UNIVERSITY OF WUPPERTAL
BERGISCHE UNIVERSITÄT WUPPERTAL

EUROPÄISCHE WIRTSCHAFT UND INTERNATIONALE MAKROÖKONOMIK

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Digitalization as a Determinant of Tax Revenues in OECD Countries: A Static and Dynamic Panel Data Analysis

Europäische Wirtschaft und Internationale Wirtschaftsbeziehungen
European Economy and International Economic Relations

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December 14th 2020

JEL Classification: H20, H25, L81, L86
Key Words: Digitalization, taxation, tax revenues, ICT, OECD countries

Summary:

The tax challenges of digitalization have been to the forefront of national and international discussions on public revenues in recent years. The digital transformation is seen as being an exacerbating factor in the erosion of tax bases and the shifting of profits to low tax jurisdictions, particularly by multinational companies, thus reducing tax revenues for governments. While there is a large literature examining the role of ICT and digitalization in raising economic growth, productivity and other macroeconomic variables, the relationship between digitalization and tax revenues has been relatively understudied – despite being one of key drivers of what could be most significant change to international tax rules in a century. This study utilizes panel data covering OECD countries during the period from 1995 to 2018, and examines the effect of the rise of digitalization on tax revenues employing both static and dynamic panel data analysis techniques. The findings indicate that digitalization may have a negative impact on the ability of a country with high digital dynamics to generate higher tax returns.

Zusammenfassung:

Die steuerlichen Herausforderungen der Digitalisierung sind in den letzten Jahren in den Vordergrund der nationalen und internationalen Diskussionen über öffentliche Einnahmen gerückt. Die digitale Transformation wird als verschärfender Faktor bei der Aushöhlung der Steuerbemessungsgrundlagen und der Verlagerung von Gewinnen in Niedrigsteuergebiete, insbesondere durch multinationale Unternehmen, gesehen, wodurch die Steuereinnahmen der Regierungen sinken. Während es eine umfangreiche Literatur gibt, die die Rolle von IKT und Digitalisierung bei der Steigerung des Wirtschaftswachstums, der Produktivität und anderer makroökonomischer Variablen untersucht, ist die Beziehung zwischen Digitalisierung und Steuereinnahmen relativ wenig erforscht - und das, obwohl sie einer der Haupttreiber der möglicherweise bedeutendsten Änderung der internationalen Steuerregeln seit einem Jahrhundert ist. Diese Studie verwendet Paneldaten, die die OECD-Länder im Zeitraum von 1995 bis 2018 abdecken, und untersucht die Auswirkungen des Anstiegs der Digitalisierung auf die Steuereinnahmen, indem sie sowohl statische als auch dynamische Paneldatenanalysetechniken verwendet. Die Ergebnisse deuten darauf hin, dass die Digitalisierung einen negativen Einfluss auf die Fähigkeit eines Landes mit hoher digitaler Dynamik haben kann, höhere Steuereinnahmen zu generieren.

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EIIW Diskussionsbeitrag 285
EIIW Discussion Paper 285

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1. Introduction

The tax challenges of digitalization have been the focus of much research by academics and policymakers at both national and international levels in recent years (OECD, 2017). This has been particularly true since the Global Financial Crisis of 2007/08, when the public finances of many countries were strained in the face of rising debt and substantial deficits. Governments came under intense pressure from voters facing years of austerity and restrictive fiscal policy, i.e., rising taxes and falling government spending, leading many people to become disillusioned with globalization and to protest at what they perceived to be "unfair" taxation (this pressure also intensified over the decade from 2008–2018 as a result of reports based on numerous financial scandals including the leaking of documents concerning tax evasion and corruption such as the so-called Swiss leaks, LuxLeaks and Panama Papers). Thus, the issue of the erosion of national tax bases and the shifting of profit from high-tax to low-tax jurisdictions has been high on the policy agenda for some time. While digital firms are not exclusively responsible for base erosion and profit shifting (BEPS), it is argued that the process of digitalization exacerbates these issues (OECD, 2014, p. 13), reducing the base available for national governments on which to levy taxes.

Digitalization has significantly and irrevocably changed all economies across the globe over the last three decades in particular. The process of digitalization, the challenges and, to a much lesser extent, the opportunities it represents to economies have been hotly debated. The diffusion of the Internet, and information communication technologies (ICT) more generally, have been well documented in the literature. However, it has also long been argued that digitalization has a negative impact on the tax raising capabilities of national governments dealing with a new, digital world "without borders". One early warning on the negative impact of Internet-based activities with regard to tax revenues came from TANZI (1996). Tanzi identified various technological developments – namely aspects of digitalization such as e-commerce, electronic money and cross-border transactions - as being a form of "fiscal termite" which would ultimately erode and undermine the foundations of national tax systems and likely lead to a discernible fall in the ratio of tax revenue to GDP in many OECD countries (TANZI, 2000, p. 15). However, the question must be asked: Is there a "Tanzi paradox" to paraphrase the well-known Solow paradox - can the transformative process of digitalization be seen everywhere, except in the tax revenue statistics?

However, despite the recent focus on the tax challenges of digitalization by policymakers and in academia in recent years, digitalization has been little studied in the literature as a determinant of taxation with a lack of solid, data-based evidence for the flaws which have been asserted to exist in the current international tax system (OLBERT/SPENGEL, 2019).

This paper investigates the relationship between digitalization and tax revenues in OECD countries (covering all 36 OECD member countries as of 2019) as a contribution towards filling this gap. As a group of developed and advanced economies, the OECD has consistently been to the forefront of attempting to find a consensus-based, multilateral solution to the issues raised by BEPS and the tax challenges of digitalization since being tasked with this role by major global economies. Representing some of the most advanced (in broader terms) and most digitalized economies globally, the OECD is the natural starting point to examining this issue – with 8 of the top 10 countries for e-commerce sales globally

being OECD members (UNCTAD, 2019) and Internet intensity reaching saturation levels in many countries.

Understanding the role of digitalization in terms of tax revenues is a crucial issue to consider as the OECD attempts to reach a solution in late 2020 as intended. The importance of digitalization during the coronavirus crisis in 2020 (with millions of people worldwide working remotely, or engaged in e-learning and other online solutions) will again bring the challenges it presents to governments to the fore as states seek to recover from the deficits and rising national debt incurred during that crisis.

Using panel data over the period from 1995–2018, including a novel proxy for digitalization, the impact of advancing digitalization over time is examined in order to test Tanzi's "fiscal termite hypothesis" on the basis of the available macroeconomic data on tax revenue.

