion	(5) Low Social condition	(6) High Social condition
MPAY	0.8694***	0.6823***	0.7924***	0.7442***	0.8192***	0.7129***
	(0.0543)	(0.0569)	(0.0593)	(0.0530)	(0.0539)	(0.0605)
PSCORE	1.5964***	0.3899	1.8453***	0.6677	1.4566**	0.7950
	(0.5720)	(0.7907)	(0.4695)	(0.7054)	(0.5975)	(0.7363)
Constant	6.6238***	7.1260***	6.2061***	7.1381***	7.2439***	6.7400***
	(0.1670)	(0.2082)	(0.1299)	(0.1930)	(0.1825)	(0.1902)
Observations	653	1272	442	1483	606	1319
R-Squared	0.38246	0.24614	0.33207	0.29046	0.44807	0.22741

Notes : Robust standard errors are in parentheses. *p<0.10, **p<0.05, ***p<0.01

4.1.3. By adoption conditions

Table 7: Effect of MPAY by adoption conditions

Dependent variable: log (total trade/GDP)	(1) No control	(2) Self-selectivity	(3) Adoption preconditions	(4) Experience
MPAY	0.8528***	0.7552***	0.7154***	0.6300***
	(0.0340)	(0.0426)	(0.0451	(0.0484)
PSCORE		1.1840	1.0137**	1.0973**
		(0.4734)	(0.4908)	(0.4868)
MPAY*(PS-$\overline{PS}$)			0.9861***	
			(0.3679)	
MPAY*time				0.0290***
				(0.0073)
Constant	6.9421***	6.8560***	6.9006***	6.8758***
	(0.0077)	(0.1294)	(0.1342)	(0.1329)
Observations	2563	1925	1925	1925
R-Squared	0.25	0.30	0.31	0.31

Notes: Robust standard errors are in parentheses. *p<0.10, **<0.05, ***p<0.01

In order to test the effect of MPAY on south-south trade by considering adoption conditions, we perform additional analyze using control function. In column 1, MPAY is regressed on total trade to GDP. The result is positive and significant. In column 2, we control for self-selection by adding the PS score estimated from column 1. the presence of self-selection bias in the model, justifying the use of PSM. The coefficient estimate is significant at 1% level and equal to 0.76 percentage point of GDP. This is high than previous result. Controlling self-selectivity enhance the estimate

results. Result in column 3 suggest that countries that meet the adoption preconditions before adopting MPAY have higher effects than others. Finally, the longer a country has adopted, the higher the effect compared to countries with fewer years of adoption (column 4).

4.2. Alternatives matching method

We now estimate an entropy balancing method (Hainmueller, J. 2012 and Hainmueller, J., & Xu, Y. 2013) to test the robustness of the results to alternative matching method. It consists of reweighting the covariates to rebalance the control group relative to the treatment group. We first estimate the weighting variable, and then evaluate the effect of the MPAY variable on the intensity of South-South goods trade using weighted least squares estimations. Table 8 shows the result of the synthetic control group construction. The estimated results are presented in tables 9 to 11. The results are substantially similar to those of the PSM. This confirms the robustness of the results and its non-sensitivity to the method of analysis.

4.2.1. Building control group

Table 8: Building the synthetic control group

	(1) A **MPAY**	(2) B **Non-MPAY**	(3) C=A-B **Difference**	(4) D **P_value**	(5) E **Webal*Non-MPAY**	(6) F=A-E **difference**	(7) G **P_value**
log (total population)	34.12145	33.25963	0.86182	0.527	34.12118	0.00027	1.000
log(gdp per capita)	16.63848	15.60847	1.03001	0.000	16.63847	0.000009	1.000
Financial depth	7.503446	7.742771	-0.239325	0.000	7.503443	0.000003	1.000
inflation	5.493279	7.548515	-2.055236	0.000	5.493579	-0.0003	0.999
Natural resources rents	9.638308	8.831073	0.807235	0.142	9.638411	-0.0001	1.000
Fixed regime	0.3327172	0.4108303	-0.0781131	0.001	0.3327155	0.0000017	1.000

Notes : The table presents the sample means of the covariates after weighting the treatment group in column (1) and the control group obtained by balancing the entropy in column (5). Columns (3) - (4) and, (6) - (7), respectively, show the mean difference and the p_value of the mean difference t-test before and after weighting.

