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

Jean-François Brun, Gérard Chambas, Jules Tapsoba, Abdoul-Akim Wandaogo

CENTRE D'ÉTUDES
ET DE RECHERCHES
SUR LE DEVELOPPEMENT
INTERNATIONAL

SÉRIE ÉTUDES ET DOCUMENTS

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

Jean-François Brun
Gérard Chambas
Jules Tapsoba
Abdoul-Akim Wandaogo

Études et Documents n° 9
October 2020

To cite this document:

Brun J-F., Chambas G., Tapsoba J., Wandaogo A-A. (2020) "Are ICT's boosting tax revenues? Evidence from developing countries ", *Études et Documents,* n°9, CERDI.

CERDI
POLE TERTIAIRE
26 AVENUE LÉON BLUM
F- 63000 CLERMONT FERRAND
TEL. + 33 4 73 17 74 00
FAX + 33 4 73 17 74 28
http://cerdi.uca.fr/

The authors

Jean-François Brun
Associate Researcher, School of Economics, University of Clermont Auvergne, CNRS, CERDI, F-63000 Clermont-Ferrand, France et Fundaçao Getulio Vargas, FGV Growth and Development, Rio de Janeiro, Brazil
Email address: j-françois.brun@uca.fr

Gérard Chambas
Senoir Fellow, FERDI
Email address: gerard.chambas@wanadoo.fr

Jules Tapsoba
Economist - Expert in Taxation, Technical Assistant to ECOWAS – Abuja (Nigeria), Member of the IMF Expert Panel
Email address: jtapsoba@linpico.com

Abdoul-Akim Wandaogo
PhD Student in Economics, School of Economics, University of Clermont Auvergne, CNRS, CERDI, F-63000 Clermont-Ferrand, France et Université Thomas Sankara, Ouagadougou, Burkina Faso
Email address: a-akim.wandaogo@etu.uca.fr

Corresponding author: Jean-François Brun

This work was supported by the LABEX IDGM+ (ANR-10-LABX-14-01) within the program "Investissements d'Avenir" operated by the French National Research Agency (ANR).

Études et Documents are available online at: https://cerdi.uca.fr/etudes-et-documents/

Director of Publication: Grégoire Rota-Graziosi
Editor: Catherine Araujo-Bonjean
Publisher: Aurélie Goumy
ISSN: 2114 - 7957

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. We provide evidences that although ICT readiness affects positively tax revenue, the effect is not significant. However, overall ICT usage increase tax revenue. This positive and significant effect remains valid for various taxes: direct taxes and VAT notably. In addition, business, government and individual use of ICTs each have a greater effect on tax revenues than global ICT usage. Regarding the transmission channels, we find that the effect passes through the control of corruption, government effectiveness and tax compliance. Finally, taking into account the time dimension of the study, the positive effect is observed over the second half of the period under study rather than during the first.

Keywords
ICTs, Tax revenues, Developing countries, Panel data

JEL Codes
H2, O1, O3

1. Introduction

In order to support some developing countries to achieve development towards 2030, the United Nations (UN) have 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 revenue remains the most reliable resource in order to make the country somewhat independent and in the sense that international donors often fail to keep their promises. Nevertheless, developing countries are often facing difficulties with the mobilization of domestic tax revenue by granting extensive exemptions, by applying complex taxation system relying on multiple rates and through failures in tax administration. Moreover, periods of crisis and uncertainty may exert negative effect on domestic revenue mobilization.

Since the beginning of the 2000s, tax administrations have made extensive use of information and communication technologies in the collection of tax revenues. Today, many countries are implementing electronic invoicing (e-invoicing) on a broad scale (Barreix & Zambrano, 2018), paving the way for radical changes in tax collection, auditing and beyond. Countries such as Brazil, India and China link tax payments to other public services, using combined data-based services, biometric IDs and social coding (Shahin & Zheng, 2018). There is an abundant literature on the determinants of tax revenue mobilization in developing countries. Paradoxically, there is no research on the effect of the introduction and use of ICTs on the budgetary performance of different tax instruments. Indeed, few applied papers look at the impact of Internet usage on domestic revenue mobilization or on the structure of public revenue. Gnangnon and Brun (2018) analyze the effect of closing the Internet gap on the mobilization of non-resource tax revenues. In another paper, Gnangnon and Brun (2019) show that Internet usage may drive changes in the structure of public revenue, in particular 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, Shifa, Shimeles, and Woldeyes (2015a and 2015b), Mascagni, Mengistu, and Woldeyes (2018) and Bellon et al. (2019), deal with the impact of electronic sales recording machines (ESRM) or electronic invoicing on tax revenue 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. Digitalization takes into account a large number of aspects that cannot be limited exclusively to the Internet. Second, the papers on ESRM and e-invoicing are usually microeconomic studies or concern only few countries, the results cannot therefore be generalized. This paper aims at empirically assessing the effects of economic digitalization on the capacity to collect tax revenues in developing countries, while taking into account the multidimensional features of digitalization. Specifically, this study investigates the effects of ICT readiness and ICT usage on tax revenue mobilization as well as on different tax instruments in developing countries. The study covers 96 countries over a 12-year period. The major contribution of this this study is that it uses fairly comprehensive measurements of the digitalization phenomenon. It takes into account availability, affordability and skills on the one hand, and integrates the use of ICTs at all levels (individual, business and government) on the other hand.

The rest of the article is structured as follows. Section 2 discusses theoretical assumptions, while section 3 focuses on methodology. Section 3 describes the dataset and provides descriptive statistics. Sections 5 and 6 presents respectively the main results of the study and further robustness tests. Section 7 is dedicated to a discussion of the results and section 8 concludes.

2. Context and theoretical considerations

2.1. Digitalization and changes in domestic tax revenues mobilization system

Previously, the tax administration system was a system of direct administration in which the tax authority had to identify the taxable matter itself, draw up a list of taxpayers and proceed with recovery. This system was inefficient because it was not only both tedious and expensive, but also entailed the risk of omitting the bigger taxpayers and concentrating on the smaller ones without any real added value. This is why, over the last few decades, we have seen a declaratory system that has the advantage of putting the taxpayer at the heart of the collection process. Here, the taxpayer must make himself known, declare his tax base, calculate his tax, attach the payment to his return and file it with the tax authorities. The latter then, proceeds to verify the accuracy of the information. Indeed, the tax authorities must manage the registration of taxpayers, centralize and enter the information contained in tax returns, collect the payments addressed to it, ensure the fulfillment of taxpayers' tax obligations, check the authenticity of declarations, and monitor tax accounts particularly, arrears management. This must be done within a short delay in order to ensure a good reactivity of the tax administration. To this end, integrated tax information processing systems have been introduced in recent years.