1.1 Digitalization

While an in-depth discussion of digitalization is beyond the scope of the present paper, it is worth making some observations on the dynamics of the process (for a broader discussion on digitalization see, e.g., CORROCHER/ORDANINI, 2002). The OECD describes the digital economy as the result of "a transformative process brought about by information and communication technology (ICT)" (OECD, 2013a, p. 11). Many forms of ICT have become general purpose technologies impacting and reshaping both economies and societies (OECD, 2013b). This process is also known as digitalization.

As Internet intensity rose from the mid-1990s (see Figure 1), traditional firms increasingly moved from a traditional "bricks and mortar" to a "clicks and mortar" business strategy, combining traditional stores and outlets with an online presence, and many new firms (based entirely online) emerged (e.g., Amazon (founded 1994), Yahoo and eBay (founded 1995), Google (founded 1998)). Fast-paced technological progress and falling real prices of ICT (WELFENS/PERRET, 2014) allowed ICTs to become ubiquitous within a very short period of time. Figure 1 shows how average Internet use grew in OECD countries particularly from 1994 on - displaying a familiar S-shaped curve for the diffusion of innovations (ROGERS, 2003). It is estimated that global e-commerce sales reached over $29 trillion in 2017 with 1.3 billion people engaging in e-commerce transactions, with growth in cross-border transactions (particularly likely to create taxing issues) outpacing growth in e-commerce over all in recent years – cross-border shoppers represented 15% of global online shoppers in 2015, but 21% in 2017 (UNCTAD, 2019; see also OECD, 2019c).

Digitalization is also a phenomenon which will continue to challenge governments and tax authorities into the future, with the so-called Fourth Industrial Revolution - involving developments such as big data, artificial intelligence, robotics, 3D printing and the Internet of Things - likely to mean that the challenges posed by digitalization to tax revenues shall continue if not even worsen over time.

Figure 1:   **Individuals using the Internet as Percentage of the Population, OECD Average, 1990–2017**

OECD Average Internet Use, % Population
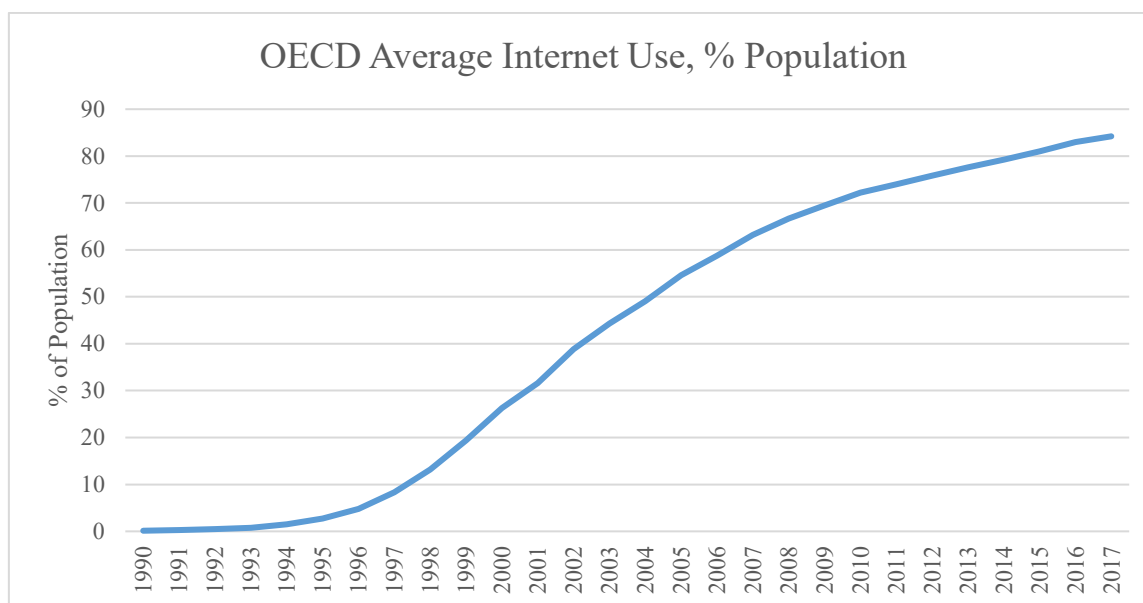
Source: Own representation of data from World Bank.

From Figure 1, one can see that average Internet use in OECD countries was relatively stable in the early 1990s, before Internet usage rates rose steadily from circa 1996 until the late 2000s as saturation intensities began to be reached in some countries, for example 98% usage in 2017 in Iceland, with Italy, Mexico and Turkey at the bottom of the OECD rankings with 63%, 64% and 65%, respectively.

1.2 The Tax Challenges of Digitalization

Within a few years of significant growth in terms of Internet usage in the early to mid-1990s, the role of ICT and e-commerce in particular came on the national and international policy agenda, with the OECD's 1998 Ottawa Ministerial Conference being the first international ministerial-level conference to deal with the issue of e-commerce (WYCKOFF/LOUX, 2019). However, in a survey of national responses to the challenge of taxing e-commerce in 2006, COCKFIELD (2006) shows that over the ten years from the mid-1990s to the mid-2000s, many countries had not enacted any significant legislation with regard to taxing the digitalizing economy. The result of this seeming inaction was that the digitalization of modern economies had "disturbed and outmanoeuvred taxes" (CORKERY ET AL., 2013, p. 1).

The effect of this lack of action – possibly due to a quasi "infant industry" motivation – was that the productivity gains associated with digitalization did not result in increased tax revenues, particularly for larger countries which have been "sorely tested" by the process (COLLIN/COLIN, 2013, p. 5). The tax challenges of digitalization are primarily related to corporate tax revenues and sales/value-added taxes on cross-border consumption with digital firms having the ability to take advantage of differentials in tax rates. Aspects of the new digitalized economies, which pose significant threats to the tax base and revenue collection of countries, include, but are not limited to corporation tax issues surrounding mobility (of

firms, users, assets), the use of data and intangibles in particular, network effects, platform models and cross-border transactions (for a broader discussion of specifics of the tax challenges of digitalization, see e.g., OECD, 2015; 2018; 2019b; SAND-ZANTMAN, 2018; KÖTHENBÜRGER, 2020). Meanwhile, digitalization also poses threats to the generation of value-added taxes as the share of e-commerce in overall retail sales continue to grow, in particular cross-border transactions which are difficult and costly to police by tax authorities. The rise of digitalization and the ease of modern communication also facilitate high income individuals relocating from high tax to lower tax jurisdictions also undermining personal income tax revenues.