4.2.2. Entropy balancing: matching result

Table 9: Entropy balancing: Matching result for Total trade

Dependant variables	(1) **Total goods trade in all items**		(2) **Total trade in primary commodities**		(3) **Total trade in all foods items**		(4) **Total trade in agricultural raw materials**	
	Baseline	Adding controls	Baseline	Adding controls	Baseline	Adding controls	Baseline	Adding controls
MPAY	0.5849***	0.5859***	0.6662***	0.6671***	0.6868***	0.6876***	0.6151***	0.6183***
	(0.0940)	(0.0291)	(0.0879)	(0.0347)	(0.0858)	(0.0355)	(0.1103)	(0.0573)
Observations	1925	1925	1925	1925	1925	1925	1923	1923
R-Squared	0.03	0.89	0.04	0.84	0.04	0.82	0.02	0.72

Note: Robust standard errors are in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01.

Table 10: Entropy balancing: Matching result for import

Dependant variables	(1) Total imports of goods in all items		(2) Total imports in primary commodities		(3) Total imports in all foods items		(4) Total imports in agricultural raw materials	
	Baseline	Adding controls	Baseline	Adding controls	Baseline	Adding controls	Baseline	Adding controls
MPAY	0.6038***	0.6047***	0.5867***	0.5876***	0.6858***	0.6866***	0.4197***	0.4237***
	(0.0932)	(0.0305)	(0.0913)	(0.0340)	(0.0821)	(0.0353)	(0.1268)	(0.0517)
Observations	1925	1925	1925	1925	1925	1925	1923	1923
R-Squared	0.03	0.88	0.03	0.85	0.04	0.82	0.01	0.82

Note: Robust standard errors are in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01.

Table 11: Entropy balancing: Matching result for export

Dependant variables	(1) Total export of goods in all items		(2) Total export in primary commodities		(3) Total export in all foods items		(4) Total exports in agricultural raw materials	
	Baseline	Adding controls	Baseline	Adding controls	Baseline	Adding controls	Baseline	Adding controls
MPAY	0.6035***	0.6047***	0.8285***	0.8294***	0.8389***	0.8397***	0.8570***	0.8602***
	(0.1068)	(0.0418)	(0.0989)	(0.0570)	(0.1125)	(0.0643)	(0.1249)	(0.0849)
Observations	1925	1925	1925	1925	1925	1925	1923	1923
R-Squared	0.02	0.84	0.04	0.67	0.03	0.66	0.03	0.56

Note: Robust standard errors are in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01.

4.3. Addressing endogeneity issues: Generalized Method of Moments (GMM)

Here, we perform a panel two step system GMM (Blundell and Bond, 1998). It will permit us in one hand to consider the panel structure of the dataset, and in other hand to deal with potential endogeneity. We consider Windmeijer (2005) standard errors to overcome the bias of finite sample. As for the proliferation of instruments issue, following Roodman, (2009), we restrict and collapse the set of instruments.

The results are displayed in table 12. First, the AR (2) and Hansen test p-value support validity of the estimations as they are higher than conventional thresholds. The coefficient of MPAY is respectively equal to 0.63, 0.625 and 0.696 for total goods trade, total import, and total export. This result suggests that MPAY adoption could help to increase trade between developing countries by average 0.63 percentage of GDP. The results are closer to PSM and entropy balancing estimation confirming the robustness of the estimation.