The 1980s saw the computerization of tax administrations.[1] Then, the need for cross-checking and overall tax management led to the use of an integrated information system. This led to significant efficiency gains. However, the dispersion of information collected remains an obstacle to cross-checking, and also to both steering and control tasks. From the 2000s onwards, most sub-Saharan African countries are introducing integrated information systems within their tax administrations, which is a milestone in the digitalization progress of African countries particularly, and in developing countries in general. Some systems are locally designed while others have been produced at an international level.[2] Despite major difficulties in their implementation,[3] the latter are increasingly being applied and, as a result, are proving increasingly favorable to the establishment of steering by management services, including for control functions. This phase contributed to a more efficient mobilization of domestic tax

[1] Table G in appendix resumes digitalization process in some African countries.
[2] 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.
[3] Including the continued use in many countries of multiple information systems (often excel spreadsheets) alongside integrated information systems.

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 that are able to transmit regular returns on the revenue collected.

2.2. Transmission channels

Allowing to benefit from the advantages offered by current digital information processing techniques, which are rapidly expanding in the majority of developing countries, digitalization of tax administrations could have a positive effect on tax revenue mobilization. Several transmission channels can support a potential impact of digitalization on tax revenue mobilization.

The first channel relies on the efficiency of companies acting as tax collectors. The good level of digitalization of big enterprises acting as tax collectors, combined with the introduction of tele-procedures, is an additional positive factor for increasing tax revenues. For them, digitalization allows a drastic reduction in physical travel, thus constituting a factor in reducing the administrative costs borne by taxpayers due to the physical filing of the declaration. In addition, it eliminates an additional cost that particularly affects companies located far from the services dedicated to their tax management. They also alleviate the difficulty for medium-sized companies to free up staff assigned to filing returns, thus reducing an obstacle to an increase in the relative proportion of domestic indirect taxes collected by medium-sized companies. Besides, tele-procedures guarantee companies a secure date for the filing of declarations and payments. In fact, uncertainties may arise in traditional procedures, for example, when a deadline is missed due to the closure of offices 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 enables real-time availability of tax data free of entry errors. Indeed, tele-procedures are a means of real-time dematerialized transmission of information produced by taxpayers in the tax administration's information system. They will, therefore, make it possible to overcome the errors caused by the manual entry of taxpayer information. Moreover, as they avoid delays in the input of information by the tax administration, the latter can immediately concentrate its resources on checking the declarations.[4] In the absence of tele-procedures, a significant part of the tax administrations staff is dedicated to the reception and entry of paper declarations. To carry out these tasks, especially the entry tasks, the staff mobilized is relatively unskilled. A digitalized tax administration will be relieved of the burden of entering tax returns and will redeploy the resources of tax administrations for other purposes.[5] With digitalization

[4] the advantage is substantial, as in practice the input of all the declarations may take several weeks, sometimes a part of the declarations remains pending while the declarations for the following month reach the input services. Losses of declarations by the tax administration services are not exceptional and deeply affect the credibility of the tax administration, which is obliged to ask the taxpayer for a duplicate of the lost declaration.

[5] Tax administrations will therefore have to undertake strategies aimed at redeploying their resources, especially human resources, to control tasks. One difficulty is the relatively low qualification of information entry staff. It would therefore be necessary to undertake training measures for staff to adapt them to the changes resulting from the introduction of tele-procedures.

and tele-procedures, it is becoming necessary, including for countries with multiple economic activity zones, to have a single Large Enterprises Department dedicated to the tax management of the largest companies. As far as medium-sized enterprises are concerned, tele-procedures make it possible to increase the portfolio of enterprises which can be efficiently managed by a single department of medium-sized enterprises. Thus, it is possible to limit the number of departments of medium-sized enterprises which, for their smooth operation, require highly qualified executives who are often difficult to mobilize.

The third hinges upon the fact that digitalization is a factor of less corruption and fiscal discipline. By reducing the need for taxpayers to travel to tax administration offices, tele-procedures remove opportunities for corruption, which is a cost and risk factor for all businesses. Moreover, the automaticity of procedures makes it more difficult for public officials and/or company employees to embezzle tax revenue fraudulently. Furthermore, the introduction of measures to facilitate the calculation of amounts due and to avoid errors provides an incentive for the taxpayer to comply with his obligations. Through tele-procedures, the tax administration promotes tax compliance, which is based on both adherence and sanction: it must therefore offer an accessible and quality service to facilitate the taxpayer's obligations while detecting and sanctioning tax evaders and bad-paying behavior.

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 total tax revenues to GDP and others tax instruments. We extracted these data from the database of the International Centre for Taxation and Development (ICTD). For missing values in this database, we use the database of the Organization for Economic Co-operation and Development (OECD) and data from the West African Economic and Monetary Union (WAEMU) to complete them if they are available.

Excepted ICT data, all other explanatory variables (GDP per capita growth, value-added of agriculture, fishing, and 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

[6] Countries list in appendix A.

[7] Table C in the Appendix provides description and sources of all variables we use in the paper.

[8] Readiness and usage data were collected for each year from 2005 to 2016, with the exception of 2011, which is not available due to the absence of the GITR in that year. We estimated it by averaging data for the years 2010 and 2011.

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. Variables description

3.2.1. Variables of interest

- **ICT readiness sub-index**

The Readiness Index assesses the factors that facilitate access to ICTs. It takes into account the availability of infrastructure and its accessibility in relation to costs and competition. This sub-index also takes into account the skill needed to claim to use ICT. However, even if ICTs are available and accessible, they cannot be useful if they are not used. Therefore, we expect a non-significant effect of readiness on tax revenue mobilization in the absence of usage.

- **ICT usage sub-index**

The usage sub-index measures the adoption of ICTs by the main components of the economy for their current activities. ICT usage includes Individual usage pillar that measures the popularization of ICT among the population, 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. And finally, government usage pillar is captured by the availability and quality of online public services and government promotion and procurement of ICT.

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 also the level of development of a country. We predict a positive effect of GDP per capita growth on tax revenues. Indeed, the increase in disposable income tends to increase the capacity to collect taxes, and the capacity to pay taxes for citizens.

Agriculture, fishing, and forestry value-added

Agriculture, fishing, and forestry value-added as a proportion of GDP is used to measure the sectoral structuring of the economy. 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

[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).

markets makes taxation of the agricultural sector difficult. Therefore, we expect a negative effect of agriculture, fishing, and forestry value-added on tax revenues.

Total natural resource rents

Total natural resources rents are the sum of oil rents, natural gas rents, coal rents (hard and soft), mineral rents, and forest rents. (World Bank). natural resources are an opportunity to raise more tax revenue through multilateral corporate taxation. Moreover, in resource-rich countries, tax revenues from natural resources represent a significant share of total tax revenues. We, therefore, expect a positive effect of natural resource rents on total tax revenues.

Imports and exports of goods and services

Imports and exports provide a measure of a country's trade openness. We suspect that exports hurt tax revenues because they are goods and services that are not subject to indirect taxation and because there is no export tax. As far as imports are concerned, we expect them to have a positive effect on tax revenue due to taxation on doors and the tax on goods and services, which allow for more tax revenue to be collected.