In the aftermath of the Global Financial Crisis and with the onset of the sovereign debt crisis in certain countries in Europe, the issue of fair taxation of multinationals began to come to the fore, with a new impetus being provided by the leaders of the G20 at the Los Cabos Summit, in Mexico, in 2012 and of the G8 at Lough Erne in 2013 as they stressed the need for governments to act in order to prevent base erosion and profit shifting (G20, 2012; G8, 2013) and from the OECD itself which had proposed work on the area of BEPS to the G20 prior to the Los Cabos summit. At the same time, expert working groups were commissioned to examine the issue of taxation and the digital economy at an international level (EUROPEAN COMMISSION, 2014; ITU, 2015).

Having received the political backing and financial support to proceed with an examination of issues surrounding BEPS, the OECD published an Action Plan, which detailed 15 areas which required particular attention, in 2013 (OECD, 2013a). The first of these areas, i.e., the OECD's Action Plan 1, tackled the tax challenges of the digital economy (OECD, 2014; 2015). With no consensus solution being found by the OECD in 2015, individual states took it upon themselves to proceed on a unilateral basis and enact various taxes and tax-related measures in order to try to generate additional tax revenue from digital firms. These measures generally take the form of turnover taxes, withholding taxes, alternative thresholds for the purposes of a permanent establishment (and thus a taxable presence) and specific measures targeting multinational firms, with measures being announced or enacted in, amongst others, the United Kingdom, France, Italy, Spain, Hungary, Turkey and Israel (for discussion of selected unilateral measures, see UN, 2017; HADZHIEVA, 2019; AGYROPOLOU, 2019) as well as proposals for a Digital Services Tax at an EU level from the European Commission (EUROPEAN COMMISSION, 2017; 2018). Having received a new mandate, work continues at OECD level to develop an international solution to the tax challenges of digitalization (OECD, 2018; 2019a). In October 2020, the OECD released the blueprints of its new "two-pillar" proposed approach to fairer international taxation for public consultation. The OECD proposals include measures designed to ensure more transparent and equitable taxation of large multinational firms include leading digital companies and digitalized economies (OECD, 2020b).

However, while many seem to accept that digitalization self-evidently poses a challenge to the tax generating capabilities of national governments, there are also analyses that question the notion that digitalization and digital firms pose a particular and pressing challenge in terms of tax (LEE-MAKIYAMA/VERSCHELDE, 2016; SCHOEN, 2018). In support of its own move towards an EU tax on digital services, the European Commission has argued that international digital firms faced an average effective corporate tax rate in the EU28 of just 9.5%, compared to the 23.3% effective corporate tax rate faced by "traditional" international firms (EUROPEAN COMMISSION, 2017). These figures have been called into question

by, amongst others, BAUER (2018), who notes that the figures used by the Commission do not even appear in the sources cited by the Commission in support of their claim and it is unclear how the Commission arrived at their suggested respective corporate tax rates. BAUER (2019) and LEE-MAKIYAMA/VERSCHELDE (2016) have argued that real-world data shows that digital firms indeed face effective corporate tax rates similar to more traditional, less digital firms (e.g., automobile manufacturers). Furthermore, recent studies of the tax planning of some firms reveal findings which seem difficult to reconcile with claims that digital firms face as more traditional firms, for example the case of Apple, with effective tax rates of key Apple subsidiaries of less than a tenth of one percent (TING/GRAY, 2019).

On the other hand, it is also broadly acknowledged that digitalization could also have a positive effect on tax revenues through direct and indirect channels. On the one hand, digitalization improves the performance of tax authorities through better software, online tax return filing, and better record keeping etc. improving both compliance on the part of taxpayers and more efficient tax collection (IMF, 2018). Digitalization can also be seen as a crucial driver of innovation and growth (OLBERT/SPENGEL, 2017). This role can indirectly improve revenue- raising capabilities of government. Digitalization is associated with economic growth, productivity, inward foreign direct investment, and international trade as will be explored in the subsequent literature review.

A brief look at average OECD tax revenues over the time period from the beginnings of the process of digitalization in 1990 to 2018, shows no prima facie evidence of tax revenues being undermined by fiscal termites, rather average tax revenues as a percentage of GDP in the OECD have risen by circa two percentage points over the same time period (with two noticeable periods of decline, namely the aftermath of the "dot-com" bubble and September 11th attacks in 2000/01, and the Global Financial Crisis from 2007/08).

Figure 2:   Average Tax Revenues OECD Countries as Percentage of GDP, 1990–2018
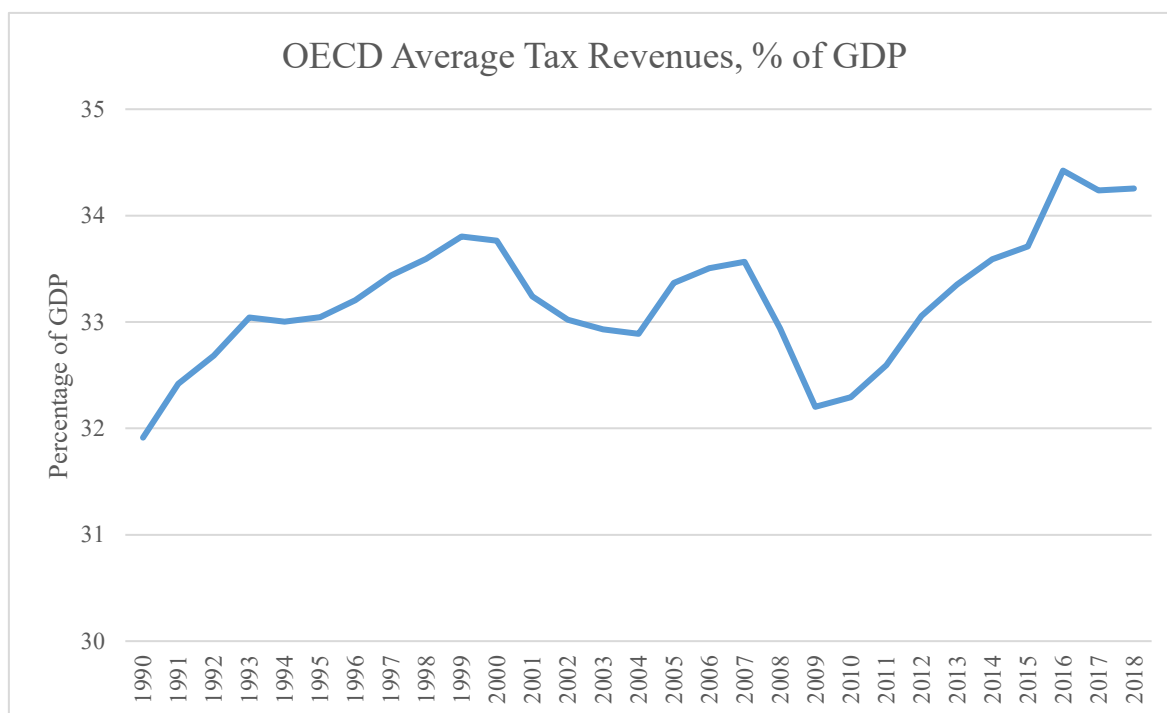
Source: Own representation based on data available from the OECD