Table 12: MPAY adoption and Goods trade: panel two step system GMM

	(1)	(2)	(3)
	Total trade	Total import	Total export
MPAY	0.630***	0.625***	0.696***
	(0.1004)	(0.1003)	(0.1322)
log (total population)	0.946***	0.880***	1.143***
	(0.0547)	(0.0557)	(0.0749)
log(gdp per capita)	0.560*	0.411	0.896**
	(0.3377)	(0.3820)	(0.4044)
Financial depth	0.014**	0.018**	0.008
	(0.0072)	(0.0084)	(0.0103)
inflation	-0.001	-0.001	-0.002
	(0.0012)	(0.0010)	(0.0015)
Natural resources rents	0.039***	0.031***	0.044***
	(0.0107)	(0.0116)	(0.0102)
Fixed regime	-0.070	-0.200	0.220
	(0.1732)	(0.1786)	(0.2507)
Observations	1786	1786	1858
Groups	120	120	120
Instruments	102	102	101
AR2-pvalue	0.24	0.59	0.74
Hansen-pvalue	0.10	0.10	0.11

Note: Robust standard errors are in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01.

5. Conclusion

This paper asses the causal effect of adopting mobile money for merchant payment on goods trade between developing countries.

The results suggest that the adoption of MPAY can help developing countries increase the value of trade among themselves. The effect is highest for trade in food and for exports.

Developing countries should therefore adopt and use mobile money services for their transactions, especially since it is easily accessible and has no income requirements.

Appendix

Appendix A: Country list and adoption year of merchant payment through mobile money

N°	Country	Year of adoption	N°	Country	Year of adoption
1	Afghanistan	2008	**61**	Liberia	2011
2	Albania		**62**	Libya	
3	Algeria		**63**	Macedonia	
4	Angola		**64**	Madagascar	2010
5	Armenia		**65**	Malawi	2012
6	Azerbaijan		**66**	Malaysia	2018
7	Bangladesh	2009	**67**	Maldives	2016
8	Belarus		**68**	Mali	2010
9	Benin	2010	**69**	Mauritania	2013
10	Bhutan		**70**	Mexico	2012
11	Bolivia	2013	**71**	Micronesia (Federated States of)	
12	Bosnia and Herzegovina		**72**	Moldova, Republic of	
13	Botswana	2011	**73**	Mongolia	2010
14	Brazil	2015	**74**	Montenegro	
15	Bulgaria		**75**	Morocco	2010
16	Burkina Faso	2012	**76**	Mozambique	2011
17	Burundi	2012	**77**	Myanmar	2017
18	Cambodia	2009	**78**	Namibia	2010
19	Cameroon	2010	**79**	Nepal	2009
20	Cape Verde		**80**	Nicaragua	
21	Chad	2012	**81**	Niger	2010
22	China		**82**	Nigeria	2011
23	Colombia	2011	**83**	Pakistan	2009
24	Comoros		**84**	Palestine	
25	Congo	2011	**85**	Papua New Guinea	2012
26	Costa Rica		**86**	Paraguay	2010
27	Cote d'Ivoire	2008	**87**	Peru	2015
28	Democratic Republic of the Congo	2012	**88**	Philippines	2004
29	Djibouti		**89**	Russian Federation	2002
30	Dominica		**90**	Rwanda	2009
31	Dominican Republic	2015	**91**	Saint Lucia	
32	Ecuador		**92**	Saint Vincent and the Grenadines	
33	Egypt		**93**	Samoa	2011
34	El Salvador	2011	**94**	Sao Tome and Principe	
35	Equatorial Guinea		**95**	Senegal	2010
36	Ethiopia	2013	**96**	Serbia	
37	Fiji	2010	**97**	Sierra Leone	2017
38	Gabon	2012	**98**	Solomon Islands	2013
39	Gambia		**99**	South Africa	2015
40	Georgia	2013	**100**	South Sudan	
41	Ghana	2009	**101**	Sri Lanka	2012
42	Grenada		**102**	Sudan	2017
43	Guatemala	2011	**103**	Suriname	
44	Guinea	2012	**104**	Swaziland	2011
45	Guinea-Bissau	2010	**105**	Tajikistan	
46	Guyana	2013	**106**	Tanzania, United Republic of	2008
47	Haiti	2010	**107**	Thailand	
48	Honduras	2011	**108**	Timor-Leste	2014
49	India	2012	**109**	Togo	2013
50	Indonesia	2007	**110**	Tonga	
51	Iran (Islamic Republic of)	2011	**111**	Tunisia	2012
52	Iraq	2015	**112**	Turkey	
53	Jamaica	2016	**113**	Uganda	2009
54	Jordan	2016	**114**	Ukraine	
55	Kazakhstan		**115**	Vanuatu	
56	Kenya	2007	**116**	Venezuela	
57	Kyrgyzstan		**117**	Viet Nam	2010
58	Laos		**118**	Yemen	
59	Lebanon		**119**	Zambia	2009
60	Lesotho	2012	**120**	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: Variables description