Liquid liabilities to GDP

The ratio of liquid liabilities to GDP. Liquid liabilities are 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.

Total population

It measures the number of people living in the territory of a country. We expect a positive effect of the total population on tax revenues because the higher the number of inhabitants, the more consumption and thus indirect tax revenues increase. In addition, 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. We can see that, on average, developing countries are just above the worst[10] range of the index for the readiness sub-index, with an average of

[10] According to the 2013 NRI map, the score can be classified in 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, forth 5-5.4 and the best 5.4-7.

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.[11]

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 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 mainly due to the fact that 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, then its trend becomes stable and increasing from 2010 onwards (figure 1). Its downward trend, unlike the readiness index, can be caused by several factors. First, the low level of general 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, certainly due to the popularization of the use of ICTs.

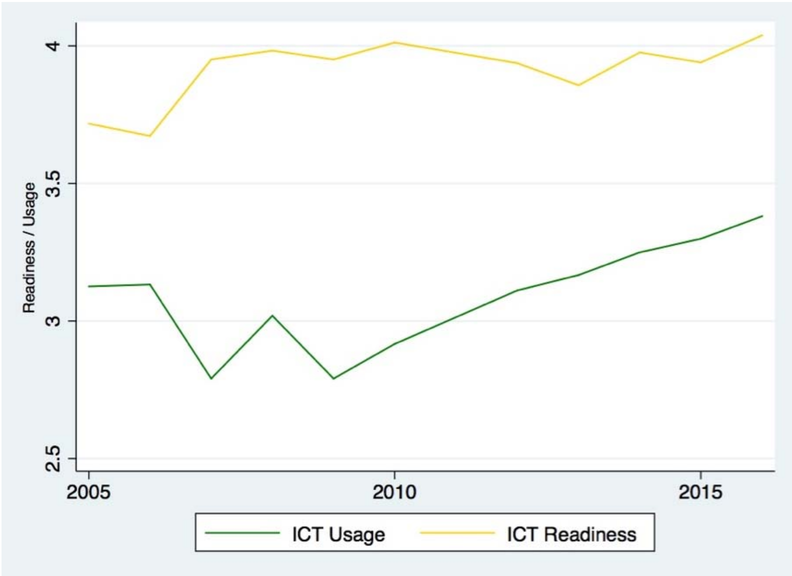
As for tax revenues, figure 2 shows that the mean of the ratios of tax revenues to GDP increased over the period considered (cf. figure2). We can observe that the upward trend operates in two stages with a decline between 2008 and 2010. The first stage is from 2005 to 2008 and the second from 2010 to 2016. The decline in tax revenues between 2008 and 2010 could be explained by the effects of the financial crisis from 2008 - 2009.

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 3). Besides, it can be seen that the values of the scatterplot are widely dispersed around the expected trend and that the relationship between the two phenomena is not linear. We will, therefore, put our explained variable in logarithm to take these observations into account. This technique

[11] Table B in appendix resumes descriptive statistics.

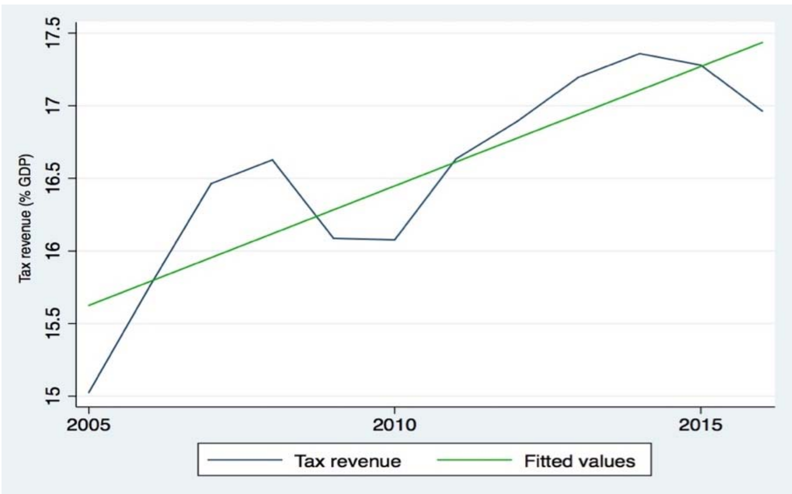
also has several advantages including that of limiting the extent of asymmetry of values (S.K Gnangnon, 2020), a logarithmic transformation could also reduce the influence of outliers. Therefore, since the variable of interest is in points, this will facilitate the interpretation of econometric results.[12]

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



Source: Author's construction with GITR data

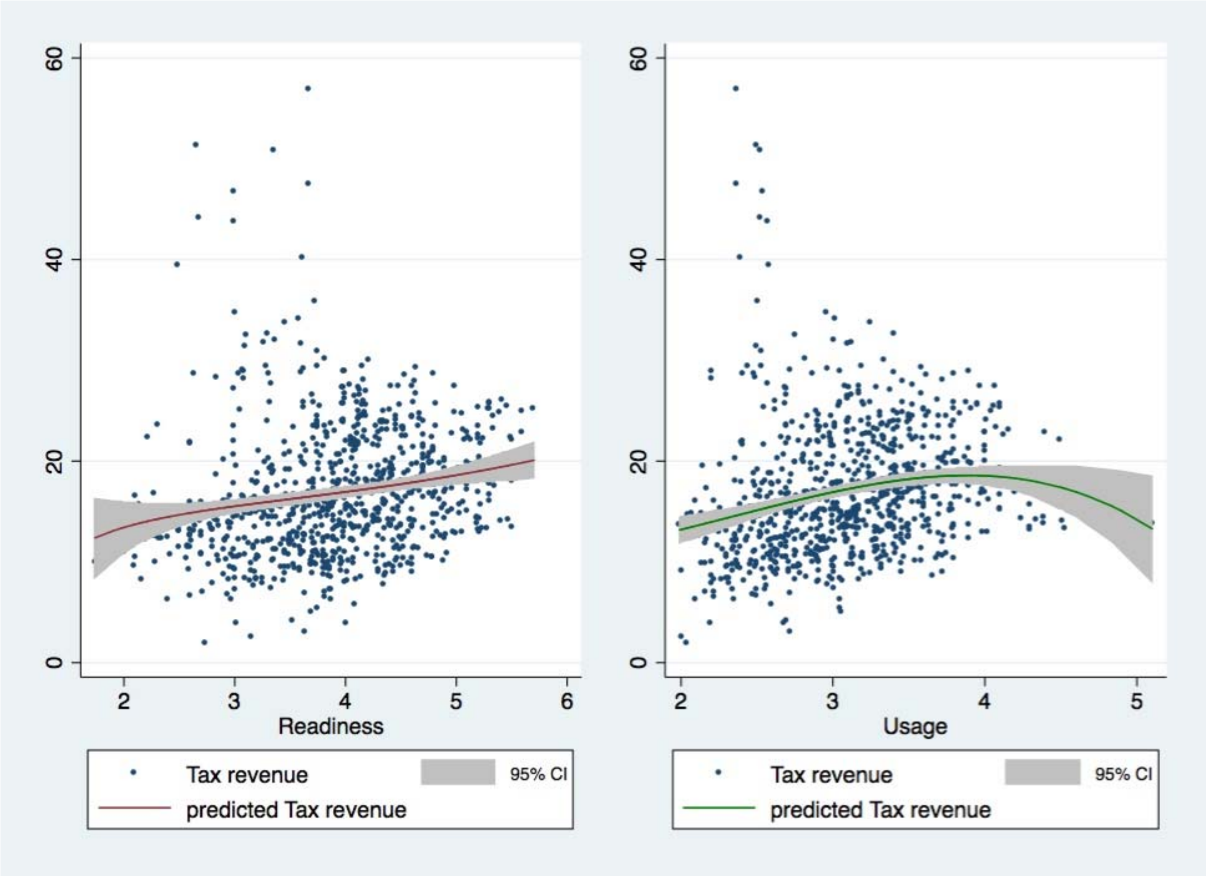
Figure 2: Trend of total tax revenue from 2005 to 2016