Thus, the following questions can be asked: Does digitalization really undermine tax revenues? What role does digitalization play as a determinant of tax revenues in some of the most digitalized economies? This paper makes two main contributions to the literature. Firstly, by examining a relatively homogeneous grouping in terms of tax and digitalization in the OECD countries, who are also to the forefront of the search for an international solution to the challenges posed by digitalization, it avoids possible misleading conclusions which would be drawn from an analysis of more heterogeneous countries who are more disparate in terms of economic development, digitalization and tax capacity. The marginal effect of digitalization on tax revenues can be expected to be different for less developed countries with lower tax capacity than for more developed economies. Secondly, this paper employs a novel proxy of digitalization in IP allocation data which allows a broader measure of digitalization than more traditional measures used in the literature such as Internet usage statistics.

The rest of the paper is structured as follows: The subsequent section presents an overview of the literature on the determinants of tax revenue from a macroeconomic perspective. This is followed by a presentation of the data and methodology used in the present analysis and subsequently the empirical models used in the analysis. Following that, the results of the empirical analysis are presented and discussed. The paper concludes with a view on the policy options and ideas for future research.

2. Literature Review

The body of literature examining the determinants of tax revenues is broad. Many contributions have sought to examine the principal determinants of tax revenue and certain key determinants shall be presented here as some of these determining factors will be included in the subsequent empirical analysis.

ELTONY (2002), looking at panel data covering a selection of 16 Arab countries, finds inter alia that the level of economic development is a strong determinant of tax revenue mobilization. GUPTA (2007), using panel data to examine over 100 developing countries over a period of 25 years, has provided further supportive evidence for earlier findings that economic development in terms of GDP per capita is a strong determinant of tax revenue, as is trade openness. Furthermore, the sectoral composition of economies is related to tax revenue generation – in particular, the share of agriculture is negatively related to tax revenue. STOTSKY/WOLDEMARIAM (1997), who use panel data covering over 40 sub-Saharan African countries during the period from 1990–1995, show that the share of agriculture in GDP is significantly negatively related to tax share as are import and export shares (i.e., openness). KARAGÖZ (2013) – looking at Turkey - finds that the share of industry is positively related to tax revenues. Other contributions to the literature consider the level of public debt (TEERA/HUDSON, 2004) and socio-economic and institutional factors such as the level of political rights, civil liberties (BIRD ET AL., 2008) and education (PIANCASTELLI, 2001). More recently, ANGELESE-CASTRO/RAMIREZ-CAMARILLO (2014) providing further support for the findings of the previous researchers using a panel dataset covering OECD countries during the period from 2001 to 2011.

Many studies have also examined the macroeconomic effects of digitalization – usually employing a proxy indicator such as Internet usage intensity. Productivity gains related to Internet usage and diffusion have been identified in macroeconomic data (OLINER/SICHEL, 2000; JORGENSON, 2001; COLLECHIA/SCHREYER, 2002). At the same time, the Internet has been found to have a significant and positive impact on economic growth (NOH/YOO, 2008; SALAHUDDIN/ALAM, 2016). Other contributions have considered the impact of the Internet on international trade (XING, 2018; MEIJERS, 2014; VEMURI/SIDDIQI, 2009; BAUNSGAARD/KEEN, 2010), foreign direct investment inflows (CHOI, 2003) and inflation (YI/CHOI, 2005; CSONTO ET AL. (2019)) - who use the same data on IPv4 and IPv6 address allocations as the present study to construct a digitalization index in order to examine the impact of digitalization on inflation). Looking at ICT and income inequality, RICHMOND/TRIPLETT (2018) examine panel data covering 109 countries over the period 2001–2014 and find that the impact of ICT on income inequality varies by type of the type of ICT considered, whereby increases in fixed broadband subscriptions are associated on average with increases in income inequality, while increases in mobile phone subscriptions are associated on average with decreases in income inequality, with the former effect larger than the latter. JAUMOTTE ET AL. (2008) also find that income inequality in many countries has increased due to the biased nature of digitalization which raises the relative demand for, and thus wage premium of, skilled workers who possess the human capital required to fully exploit the benefits of these technological developments (on inequality issues, see also ALLEN, 2017).

Combining these two strands of the literature on the determinants of tax revenue and digitalization using macroeconomic data is a newly emerging field for research. Those studies which have looked at this issue have considered large samples of developed and developing countries, the highly digitalized with the less digitalized (where the marginal effects of increasing digitalizing on e.g., growth and tax revenues may be larger) and high tax countries with countries with lower overall tax burdens. KOYUNCU ET AL. (2016) explore the impact of ICT penetration on tax revenues. Looking at 157 countries and four indicators of ICT penetration, the authors find that ICT penetration does increase tax revenue across countries during the period 1990 to 2013. GNANGNON/BRUN (2018) consider their work to be the first study to investigate the linkage between a variable that they calculate as representing each country's "Internet gap" (i.e., the ratio of a country's internet usage intensity to the world average internet usage intensity) and public revenue mobilization in a sample of 164 countries for the period from 1995 to 2013. Their analysis suggests that by reducing the Internet gap, countries can raise their public revenues with low-income countries standing to benefit the most. Meanwhile, GNANGNON/BRUN (2019) analyze the impact of the Internet on resource versus non-resource revenue for 99 countries over the period 1995–2015, finding that a higher Internet usage intensity has a negative effect on resource revenue and a positive effect on non-resource revenue (with the impact of the Internet being higher for less developed countries). The OECD, as a more homogenous group in terms of economic development, digitalization and the tax burden, while also being to the fore in examining the issue of the tax challenges of digitalization, is an interesting sub-group for the subsequent analysis.