Variables	Description	Sources
Merchant Payement	Merchant Payement 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 developping countries and exports to developing 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 developing countries and exports to developing countries of goods in percentage of GDP	UNCTAD
Foods items (% GDP)	It denotes the sum of imports from developing countries and exports to developing 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 developing countries and exports to developing 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
Financial sector rate	Financial sector rate assesses the structure of the financial sector and the policies and regulations that affect it. It ranges from 1 (low rating) to 6 (high rating).	World Bank Group, Country Policy and Institutional Assessment (CPIA) database
Social inclusion	Social inclusion includes gender equality, equity of public resource use, building human resources, social protection and labor, and policies and institutions for environmental sustainability. Ranges from 1 (low inclusion) to 6 (high inclusion)	World Bank Group, CPIA database
Socioeconomic conditions	It assesses the socio-economic pressures at work in the society that could limit government action or fuel social discontent. It takes into account unemployment, poverty and consumer confidence. The score ranges from 0 (A weak socio-economic environment) to 12 (A very strong socio-economic environment).	International Country Risk Guide (ICRG)

Appendix C: Descriptive statistics

Variables	Observation	Mean	Std. Dev.	Min	Max
Merchant payment	1926	0.280893	0.4495521	0	1
Total goods trade gdp/GDP	1925	10704.13	38195.18	5.637881	406886.2
Total goods import/GDP	1925	6253.017	21285.2	5.093095	226439
Total goods export/GDP	1925	4451.109	17407.59	0.1687425	206776.6
Total agricultural raw materials trade/GDP	1923	251.6691	731.6963	0.0179052	7508.854
Total agricultural raw materials import/GDP	1924	124.9274	498.5957	0	5778.985
Total agricultural raw materials export/GDP	1924	126.6119	321.6622	0	4015.286
Total primary commodities trade/GDP	1925	1902.366	5123.161	0.679817	50492.54
Total primary commodities import/GDP	1925	1001.081	3162.401	0.3166478	39437.68
Total primary commodities export/GDP	1925	901.2853	2317.511	0.0051868	28091.19
Total all food idem trade/GDP	1925	1080.216	2396.261	0.4996712	27009
Total all food idem import/GDP	1925	575.3323	1164.768	0.226159	9979.266
Total all food idem export/GDP	1925	504.8834	1368.601	0.0028758	18207.37
Financial depth	1926	33.50171	28.73866	0.4025806	160.1248
GDP per capita	1926	3383.32	3112.12	191.5719	20532.95
Inflation	1926	6.971214	16.40019	-21.53169	513.9068
Total natural resources rents	1926	9.05782	11.705	0	84.22876
Total population	1926	5.22e+07	1.82e+08	69650	1.39e+09
Fix regime	1926	0.3888889	0.4876246	0	1
Financial sector rating	851	3.082256	0.5193232	1.5	4.5
Social inclusion	848	3.337736	0.4619302	1.8	4.3
Socioeconomic Conditions	1323	4.211766	1.711344	0	10.29167

Chapter VI: Does mobile money services adoption foster intra-African goods trade?