Source : Author construction with ICTD, OECD and WAEMU data

[12] In this case, we will interpret results like that: if ICT Readiness/Usage increase by one unit, tax revenue will change by roughly x percent.

Figure 3: Scatterplot of ICT indices and total tax revenue



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

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), we specified a panel fixed effect model to estimate the effect of ICT readiness and ICT usage on tax resources mobilization in developing countries. We specified the empirical model as follows:

$$\boldsymbol{Log(Tax\ revenue) = \alpha(Digital)_{it} + \beta X_{it} + \varepsilon_{it}} \qquad \textbf{(I)}$$

Where Tax revenue is the ratio in the proportion of GDP of total tax revenue. Digital represents the digitalization score for country i in the year j. Digital has two-component which are readiness and usage. Concerning the usage component, we have individual usage, business usage, and government usage. X_{it} includes control variables that are determinant 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. It includes δ_i to take account of the individual effect, γ_i which captures the time effect, and θ_{it} is the idiosyncratic error term.

5. Main Results

5.1. ICT effects on total tax revenues

Referring to the literature, we perform a panel fixed effect (FE) model to estimate the impact of digitalization on tax revenue mobilization in developing countries. Besides, we estimate à fixed effect model with Driscoll-Kray standard errors (FE-DK) to deal with heteroskedasticity 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. Moreover, we suspect that readiness and usage variables could 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 usage of ICTs within the tax administration and at the level of the general population.[13] Furthermore, if ICTs enable the government to be efficient and to collect more resources, there will be more incentives to increase the use of ICTs in the process of tax revenue mobilization. In other words, the more tax resources government collects through the access and use of ICTs, the greater is 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 as a means of facilitating tax avoidance and optimizing taxation. In this way, tax mobilization can have a positive effect on 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 means of communication that offer larger benefits through "free" messaging and calling applications. In this way, taxation will create a substitution effect by moving away from traditional (fixed phones, direct calls, and messaging.) means towards more sophisticated such as smartphones and the Internet which facilitate access to free calling and messages applications (iii). Thus, to overcome endogeneity, we performed a regression with instrumental variables (IV). For this, we identified 4 instruments to deal with endogeneity. At first, we have the ***telecommunication investments***, which represent an annual investment in telecommunication services. ***Computer access*** is an indicator that estimates the percentage of households with access to a computer at home or office. And ***mobiles subscription*** which is the mobile-cellular subscription per 100

[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. We have for example Burkina Faso and Côte d'Ivoire. In Burkina Faso, there is a tax rate of 2% is found to access to universal services and 0,5% of 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.

habitants. The last two are the main device that is used in daily activities. The fourth is ***Internet users*** that is the percentage of households using the Internet.[14] We adopted these indicators because the government may be motivated to introduce online procedures or online payment of taxes if it observes a significant increase in computer access and Internet use.[15] For readiness, we use telecommunication investments, computer access, and mobile subscription. As for usage, we choose Computer access and Internet user because we know that Internet uses go together computer access.[16]

The results in table 1 present the effects of ICTs readiness on total tax revenues in the percentage of GDP. In column 1, we estimate using only the variables of interest. The results show that ICT readiness does not have a significant effect on tax revenues. This estimation model suffers from bias due to the omission of variables. In column 2, we associate the explanatory variables mainly used in the literature. We can observe that the effect of ICT readiness on tax revenue remains non-significant. The result of estimation with Driscoll-Kray standard errors (Column 3) is the same with previous results but the effect of some variables became more significant. It is precisely, first of all, the total rents of natural resources and the total population for which the threshold of significance passed from 10% to 1%. Also, for the export of goods and services, it passed from 5% to 1%. In column 4, we have the results of instrumental variables regression.

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 Significance thresholds. This 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 Instruments because the p-value (0.362) is higher than all convention threshold. In addition, the first-stage results show that our instruments are valid because they explain the endogenous variables at conventional thresholds.

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

[14] Let's know that access to the internet is different from using the internet. Being covered by the internet does not mean you are using it. You 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 a tele-procedure for VAT declaration and refund of VAT credit. This type of procedure is under way in Burkina Faso and has been introduced in Morocco.
[16] use of key aspects of digitalization certainly depends on the size and quality of the Internet network.

Table 1: Impact of ICT readiness on tax revenue

Log (tax revenue % GDP)	(1) FE	(2) FE	(3) FE-DK	(4) FE-IV
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		-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***	0.0000***
		(1.36e-09)	(5.34e-10)	(0.0000)
No. of Obs.	936	890	890	530
No. of group	96	93	93	78
R-Squared	0.00	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

As concerning ICT usage (Table 2), the fixed effect panel model (column 1 and 2) and fixed effect with Driscoll-Kray standard errors (Column 3) show that ICT usage has a positive and significant effect on total tax revenue in developing countries. The results of both estimations are similar although total natural resource rents, the export of goods and services, and total population effects are more significant in DK-FE estimation.

The results of instrumental variables estimation for ICT usage are display in column 4 of Table 2. When we instrumented the usage variable, the first stage results show that computer access and Internet user, explain usage respectively at 5% and 1% threshold.[17] The Anderson canonical correlation test (test of under-identification) indicates that the instrumental variables are correlated to the endogenous variable (usage) because it rejects the null hypothesis of under-identification since the p-value associated with this test (0.000) is inferior to 1%. At last, the p-value of the Sargan-Hansen test of overidentification is

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

high than the conventional thresholds (0.124). Then the hypotheses of an absence of correlation between the instrumental variables and the error term do not reject. All these tests together prove that the instruments choose for ICT usage are exogenous and relevant. After the instrumental variable estimation, the results remain the same as previous estimations. However, the coefficient and significance of the interest variable increase. We can observe that the coefficient of usage has more than doubled from 0.0562 to 0.1256 and the significance level becomes 1%. That is mean instrumental variables correct the endogeneity bias in fixed-effect estimation.