3. Methodology

3.1 Measuring Digitalization

The impact of digitalization on tax revenues is examined using a model where the explanatory variables are standard in the existing literature on the determinants of tax revenue with the exception of the variable of interest – a singular measure of digitalization. In the literature, a number of variables have been found to be significant determinants of public revenues as discussed in the literature review, namely the level of economic development, sectoral composition, international openness, as well as socio-economic factors including life expectancy, health, education and political and civil rights of residents.

Trying to measure digitalization has proved a difficult task. While many individual indicators exist, it is rarely possible to get a complete picture without combining several indicators. Many attempts have been made, primarily by international organizations, to measure digitalization to allow cross-country comparison. First published in 1997, a pioneering attempt was made by the International Data Corporation and its Information Society Index covering 53 countries. Since then, a number of broadly similar indices have been published by the World Economic Forum (Networked Readiness Index from 2002, Knowledge Economy Index from 2005), the International Telecommunications Union (ICT Development Index from 2002, Digital Access Index from 2003, Digital Opportunity Index

(now known as the ICT Development Index) and the ICT Opportunity Index from 2005), the United Nations (Technology Achievement Index from 2001, E-Government Development Index from 2002, ICT Diffusion Index from 2006) and the EU (Digital Economy and Society Index from 2014) with a variety of countries, indicators and sub-indicators and time periods covered (for more, see KONONOVA, 2015).

Meanwhile, CORROCHER/ORDANINI (2002) created a synthetic index and used their index to determine a "digital divide" by means of the standard deviation of each country's result from the mean. More recently, some researchers have compiled digitalization indices for their own research. KATZ ET AL. (2014) construct an index comprised of six components (affordability, infrastructure reliability, network access, capacity, usage and human capital) and 24 sub-indicators. CAMARA/TUESTA (2017) have created the DiGiX, a digitization index, with six principle dimensions (infrastructure, households' adoption, enterprises' adoption, costs, regulation and contents) and 21 sub-indicators, for 100 countries in 2016 with a ranking for that year based on data for 2015.

The varying nature of individual indices from year to year (where new indicators have been added, other indicators dropped etc. – consider the rise of mobile internet and the role of apps in recent years which are not reflected in earlier years), or the relatively small number of sample years available means that such synthetic indices are not conducive to be used for an analysis over a longer time period.

This paper adapts the proxy used in CSONTO ET AL. (2019) – i.e., the number of internet protocol (IP) addresses allocated per country as a measure of digitalization. An IP address is a numerical label or identification key which is assigned to every device connected to a computer network communicating using internet protocol – i.e., every device connected to the internet including desktop computers, laptops, tablets, smartphones and networked devices such as printers, scanners etc.

With the exponential growth of Internet usage and the progress of digitalization, the number of devices connected to the Internet and thus the demand for the number of IP addresses has also grown exponentially. In use since the 1980s, IPv4 allows for 232 IP addresses. Meanwhile, with a view to the growing demand, IPv6 was introduced in 2012 as a parallel network and allows for 2128 IP addresses, thus ensuring a supply of addresses to meet growing demand, as internet diffusion continues and the Internet of Things continues to see more and more devices connected to the internet, from household appliances to cars. Since its introduction, the allocation of IPv6 addresses has also grown dramatically (see Figure 3; a table with all OECD countries ranked according to their IP address allocations for 2018 can be found in the appendix, Table 5) with IP addresses being allocated by the Regional Internet Registry to service providers or private or public entities. Following the introduction of iOS and Android operations systems in 2007 and 2008, respectively, the rapid diffusion of smartphones globally over the following years can be seen in the striking growth in IP address allocations (on smartphone diffusion, see CHO (2015) and GÜNDÜC (2019)).

Figure 3:   Average Number of IP Addresses Allocated per Capita in the OECD
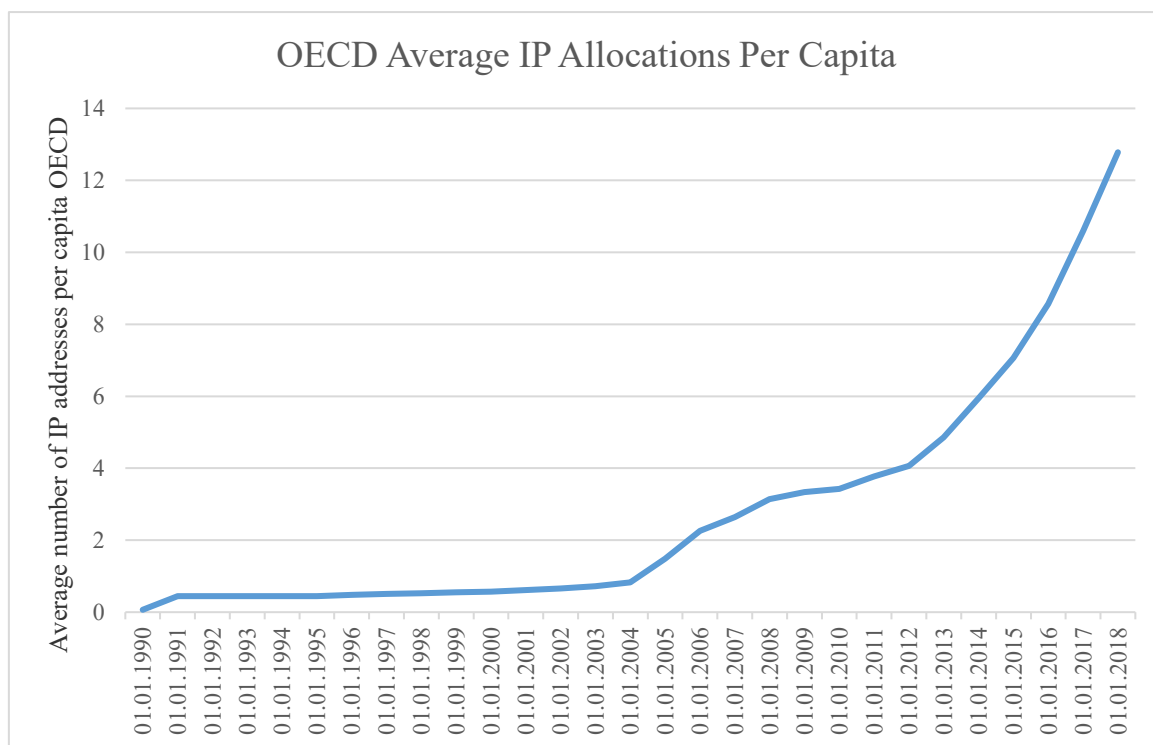
Source: Own representation based on data available from the APNIC.