This chapter is a joint paper with Fayçal SAWADOGO

A shorter version was published in Economics Letters:

Sawadogo, F., & Wandaogo, A. A. (2021). Does mobile money services adoption foster intra-African goods trade?. Economics Letters, 199, 109681.

Abstract: This paper analyzes the causal effect of adopting Mobile money payment on goods trade between 48 African countries from 1994 to 2018. For this purpose, we use a propensity score matching methodology. We find that countries that adopted MM register a higher goods trade share in GDP of about 0.6 percent in comparison to non-adopters. The effect is higher for food products. These results are robust to the alternative matching method (entropy balancing). Finally, when we consider the panel structure of the data and treat endogeneity by applying GMM, the results do not change.

JEL classification: F10, O23, O33, O55.

Keywords: Mobile money, Goods trade, Impact analysis, Africa

Résumé : Cet article analyse l'effet causal de l'adoption du paiement par Mobile Money (MM) sur le commerce de marchandises entre 48 pays africains de 1994 à 2018. À cette fin, nous utilisons une méthodologie d'appariement par score de propension (Propensity score matching – PSM). Nous constatons que les pays qui ont adopté le MM enregistrent une part plus élevée du commerce de biens en pourcentage du PIB d'environ 0,6 % par rapport aux non-adoptants. L'effet est plus élevé pour les produits alimentaires. Ces résultats sont robustes à la méthode d'appariement alternative (entropy balancing). Enfin, lorsque nous considérons la structure de panel des données et traitons l'endogénéïté en appliquant la GMM, les résultats ne changent pas.

Classification JEL : F10, O23, O33, O55.

Mots clés : Mobile Money, Commerce de biens, Analyse d'impact, Afrique

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, W., and Suri, T., 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 P. & Arunjay K. 2013; GSMA, 2014; Burns, S., 2015; Asongu, S. A., 2013; Donovan, K., 2012), which in turn increase international trade (Hajilee, M., & Niroomand, F., 2019; Demir, F., & Dahi, O. S., 2011; Hur, J., Raj, M., & Riyanto, Y. E., 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 P. & Arunjay K. 2013; M. K. 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. With regard to the object of the trade, 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. The section 5 concludes the study and give 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.[68] 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, S. K., & Iyer, H., 2018; Nath, H. K., & Liu, L., 2017; Choi, C., 2010). Appendix A and B respectively present descriptive statistics of the data and variables details.

[68] We consider them in logarithm for interpretation purpose.

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

Following Sawadogo, P. N. (2020), Girma, S. et al. (2003), and Wagner, J. (2002), we use 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:

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

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 of to match 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