With regard to 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 revenue 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 very small. As for financial development, it does not have a significant impact on tax revenue mobilization in developing countries.

Table 2: Impact of ICT usage on total tax revenue

Log (tax revenue % GDP)	(1) FE	(2) FE	(3) FE-DK	(4) FE-IV
ICT Usage	**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		-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)
No. of Obs.	936	890	890	821
No. of group	96	93	93	88
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

These results confirm that it is ICT usage that affect 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 in order for the effects of digitalization to be perceived.

We assume that the use of ICT is preceded by readiness. Thus, the usage score implicitly reflects a considerable part of readiness. We will therefore focus on the use index in the rest of our work.

5.2. Effects of ICT usage on main taxes

We now estimate the effects of ICT usage on main taxes. First, we assess the effects on direct and indirect tax revenues. Second, we distinguish corporate income tax (CIT), property tax (PT), personal income tax (PIT), value added tax (VAT) and excise duties. The results are displayed in Table 3. The ICT usage economy appears to improve tax revenue collection in developing countries, regardless of the tax considered. 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 property tax.

5.3. ICT usage and tax revenue: effect of ICT usage components

In Table 4, we estimate the effects of the sub-components of "ICT usage" on total tax revenues using the same instruments for all components as for overall use. The results suggest that, in developing countries, ICT usage at all levels has a positive and significant effect on tax revenue collection. But statistical tests have not confirmed the validity of the instruments for governments and businesses usages (column 1 and 2) as Hansen p-value is less than 10% threshold for the first and Anderson canonical test of under identification is high than 10% level for the second.

Table 3: Impact of ICT usage on tax instruments

	(1) Log (Direct)	(2) log (indirect)	(3) log (CIT)	(4) log (PIT)	(5) log (PT)	(6) Log (VAT)	(7) Log (Excise)
ICT Usage	**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	-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)
No. of Obs.	681	766	582	731	439	665	633
No. of group	80	83	64	81	53	68	67
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

Table 4: Impact of ICT usage component on tax revenue

Log (tax revenue % GDP)	(1) government	(2) business	(3) individual
Government IC usage	**0.2006****		
	(0.0901)		
Business ICT usage		**0.3559***	
		(0.1956)	
Individual ICT usage			**0.0443*****
			(0.0156)
Liquid liabilities to GDP	-0.0005	0.0024	-0.0006
	(0.0004)	(0.0017)	(0.0004)
GDP per capita growth	0.0012	-0.0052	0.0030**
	(0.0016)	(0.0054)	(0.0014)
Agriculture forestry and fishing	-0.0034	-0.0014	-0.0045
	(0.0047)	(0.0047)	(0.0039)
Total natural resources rents	0.0098*	0.0079	0.0096**
	(0.0053)	(0.0054)	(0.0047)
Imports of goods and services	0.0064***	0.0046**	0.0061***
	(0.0015)	(0.0018)	(0.0016)
Exports of goods and services	-0.0033**	-0.0041*	-0.0031**
	(0.0016)	(0.0021)	(0.0015)
Population total	9.81e-10	6.30e-09*	2.14e-09
	(1.38e-09)	(3.58e-09)	(1.34e-09)
No. of Obs.	821	821	821
No. of group	88	88	88
R-Squared	0.157	0.001	0.004
Anderson canonical cor. p-value (H0: under identification)	0.000	0.146	0.000
Sargan-Hansen p-value	0.086	0.374	0.107

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

6. Further analysis

6.1. Dynamic panel estimation of ICT effect on tax revenue

In fact, tax revenues collected in previous years have an impact on a country's current tax revenues to be collected (Besley and Persson, 2009), as part of the tax revenues collected in previous years is used to finance the collection of the current year's tax. In this sense, Gupta (2007), Gnagnon and Brun (2017) explain that the current level of tax revenue for a given country is affected by its past values. So, this is something that needs to be taken into account, otherwise, there is a risk of bias of the relevant omitted variable. Therefore, to address this issue, we include a lag value for tax revenues among the explanatory variables. The model will then look as follows:

$$\boldsymbol{Log(Tax\ revenue\ ) = \rho(Tax\ revenue\ )_{it-1} + \alpha(ICT\ usage)_{it} + \beta X_{it} + \varepsilon_{it}} \qquad \textbf{(II)}$$

The results presented in Table 4 (from columns 1 and 2) confirm that tax revenues collected in the past have a positive impact on current tax revenues. Furthermore, the results do not change from previous estimates. The effect of ICT usage on tax revenues in developing countries remains positive and significant, but the coefficient has decreased slightly due to the inclusion of a relevant variable.

However, the inclusion of lagged variables in the model makes fixed panel estimation inappropriate. Indeed, this lagged variable will generate an endogeneity bias because there will be an autocorrelation between it and the error terms. To overcome this problem of endogeneity of the lagged dependent variable as well as other potentially endogenous explanatory variables, it will, therefore, be necessary to estimate using a dynamic panel model. Based on the tax revenue literature on dynamic panel estimation (Mahdavi, S. 2008, Brückner, M. 2012, Brun, J. F. et Gnagnon, 2018, Gnangnon, S. K., & Brun, J. F. 2019a; 2019b), we use the System-GMM estimator developed by), Arellano and Bond (1991), Arellano and Bover (1995) and Blundell and Bond (1998).

In the System-GMM estimator, the level and difference equations are combined as a system and the level variables are instrumented by their lagged differences. As for the different variables, they are instrumented by the lagged level variables. Specifically, the lagged levels and the differences of the explanatory variables are used as instruments to identify the coefficients of interest. The main advantage of this estimator is that it can instrument other explanatory variables that could be potentially endogenous in addition to the main regressor (the variable referred to here as ICT usage) which is endogenous. This is interesting in our case where control variables such as GDP per capita growth could be endogenous because of the inverse causality of tax revenues to each of these variables. Therefore, in estimating the System-GMM, we consider the lagged dependent variable and all other explanatory variables as potentially endogenous. We also improve the efficiency of the estimation by adding the two external instruments that were used previously (computer access and Internet user) to the set of internal instruments. The validity of the instruments in the estimation of the GMM in the system is verified with

Hansen's restriction overidentification test, which tests the validity of the instrumental variables used in regressions and Arellano and Bond autocorrelation tests.[18] Also, with the System-GMM estimator, we need to ensure that the total number of instruments does not exceed the number of countries to avoid the problem of "instrument proliferation" (Rodman. D, 2006).