Thus, the IP address allocation data allows for a good proxy of digitalization with advantages over other common proxies. Internet intensity/usage (e.g., percentage of the population) does not capture the true diffusion of digital technologies. A single person reporting having used the Internet could have access to the Internet at work, but not at home (or vice versa). The person could have a single desktop computer, which is a different circumstance from an individual with multiple connected devices (i.e., highly digitalized) each with a separate IP address. The same goes for the sheer number of connected devices in smart homes etc. Using IP data also avoids the problem – common to the most frequently used measures or indices of digitalization in the literature - of the addition or dropping of indicators with the emergence of new technologies or devices, i.e. a modern smartphone in 2017 is allocated an IP address in the same way as a desktop personal computer in 1995. However, there are also some caveats: Firstly, the allocation of IP addresses does not perfectly reflect actual usage. Secondly, in some circumstances a single IP address may, by way of a network address translator, be shared by a number of separate devices. Thirdly, where no allocation has been recorded, it does not definitively mean that no connected devices are being used in a particular jurisdiction. However, these caveats are not of sufficient concern to invalidate the usage of the data as a proxy (as also argued in CSONTO ET AL., 2019).

Data on IPv4 and IPv6 allocations is provided by the Asia-Pacific Network Information Centre (APNIC) which has data for almost 200 countries and territories with data on IPv4 from 1990 and on IPv6 from 2009 – data is available on a monthly basis. While CSONTO ET AL. (2019) use high frequency data (monthly) to construct an index of digitalization based on growth rates per country, for the purposes of the present study, we use annual data (i.e., the number of IP addresses as of 1 January (or closest available date) each year as the macroeconomic data is frequently only available on an annual basis.

3.2 Data

The dataset used in the present study is a panel of 36 members of OECD members (as of 2019) covering the period from 1995 to 2018[1]. An overview of the variables is provided in Table 1 (while a brief description of each variable and its source is available in the appendix – Table 4).

Table 1:   Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
TaxRev	860	33.318	7.508	9.912	48.917
LnGDPpc	862	10.269	0.676	8.545	11.615
TradeGDP	862	90.293	53.311	16.679	408.362
AgriGDP	847	2.749	2.058	0.214	16.855
IndustGDP	847	25.633	5.338	10.517	41.107
GovtDebtGDP	839	57.668	38.632	3.664	237.115
UrbanPop	862	75.939	11.18	50.622	98.001
Unemployment	862	7.805	4.142	1.805	27.466
inFDIGFCF	855	0.22	0.444	-1.647	4.313
Inflation	862	3.707	7.741	-4.478	89.113
PolRights	862	1.194	0.581	1	5
CivLib	862	1.447	0.769	1	6
BankingCrisis	862	0.122	0.327	0	1
SovCrisis	862	0.013	0.112	0	1
POPgrowth	826	0.552	0.781	-2.233	2.963
Digital	858	3.295	5.574	0	50.145

Source: Own representation.

The dataset is comprised of economic, institutional, specialization and social determinants of tax revenue, most of which are commonly used in the literature. In addition, our variable of interest is added, as are dummy variables to represent banking crises and sovereign debt crises.

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[1]After initial reviews of the data, two observations were dropped from the analysis. Firstly, the data for Iceland for the year 2016. Due to an exceptional item of tax revenue – "stability contributions" - related to banks and credit institutions which amounted to over 17% of 2015 GDP - resulting in a tax revenue to GDP rate of over 50% in 2016, compared to 35% in 2015, and 37% in 2017 (for more, see BALDURSSON ET AL., 2017). Also dropped was one observation for Luxembourg which preliminary tests showed high residuals and leverage making it a significant outlier in the data.

LnGDPpc is the natural log of GDP per capita (in 2010 international dollars) as a measure of the economic development of an economy (GUPTA, 2007). In the literature on the determinants of tax, this variable is expected to have a positive sign, as economies grow they tend to become more formalized and thus easier to tax, rising GDP per capita also reflects an advantageous stage of the economic cycle which should, amongst others, generate more profits and income and thus higher taxes (CLAUSING, 2007). However, many of the contributions which make this finding consider developing countries. In developed economies, where tax revenues as a share of income tend to already be relatively high (such as the OECD), and in crisis years, during which governments follow expansive fiscal policy to support economic growth and reduce the tax burden, the variable could also have a negative sign (see, e.g., ARNOLD ET AL., 2011; BIRD ET AL., 2008).

TradeGDP is the sum of imports and exports of both goods and services as a percentage of GDP. This variable serves as a proxy of the openness of an economy and is expected to have an ambiguous effect on tax revenues (ANGELES-CASTRO/RAMIREZ-CAMARILLO, 2014). On the one hand, higher levels of trade are a sign of openness and competitiveness which should reflect a formal economy and a good opportunity to generate higher tax revenues (for example, directly via tariffs, and indirectly via overall economic growth). On the other hand, the sample of countries in the present study are characterized by high levels of openness, integration and low barriers to trade which should mean that, particularly the direct channel, should not result in significantly higher tax revenues.

AgriGDP is the share of agriculture, forestry and fishing value-added as a percentage of GDP. The share of agriculture in value-added is expected to be negatively related to tax revenues based on the literature, as the sector is difficult to tax - with a high share of self-employed individuals and small and medium enterprises and shadow economy effects (GUPTA, 2007).

Industry is the share of industry value-added as a percentage of GDP. This is expected to have a positive effect as it reflects a more formal, advanced sector of the economy which is easier to tax and which creates a larger tax base (ELTONY, 2002).

GovtDebtGDP is General Government Gross Debt as a percentage of GDP (TEERA/HUDSON, 2004). On one hand, government debt could have a positive effect on tax revenue, as government seeks to increase tax revenues in order to service the costs of servicing increasing debt. On the other hand, government debt could also be used to finance public spending, and governments may wish to borrow to fund spending in a favorable interest rate environment rather than raise taxes in a period of expansive fiscal policy.

Urban Pop considers the percentage of the overall population living in urban settings. This is expected to have a positive effect on tax revenue. Firstly, a higher percentage of the population living in urban areas indicates a higher level of industry, a larger service sector and a lower share of agriculture (GUPTA, 2007). Secondly, a higher share of urban-dwellers reduces the costs for tax authorities to enforce tax compliance.