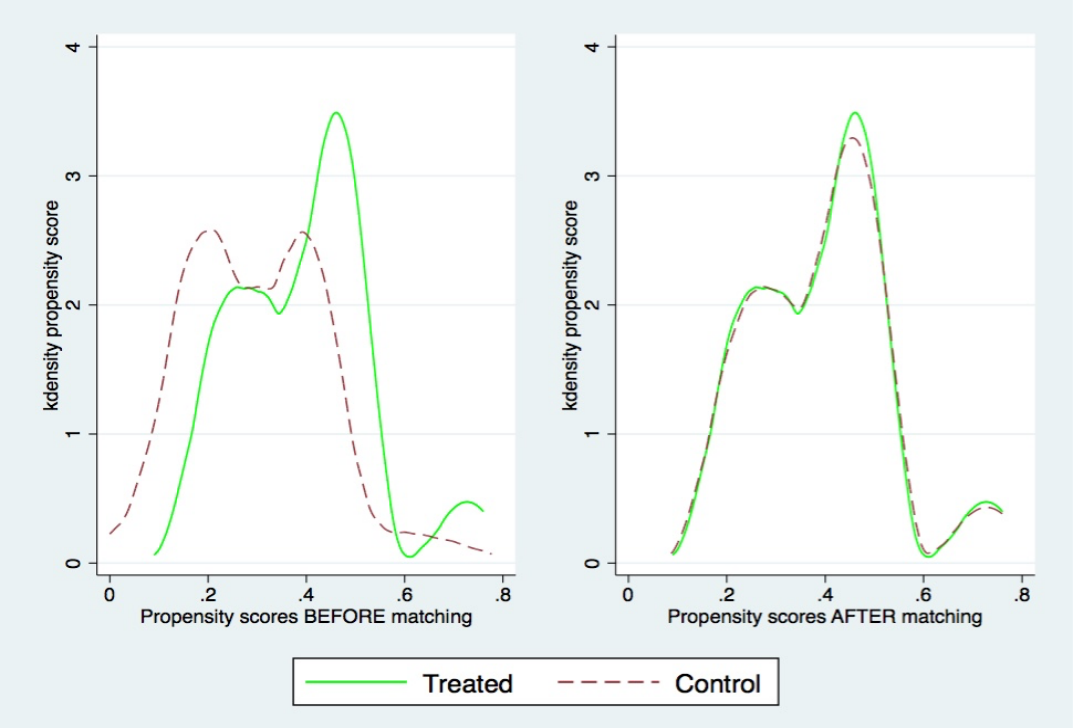
We present the results of the PS estimations in Table 1. The results show that population, financial depth, and fixed exchange rate regime have a positive and significant effect on MM adoption at conventional thresholds. We find that Log (GDP per capita) effect on MM adoption is negative but not significant. 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. Results of matching on propensity scores

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[69] which analyses if there are no unobservables that could affect the effect of MM adoption on goods trade.

Table 1: 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			Local Linear Regression Matching	Kernel Matching
				r=0.005	r=0.01	r=0.05		
	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

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

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 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 2: 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 3: 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**

4. Robustness

4.1. Alternative matching method: entropy balancing

In order to test the sensitivity of our results to the matching method, we carry out the entropy balancing method (Hainmueller, J. 2012 and Hainmueller, J., & Xu, Y. 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 for Log (Total goods trade/GDP)

	Total goods	Agriciltural 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

5. Addressing endogeneity issue: Generalized Method of Moments (GMM)

Here we assume that the adoption of the 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 take into account the panel structure of our sample. We therefore estimate a panel two step system GMM[70] (Blundell and Bond, 1998) to consider any potential endogeneity as in Choi, C. (2010) first, and then to capture the panel dimension of the

[70] This also permits us to address the panel structure of the data.

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.

6. 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

Appendix

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: Variable details

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

General conclusion

The issue of digitalization is of increasing interest to economists in recent years. Given the technological advances that the world has known since the early 2000s, accompanied by the accessibility and widespread use of information and communication technologies, the question of the effects of digitalization in economic development is central. Now used in almost every field, the effects of digitalization are far from being well known and are very little discussed in the literature. This thesis is therefore interested in the effects of digitalisation on some economic development factors such as tax revenue, government quality and trade facilities. The thesis consists of six chapters divided into three parts of two chapters each.

The first part explores the effects of digitalisation on domestic tax revenue mobilisation. **Chapter 1** focus on analysing the effects of ICT readiness and ICT usage on total tax revenue including direct and indirect taxes. It reveals that ICT readiness, while important, is not a determining factor in improving tax revenues. However, the use of ICT improves direct and indirect tax revenues in developing countries. This effect is more important for direct tax revenues than for indirect tax revenues. Moreover, the effect is higher in low-income countries than in low-middle-income countries, while it has no significant effect on tax revenues in upper low-income countries. In addition, experience in using ICT matters as the results show that the effect is not significant in the early years, but it becomes greater as time passes. **In chapter 2**, the thesis studies the effect of mobile money adoption on tax revenues. It investigated the effect of mobile tax payments on direct tax revenues. It shows that the introduction of mobile payments from peers to the government improves direct tax revenues in developing countries. The effect is greater as more years as have passed since adoption and as the country meets the preconditions for adoption. However, the positive effect of P2G on direct tax is only significant for low middle-income counties. In addition, the effect of using ICT and adopting P2G passes through improvements in tax compliance and institutional quality (e.g., government effectiveness, control of corruption, or the quality of public administration).