Table 5: Dynamic panel estimation of ICT effect on tax revenue

Log (Tax revenue in % GDP)	**(1) FE-IV**	**(2) GMM-System**
ICT usage	**0.0598****	**0.0775***
	(0.0269)	**(0.0418)**
Tax revenue (t-1)	**0.0277*****	**0.0321*****
	(0.0046)	(0.0108)
Liquid liabilities to GDP	0.0005	-0.0003
	(0.0013)	(0.0006)
GDP per capita growth	0.0038***	0.0129***
	(0.0011)	(0.0041)
Agriculture forestry and fishing	-0.0004	-0.0048
	(0.0025)	(0.0048)
Total natural resources rents	0.0046	-0.0012
	(0.0030)	(0.0037)
Imports of goods and services	0.0033***	0.0048**
	(0.0010)	(0.0024)
Exports of goods and services	-0.0013	-0.0027
	(0.0010)	(0.0018)
Population total	6.44e-10	5.14e-11
	(9.10e-10)	(7.90e-11)
No. of Obs.	765	748
No. of group	87	86
No. of instruments	2	18
Ar1p-value		0.002
Ar2 p-value		0.127
Sargan-Hansen, p-value	0.138	0.148
Hansen, p-value		

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Included instruments are lag from 2 to 4 of tax revenue, and from 2 to 3 of all other explanatory variables in addition of computer access and Internet users.

At the bottom of column 2, the statistical diagnostics of the estimate can be observed. It shows that the first-order residual autocorrelation (Ar1) cannot be rejected at the 1% threshold whereas there is no evidence of second-order residual autocorrelation (The AR2 p-value equal to 0.148 which is higher than

[18] See Rodman. D (2009) about GMM estimation on stata.

all significance thresholds). In addition, Hansen's p-value confirms that all instruments are relevant since the p-value is greater than 10%. Furthermore, the number of instruments is 18, which is less than the number of countries (86), so the estimate is not subject to instrument proliferation bias. All these tests, therefore, suggest that our estimation model is correct.

The result of the GMM analysis confirms previous results. Using ICT positively and significantly affect tax revenue collection. And furthermore, the dynamics of tax collection are confirmed as the one-period lagged effect is positive and statistically significant at the 1% level.

6.2. Test of the transmission channels

In this section, we analyze the channel through which ICTs affect tax revenue collection. We hypothesize that the effect passes through better control of corruption, improved government effectiveness and better tax compliance. The corruption and government effectiveness indicators are taken from the International Country Risk Guide (ICRG) database and the tax compliance indicator from economic freedom. For all these indicators, we divide the database in two groups basing on country mean of the indicator on the period of study. When the average of the control of corruption or government effectiveness is below 0, the country is considered more corrupt or less effective respectively. With respect to tax compliance, we assume that a country's taxpayers are more compliant when the average is above 7 and non-compliant otherwise.[19] The results are presented in tables 5, 6 and 7.

The results in Table 5 suggest that the effect of ICT usage on tax revenue mobilization is through enhancing the capacity to control corruption. Indeed, in columns 1, 2 and 3, we observe that the effect of ICT usage on total tax revenues, direct and indirect taxes is positive and significant at a threshold of 1% for countries with a low corruption control score. On the other hand, the effect is non-significant for groups that can control corruption (columns 4, 5 and 6), i.e. with a corruption control score above zero. This suggest that ICT affect tax revenue collection through control of corruption.

With regard to government effectiveness (Table 6), we found that the use of ICT has a positive and significant effect at 1% threshold on total tax revenues and tax instruments in countries with low government effectiveness (Column 1,2 and 3). As for countries in which the government electiveness index is positive, the results in column 6 shows that the effect of ICT usage is non-significant on tax revenue mobilization. This is means that ICT usage improves tax revenue mobilization through enhancing the effectiveness of governments in developing countries.

[19] The control of corruption and government effectiveness indicator is ranges from -2,5 to 2,5 while tax compliance data is ranges from 0 to 10.

As for tax compliance, the results in Table 7 suggest that ICTs usage has a positive impact on tax resource mobilization regardless of the degree of tax compliance of the country's taxpayers. In columns from 1 to 3, we can see that the effect of ICT usage is positive and significant on total tax, direct tax, and indirect tax revenue in countries with low level of compliance.[20] The effect remains the same for the group with a higher level of tax compliance while it is not significant for indirect tax revenue. Nevertheless, the effect is relatively higher for the first group according to the total tax revenue (0.2659>0.1518) and more significant (5% and 10%) for the first group compared to the second. These results suggest that ICT affect tax revenue by enhancing compliance for indirect tax.

Table 6: Testing transmission channel of ICT usage through control of corruption

	Countries with high level of corruption (Control of corruption less than 0)			Countries that can control corruption (Control of corruption higher than 0)		
Log (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 Usage	**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	-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)
No. of Obs.	703	575	655	118	106	111
No. of group	76	68	71	12	12	12
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

[20] When the compliance score is lower than 7.

Table 7: Testing transmission channel of ICT usage through government effectiveness

	Countries with low government effectiveness (government effectiveness < 0)			Countries with high government effectiveness (government effectiveness > 0)		
	(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 Usage	**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 add	-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)
No. of Obs.	622	494	574	187	192	199
No. of group	70	62	65	18	18	18
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

Table 8: Testing transmission channel of ICT usage through tax compliance

	Less compliant			More compliant		
	(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 Usage	**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 add	-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)
No. of Obs.	367	424	445	376	314	342
No. of group	44	46	47	41	36	37
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

6.3. Study period sensitivity analysis

In fact, over a 12-year period, 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 our analysis. As we have seen above, the use of ICT evolved in two phases. Based on the trend of ICT usage, we divide our data into two subgroups to address this issue: Before 2011 (from 2005 to 2010) and after 2010 (from 2011 to 2016).

In Table 8, the results in columns 1, 2 and 3 suggest that the use of ICTs does not significantly affect tax revenue mobilization in developing countries from 2005 to 2010. However, from 2011 to 2016, the effect becomes positive and significant (columns 4, 5 and 6). Appendices E and F shows the effects on tax instrument along each of both periods. It confirms 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 of second period are conforms to main results on the 12 years (table 2 and table 3).

Table 9: Sensitivity of the effect of ICT on tax revenue to the temporal dimension

	first period (2005 - 2010)			Second period (2011 - 2016)		
	(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 Usage	**-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 add	-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)
No. of Obs.	385	327	358	436	354	408
No. of group	80	71	75	83	71	77
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

7. Conclusion

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

We found that ICT readiness does not have a significant effect on tax revenue, whereas the ICT usage has a positive and significant effect on tax revenue collection. 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 government effectiveness, control of corruption, and tax compliance.

In terms of policy implications, the results imply that the ICT readiness and the ICT usage are relevant for public revenue mobilization. Indeed, it has a positive impact on public revenue mobilization through fiscal discipline, control of corruption and by improving administration effectiveness. Therefore, developing countries need to build and improve infrastructures related to new technologies and to modernize their tax administration. However, to take full advantage of ICTs, they also have to adopt best practice in tax legislation.