Inward FDI/GFCF relates to inward foreign direct investment (FDI) relative to gross fixed capital formation (GFCF). This variable could have a negative effect on tax revenues as higher inward GDI could reflect government approach of using tax policy and other fiscal incentives in order to attract FDI from investors abroad (CASSOU, 1997). On the other hand, higher levels of inward FDI could also be a sign of an economy which is competitive on

global markets and of the confidence of investors in the stability, including the fiscal sustainability, of a country (GUGLER/BRUNNER, 2007).

Inflation can reduce tax revenues in real terms due to the time lag between the tax debt being incurred and the government actually collecting revenues (GNANGNON/BRUN, 2019). This phenomenon is known as the Olivera-Tanzi effect (see, e.g., TANZI, 1977).

Political Rights and *Civil Liberties* are expected to be positively related to tax revenues (ANGELES-CASTRO/RAMIREZ-CAMARILLO, 2014). In democratic states with high levels of civil liberty, taxpayers may be more likely to willingly cooperate with state authorities to contribute to public coffers and have a lower incentive to seek to avoid or evade taxes (ALM/TORGLER, 2006). Strong state protection of individual rights also extends to property rights etc. which are conducive to functioning markets. In this instance a positive relationship will be indicated by a negative sign of the correlation as lower marks for political rights and civil liberties indicate a better performance in those areas.

Population Growth is used here as a proxy variable for social development and is expected to be positively related to tax revenues. Many factors contribute to a growing population including low levels of infant mortality, higher life expectancy, a (relatively) stable birth rate and immigration. The above factors reflect an economy with a functioning and adequate social security system, health care system and a high standard of living, while a growing economy may attract inward migration (BAHL, 2003; GNANGNON/BRUN, 2019).

Banking Crisis and *Sovereign Debt Crisis* are dummy variables which take the value of 1 for the years a particular country was experiencing either a banking crisis (e.g., for many of the OECD countries this covers the Global Financial Crisis of 2007/8–2012) or a sovereign debt crisis. As can be seen in Figure 2, average tax revenues in the OECD fell by almost 1.5 percentage points from 2007 (33.6%) to 2009 (32.3%) before rising from 2010 on. Therefore, the effect of these two dummy variables is *ex ante* ambiguous. Some countries responded to the crises by implementing austerity measures and raising taxes in order the stabilize public finances particularly in relation to rising interest rates and debt levels (BOZIO ET AL., 2015) whereas banking crises are also associated with a decline in tax revenues (ROGOFF/REINHART, 2008; LIMBERG, 2020). To construct the dummy variables, information on the years individual countries experienced a crisis was taken from the data on systemic crises from LAEVEN/VALENCIA (2018) and the Systemic Banking Crises Database II of LAEVEN/VALENCIA (2020).

Digitalization is our primary variable of interest and as discussed previously is a measure of the number of IP addresses (IPv4 and IPv6) allocated per capita. This variable has been used in CSONTO ET AL. (2019). On the one hand, digitalization should have a positive effect on tax revenue via the direct and indirect channels. On the other hand, a highly digitalized economy could see a negative relationship, as digitalization exacerbates the problems of tax base erosion and profit shifting. A correlation matrix for all variables is included in the appendix (Table 6).

3.3 Empirical Model

The empirical model estimated is based on the literature, theoretical considerations and the hypothesis that digitalization is a relevant determinant of tax revenues. Thus, panel data analysis is deemed to be the most appropriate approach.

Static Analysis

The following regression is estimated (with subscripts i and t representing each country and time period, respectively):

$$TaxRev_{it} = \beta_0 + \beta_1(LnGDPpc_{it}) + \beta_2(AgriGDP_{it}) + \beta_3(TradeGDP_{it}) + \beta_4(IndustGDP_{it}) + \beta_5(GovtDebtGDP_{it}) + \beta_6(UrbanPop_{it}) + \beta_7(Unemployment_{it}) + \beta_8(inFDIGFCF_{it}) + \beta_9(Inflation_{it}) + \beta_{10}(POPgrowth_{it}) + \beta_{11}(PolRights_{it}) + \beta_{12}(CivLib_{it}) + \beta_{13}(BankingCrisis_{it}) + \beta_{14}(SovCrisis_{it}) + \beta_{15}(Digital_{it}) + \eta_i + \delta_t + \upsilon_{it}$$

where η_i are time invariant unobservable country-specific effects, δ_t are time effects and υ_{it} the error term.

To determine the model specification, we begin with the standard pooled ordinary-least-squares method (POLS), followed by a fixed effects (FE) method – using diagnostic tests, it is determined that the fixed effects model is preferable to the POLS and a random effects (RE) model using the standard F-test and Hausman test (HAUSMAN, 1978) test. Following further diagnostic tests, it was determined that time-fixed effects should be included in the model and that there is a presence of heteroscedasticity (modified Wald statistic), cross-sectional/temporal dependence (using Pesaran's test for cross-sectional independence (PESARAN, 2004)) and serial correlation in the error term (Wooldridge test for autocorrelation). Therefore, the Pooled OLS and FE model are estimated with DRISCOLL/KRAAY (1998) standard errors which account for and correct standard errors given these characteristics.

Dynamic Analysis

Extending the static analysis to a dynamic panel data analysis by including a lagged dependent variable on the right hand side is important for two reasons: Firstly, the inclusion of a lagged dependent variable in the model is required in order to examine the relationship between previous values of tax revenue as a percentage of GDP on current year values. In the literature, it has been found that prior tax revenues are a determinant of current revenues. Secondly, it is needed to test the possibility that an omitted lagged dependent variable is causing model misspecification and giving rise to autocorrelation. Thus, an extended General Method of Moments estimator is applied as proposed by BLUNDELL/BOND (1998) which uses lagged differences of Y_{it} as instruments for equations in both levels and first differences, i.e., the system GMM estimation (or sys-GMM). To allow this dynamic panel data analysis, it was required to take a sub-sample, which was done on the basis of time. For this purpose, the sys-GMM was applied to the data for the years 2007 to 2018, the period in which the average allocation of IP addresses per capita, our variable of interest which acts as a proxy of digitalization, increased substantially across the OECD (see Figure 3). Reducing the time period analyzed is also necessary to avoid instrument proliferation and to ensure that the short N, long T requirement is met. The sys-GMM estimator is based on the assumption that disturbances are not serially correlated, as otherwise the estimator would be inconsistent. Thus, tests of autocorrelation up to order 2 in the first-differenced residuals

are required. The test of serial correlation in the first-differenced residuals is consistent with the maintained assumption of no serial correlation. The AR(2) test fails to reject the null hypothesis that the first-differenced residual error term is not second-order serially correlated, while the AR(1) test rejects the null (at 5 per cent level of significance). The results of the sys-GMM dynamic panel data are presented in Table 3.