Part II focuses on the effects of digitalization on government effectiveness and efficiency. **Chapter 3** analyses the effect of digitalisation on the effectiveness of government. We use ICT usage index and government effectiveness index. The use of ICT by government improves its effectiveness. This effect is greater in developed countries than in developing ones. Moreover, general use has a greater effect than government use only. Also, e-governance, e-services, and e-

citizen participation are important factors in the quality of governance. **Chapter 4** shows that ICT investments improve the efficiency of public spending on health and education in developing countries. This result does not depend on geographic location. Paradoxically, while natural resources are detrimental to government effectiveness, they improve efficiency.

Part III investigates the effects of new means of payment on trade of goods between groups of countries. **Chapter 5** shows that the adoption of mobile payments for merchant payments (MPAY) increases trade among developing countries. This increase is larger for low-income countries and for agricultural products. It also depends on socio-economic conditions. In fact, the worse the socio-economic conditions, the more mobile money can improve direct tax revenues. **Chapter 6,** following the same idea, focuses on Intra-African trade. It shows that the adoption of MM boosts trade. However, the effect f is for trade of food products. The effect of MPAY and MM on intra-regional trade goes through the improvement of socio-economic conditions. It also depends on the experience of the adopting countries.

The results of the thesis can lead to the proposal of some policy recommendations. First, developing countries need to implement measures that would facilitate the accessibility and diffusion of technology. This can be done by easing the conditions for importing technology goods, by setting up technology clusters, and by establishing technology goods manufacturing companies. Also, by reducing the tax burden on the use of telecommunication services without granting tax benefits or incentives. The main gain would be to lighten the burden rather than taxing heavily, especially since the loss of revenue due to weak tax administration, fraud and even evasion is greater than the taxes that will be dropped or lightened. This must necessarily be done through tax reforms and not through exemptions. In addition, governments in developing countries need to implement a general reform of public administration by digitalising procedures and administrative processes as much as possible and dematerializing payments as much as possible. Digitalisation must also be an important part of the government's vision. There is no sense in putting in place measures that are not sustainable. But, upstream of these measures, the political will is a precondition. In general, those who are supposed to implement the digitalization will usually not benefit from it, there situations may even be undermined by the digitalization situation. They will therefore be reluctant to implement the digitalization.

One of the limitations of the thesis is about the data availability. The indicators used in the chapter 1, 3 and 4 cover the periods up to 2015 and 2016. In the field of digitalisation, things are moving very fast. A lot happens over 5 years. So, the data often do not reflect recent realities very well.

This digitalisation data needs to be updated. However, there is a real lack of data on digitalisation. It would be interesting to use primary data. These data, in addition to their originality, reflect the realities and allow for many interesting studies. Concerning the first part of the thesis, using primary data, one can analyse the effect of digitalization on tax behaviour (tax compliance, tax avoidance, tax enforcement). In the second part, data collection from public authorities could allow to effectively estimate the investments made in ICT. In fact, using ICT imports can lead to an overvaluation of these investments insofar as most imports are made by individuals and businesses. On the other hand, it can lead to an undervaluation because internal investments in installation or maintenance and in research and development will not be considered. As for the last part, it should be noted that the adoption of the mobile money service is different from its use. It would therefore be interesting to extend the study by considering the number (or rate) of subscriptions to the service and the number (or rate) of use or users of the MM service (also MPAY and P2G). These are all avenues to be explored.

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