References

Ali, M., Shifa, A. B., Shimeles, A., & Woldeyes, F. (2015). *Building fiscal capacity in developing countries: Evidence on the role of information technology*, CMI Working Paper.

Ali, M., Shifa, A., Shimeles, A., & Woldeyes, F. B. (2015). *Information technology and fiscal capacity in a developing country: evidence from Ethiopia.* Appendices

Arellano, M., & Bond, S. (1991). "Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations", *The review of economic studies*, *58*(2), 277-297.

Arellano, M., & Bover, O. (1995). "Another look at the instrumental variable estimation of error-components models", *Journal of econometrics*, 68(1), 29-51.

Baller, S., Dutta, S. & Lanvin, B. (Eds.) (2016). *Global Information Technology Report 2016. Innovating in the Digital Economy*, Geneva: World Economic Forum and INSEAD. Retrieved July 07, 2016 from http://www3.weforum.org/docs/GITR2016/WEF_GITR_Full_Report.pdf

Barreix, A. D., Zambrano, R., Costa, M. P., da Silva Bahia, Á. A., de Jesus, E. A., de Freitas, V. P., ... & Drago, C. (2018). *Factura electronica en america latina* (Vol. 595), Inter-American Development Bank.

Baunsgaard, T., & Keen, M. (2010). "Tax revenue and (or?) trade liberalization", *Journal of Public Economics*, 94(9-10), 563-577.

Bellon, M. M., Chang, J., Dabla-Norris, M. E., Khalid, S., Lima, F., Rojas, E., & Villena, P. (2019). *Digitalization to improve tax compliance: evidence from VAT e-Invoicing in Peru*, International Monetary Fund.

Besley, T., & Persson, T. (2009). "The origins of state capacity: Property rights, taxation, and politics", *American economic review,* 99(4), 1218-44.

Bilbao-Osorio, B., Dutta, S. & Lanvin, B. (Eds.) (2013). *Global Information Technology Report 2013. Growth and Jobs in a Hyperconnected World*. Geneva: World Economic Forum and INSEAD. Retrieved April 10, 2013 from http://www3.weforum.org/docs/WEF_GITR_Report_2013.pdf

Bilbao-Osorio, B., Dutta, S. & Lanvin, B. (Eds.) (2014). *Global Information Technology Report 2014. Rewards and Risks of Big Data*. Geneva: World Economic Forum and INSEAD. Retrieved April 25, 2014 from http://www3.weforum.org/docs/WEF_GlobalInformationTechnology_Report_2014.pdf

Blundell, R., & Bond, S. (1998). "Initial conditions and moment restrictions in dynamic panel data models", *Journal of econometrics*, 87(1), 115-143.

Brückner, M. (2012). "An instrumental variables approach to estimating tax revenue elasticities: Evidence from Sub-Saharan Africa", *Journal of Development Economics*, 98(2), 220-227.

Clist, P., & Morrissey, O. (2011). "Aid and tax revenue: signs of a positive effect since the 1980s", *Journal of international development*, 23(2), 165-180.

Driscoll, J. C., & Kraay, A. C. (1998). "Consistent covariance matrix estimation with spatially dependent panel data" *Review of economics and statistics*, 80(4), 549-560.

Dutta, S. & Bilbao-Osorio, B. (Eds.) (2012). *Global Information Technology Report 2012. Living in a Hyperconnected World*. Geneva: World Economic Forum and INSEAD. Retrieved April 07, 2012 from http://www3.weforum.org/docs/Global_IT_Report_2012.pdf

Dutta, S. & Mia, I. (Eds.) (2007). *Global Information Technology Report 2006-2007: Connecting to the Networked Economy*. Basingstoke: Palgrave Macmillan.

Dutta, S. & Mia, I. (Eds.) (2009). *Global Information Technology Report 2008-2009: Mobility in a Networked World*. Basingstoke: Palgrave Macmillan. Retrieved March 29, 2009 from http://www.weforum.org/pdf/gitr/2009/gitr09fullreport.pdf

Dutta, S. & Mia, I. (Eds.) (2010). *Global Information Technology Report 2009-2010: ICT for Sustainability*. Basingstoke: Palgrave Macmillan. Retrieved March 25, 2010 from http://www.weforum.org/pdf/GITR10/GITR%202009-2010_Full%20Report%20final.pdf

Dutta, S. & Mia, I. (Eds.) (2011). *Global Information Technology Report 2010-2011: Transformations 2.0*. Basingstoke: Palgrave Macmillan. Retrieved April 17, 2011 from http://reports.weforum.org/global-information-technology-report/content/pdf/wef-gitr-2010-2011.pdf

Dutta, S., Geiger, T. & Lanvin, B. (Eds.) (2015). *Global Information Technology Report 2015: ICTs for Inclusive Growth*. Geneva: World Economic Forum and INSEAD. Retrieved April 20, 2015 from http://www3.weforum.org/docs/WEF_Global_IT_Report_2015.pdf

Dutta, S., López-Claros, A. & Mia, I. (Eds.) (2006). *Global Information Technology Report 2005-2006: Leveraging ICT for Development*. Basingstoke: Palgrave Macmillan

Dutta, S., López-Claros, A. & Mia, I. (Eds.) (2008). *Global Information Technology Report 2007-2008: Fostering Innovation through Networked Readiness*. Basingstoke: Palgrave Macmillan.

Gnangnon, S. K. (2020). "Internet and tax reform in developing countries", *Information Economics and Policy*, Elsevie, vol 51(C).

Gnangnon, S. K., & Brun, J. F. (2018). "Impact of bridging the Internet gap on public revenue mobilization", *Information Economics and Policy*, 43, 23-33.

Gnangnon, S. K., & Brun, J. F. (2019). "Internet and the structure of public revenue: resource revenue versus non-resource revenue", *Journal of Economic Structures*, 8(1), 1.

Gnangnon, S. K., & Brun, J. F. (2019). "Trade openness, tax reform and tax revenue in developing countries", *The World Economy*, 42(12), 3515-3536.

Mahdavi, S. (2008). “The level and composition of tax revenue in developing countries: Evidence from unbalanced panel data”, *International Review of Economics & Finance*, 17(4), 607-617.

Mascagni, G., Mengistu, A., & Woldeyes, F. B. (2018). “Can ICTs increase tax? Experimental evidence from Ethiopia”, Institut of development studies Working Paper 82

Roodman, D. (2006). “How to do xtabond2: An introduction to difference and system GMM in Stata”, Center for Global Development Working Paper, Number 103.

Roodman, D. (2009). “Practitioners’ Corner A Note on the Theme of Too Many Instruments”, *Oxford Bulletin of Economics and Statistics*, 71, pp. 135-158.

Shahin, S., & Zheng, P. (2020). “Big data and the illusion of choice: Comparing the evolution of India’s aadhaar and China’s social credit system as technosocial discourses”, *Social Science Computer Review*, 38(1), 25-41.

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	High 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
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
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.	
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	
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	

Table C: Descriptive statistics

Variables	No. Obs	Mean	SD	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**	5,66E+07	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 investement	**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

Table D: First stage regression

	ICT Usage
Liquid liabilities to GDP	0.00079
	(0.0004)
GDP per capita growth	0.0105
	(0.0032516)
Agriculture forestry and fishing	-0.0123
	(0.0068)
Total natural resources rents	-0.0049
	(0.0042)
Imports of goods and services	-0.0035
	(0.0018)
Exports of goods and services	0.0031
	(0.0021)
Population total	-3.29e-9
	(2.77e-09)
Computer access	**0.0045****
	(0.0022)
Internet user	**0.0109*****
	(0.0021)
No. of Obs.	821
No. of group	88
R-squared	0.39

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table E: Effect of ICT usage on tax instruments in the first period of study period (20005 – 2010)

	log (CIT)	log (PIT)	log (PT)	Log (VAT)	log (Excise)
ICT Usage	**0.4545**	**-1.0486**	**-5.4654**	**-0.3750**	**-1.2418**
	(1.2875)	**(0.9104)**	**(6.6180)**	**(0.4960)**	**(1.3408)**
Liquid liabilities to GDP	0.0017**	0.0021**	0.0213	-0.0002	-0.0012
	(0.0009)	(0.0009)	(0.0400)	(0.0004)	(0.0015)
GDP per capita growth	-0.0032	0.0122	0.0671	0.0046	0.0037
	(0.0105)	(0.0115)	(0.0625)	(0.0057)	(0.0115)
Agriculture forestry and fishing value add	-0.0175	-0.0146	0.0715	-0.0038	0.0062
	(0.0271)	(0.0171)	(0.0965)	(0.0089)	(0.0259)
Total natural resources rents	0.0447***	0.0151	0.1124	0.0025	-0.0106
	(0.0167)	(0.0152)	(0.0802)	(0.0048)	(0.0162)
Imports of goods and services	0.0065	-0.0025	-0.0184	0.0062**	0.0041
	(0.0065)	(0.0046)	(0.0197)	(0.0025)	(0.0059)
Exports of goods and services	-0.0116	0.0054	0.0067	-0.0040	-0.0022
	(0.0125)	(0.0081)	(0.0214)	(0.0032)	(0.0098)
Population total	7.01e-09	(-3.95e-09)	(-2.66e-8)	(-3.34e-9)	(-2.35e-08**)
	(7.48e-09)	(5.87e-09)	(3.96e-08)	(5.22e-09)	(9.54e-09)
No. of Obs.	273	344	219	298	301
No. of group	60	74	50	61	61
Anderson canonical cor. p-value (H0: under identification)	0.000	0.000	0.000	0.000	0.000
Sargan-Hansen p-value	0.939	0.573	0.781	0.879	0.941

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

Table F: Effect of ICT usage on tax instruments in the second period of study period (2011 – 2016)

	Log (CIT)	log (PIT)	log (PT)	Log (VAT)	log (Excise)
ICT Usage	**0.2236**	**0.2067******	**0.7901**	**0.1769****	**0.6695****
	(0.1714)	**(0.0712)**	**(0.6889)**	**(0.0815)**	**(0.3288)**
Liquid liabilities to GDP	-0.0042	0.0011	-0.0221	0.0038	-0.0073
	(0.0035)	(0.0026)	(0.0148)	(0.0042)	(0.0094)
GDP per capita growth	0.0093*	0.0041*	0.0023	0.0112***	0.0049
	(0.0055)	(0.0023)	(0.0218)	(0.0037)	(0.0060)
Agriculture forestry and fishing value add	-0.0291	-0.0138	-0.0206	0.0069	0.0058
	(0.0179)	(0.0102)	(0.0643)	(0.0180)	(0.0388)
Total natural resources rents	0.0122	0.0079*	-0.0789	0.0054	-0.0075
	(0.0127)	(0.0045)	(0.0718)	(0.0073)	(0.0132)
Imports of goods and services	-0.0018	0.0036	-0.0020	0.0116***	-0.0008
	(0.0046)	(0.0025)	(0.0247)	(0.0025)	(0.0096)
Exports of goods and services	0.0074	0.0004	-0.0004	-0.0103***	0.0103
	(0.0059)	(0.0034)	(0.0200)	(0.0040)	(0.0130)
Population total	7.69e-09	3.56e-09	1.77e-09	(-6.29e-09**)	3.37e-09
	(5.37e-09)	(3.54e-09)	(1.67e-08)	(2.85e-09)	(1.10e-08)
No. of Obs.	309	387	220	367	332
No. of group	57	74	44	67	62
Anderson canonical cor. p-value (H0: under identification)	0.000	0.000	0.000	0.000	0.000
Sargan-Hansen p-value	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: Digitalization of the tax administration of WAEMU member countries

Benin: Since March 2018, the DGI has been gradually implementing tele-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, tele-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 tele-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 tele declare their taxes 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 good performance of both direct and indirect taxes can be attributed in part to the generalization of tele-procedures including the development of applications such as "my personal space" e-tax and m-tax dedicated to improving the fiscal citizenship of the main business segments, e-VAT in the course of implementation to improve the control of VAT invoicing.

Togo: The togolais office of Recipes (OTR) has given a large place in its strategy to improve tax revenue mobilization to the development of tele-procedures while revenue collection is done through the banking system.

Source : Authors constructions

Table H: ICT readiness index construction (2016 edition)

Readiness index = 1/3 Infrastructure + 1/3 Affordability + 1/3 Skills

Pillar: Infrastructure

- Electricity production, kWh/capita
- Mobile network coverage, % population
- International Internet bandwidth, kb/s per user
- Secure Internet servers per million population

Pillar: Affordability

- Prepaid mobile cellular tariffs, PPP $/min.
- Fixed broadband Internet tariffs, PPP $/month
- Internet and telephony sectors competition index, 0–2 (best)

Pillar: Skills

- Quality of education system
- Quality of math and science education
- Secondary education gross enrollment rate, %
- Adult literacy rate, %

Source : The Global Information Technology Report 2016

Table I: ICT usage index construction (2016 edition)

Usage subindex = 1/3 Individual usage + 1/3 Business usage + 1/3 Government usage

Pillar: Individual usage

- Mobile phone subscriptions per 100 population
- Percentage of individuals using the Internet
- Percentage of households with computer
- Households with Internet access, %
- Fixed broadband Internet subscriptions per 100 population
- Mobile broadband Internet subscriptions per 100 population
- Use of virtual social networks

Pillar: Business usage

- Firm-level technology absorption
- Capacity for innovation
- PCT patent applications per million population
- ICT use for business-to-business transactions
- Business-to-consumer Internet use
- Extent of staff training

Pillar: Government usage

- Importance of ICTs to government vision
- Government Online Service Index, 0–1 (best)
- Government success in ICT promotion

Source : The Global Information Technology Report 2016