4. Empirical Results

Two estimation methods are employed: pooled OLS and fixed effects (FE) in a static analysis. Both specifications include year dummies; standard errors are robust to arbitrary heteroscedasticity and serial correlation. The results of the chosen estimators (Pooled OLS with Driscoll-Kraay Standard Errors (model 1) and Fixed Effects with Driscoll-Kraay standard errors (DKSE) (model 2) presented in Table 2.

Table 2:   **Results of the Static Model**

	(1)	(2)
	Pooled OLS DKSE	**Fixed Effects DKSE**
LnGDPpc	7.422***	-5.525***
	(0.389)	(0.941)
TradeGDP	0.01**	-0.001
	(0.004)	(0.005)
AgriGDP	0.02	-0.903***
	(0.162)	(0.123)
IndustGDP	-0.232***	-0.08*
	(0.065)	(0.042)
GovtDebtGDP	-0.011***	0.032***
	(0.004)	(0.003)
UrbanPop	0	0.081***
	(0.02)	(0.028)
Unemployment	0.286**	-0.134***
	(0.122)	(0.029)
inFDIGFCF	-0.831	-0.005
	(1.007)	(0.148)
Inflation	0.312***	-0.015
	(0.053)	(0.019)
PolRights	-3.273***	-0.047
	(0.577)	(0.306)
CivLib	-0.022	-0.052
	(0.519)	(0.158)
POPgrowth	-3.07***	0.563**
	(0.398)	(0.248)
BankingCrisis	-1.705**	-0.452**
	(0.63)	(0.162)
SovCrisis	1.17	1.91***
	(0.917)	(0.447)
Digital	-0.218***	-0.074***
	(0.047)	(0.011)
Cons	0	89.524***
	(0)	(11.581)
Observations	787	787
(Within) R squared	0.4864	0.3475
Year Fixed Effect	Yes	Yes

Standard errors are in parentheses.
***p<0.01, **p<0.05, * p<0.1

Table 3:   Sys-GMM Dynamic Panel Data Analysis 2007–2018

TaxRev	Sys-GMM
TaxRev$_{t-1}$	1.169***
	(0.124)
LnGDPpc	-2.484*
	(1.321)
TradeGDP	-0.003
	(0.004)
AgriGDP	-0.139
	(0.133)
IndustGDP	-0.018
	(0.046)
GovtDebtGDP	0.007
	(0.005)
UrbanPop	0.012
	(0.019)
Unemployment	-0.135*
	(0.077)
inFDIGFCF	0.045
	(0.164)
Inflation	-0.049
	(0.038)
PolRights	0.363
	(0.416)
CivLib	-0.227
	(0.334)
POPgrowth	0.613
	(0.389)
BankingCrisis	0.442
	(0.236)
SovCrisis	0.449
	(0.615)
Digital	0.059*
	(0.031)
Constant	20.292*
	11.651
Number of obs.	786
Number of groups	36
Number of instruments	32
AR(1)	0.000
AR(2)	0.467
Hansen test	0.545

Standard errors are in parentheses.
***p<0.01, **p<0.05, * p<0.1

In terms of the static analysis which examined the determinants of tax revenues for 36 OECD countries over the period from 1995 to 2018, the results are broadly in line with expectations. The coefficient for GDP per capita is negative and significant at the 1 per cent level. The share of value added contributed by agriculture is also negative and significant at the 1 per cent level, as is the unemployment level. The coefficients of the share of the urban population, the sovereign debt crisis and the level of government debt to GDP all have a positive sign and are all significant at the 1 per cent level, with population growth positive at the 5 per cent level. Meanwhile, the existence of a banking crisis is negatively related to tax revenues at the 5 per cent level. While this is in line with the theory (see LIMBERG, 2020), caution is needed in interpreting the relationship as data on the digitalization proxy was unavailable for the United States and Canada for the years 2008 and 2009 which may have impacted the results.

While GNANGNON/BRUN (2018) consider an "Internet gap" (i.e., the ratio of a country's internet usage intensity to the world average internet usage intensity) and tax capacity in a sample of 164 countries, their findings suggest that by reducing the Internet gap, countries can raise their public revenues with low-income countries standing to benefit the most. GNANGNON/BRUN (2019) examine the Internet on resource versus non-resource tax revenue for 99 countries, finding that a higher Internet usage intensity has a negative effect on resource revenue and a positive effect on non-resource revenue (again with the impact of the Internet being more significant for less developed countries). In the present study, the variable of primary interest, a broader proxy measure of digitalization, is negative and significant at the 1 per cent level in the static analysis. This indicates that digitalization may indeed have a negative effect on the ability of governments in relatively highly digitalized and high tax jurisdictions to raise taxes – providing some evidence in support of Tanzi's fiscal termite warning. Thus, digitalization may indeed be exerting downward pressure on revenues generated which may be a factor in explaining the role of policymakers in OECD countries pushing, via the OECD itself and the OECD/G20 framework, for a multilateral solution to the tax challenges of digitalization.

Based on the dynamic analysis of the subsample of 2007–2018, most variables maintain the sign of their coefficient but lose significance. It can be noted that the lagged dependent variable is positive and significant at the 1 per cent level, showing prior year values of the overall tax burden are good determinants of current year values as expected according to the literature. However, in the dynamic analysis for the subsample of 2007–2018, the variable of interest, namely digitalization, is now positively related to tax revenues but only at the 10 per cent level, contrary to what could be expected in line with Tanzi's fiscal termite prognosis. This suggests that the rapidly increasing digitalization in more recent years (with the diffusion of mobile devices etc.) has in fact had a positive effect on tax revenues. Thus, the findings for digitalization across both the static and dynamic analyses here are ambiguous and must be interpreted with caution. However, the findings are interesting and may nevertheless be useful in the policy debate as they may temper overly positive or negative attitudes on digitalization and tax capacity.

One question that could be raised concerns the argument that macroeconomic data such as gross domestic product, and by extension tax revenues as a percentage of GDP, are increasingly being misstated due to, for example, zero priced digital services and the role of prosumers (WELFENS/PERRET, 2014; AHMAD ET AL., 2017; MOULTON, 2018;

ITKONEN, 2019; OECD 2020a). Even a minor restatement of GDP upwards to reflect the realities of the modern digitalized economy, could see tax revenues (expressed as a percentage of GDP) plateauing or even falling. A better denominator for expressing comparable tax revenues across countries may better facilitate using macroeconomic data to analyze the true effects of digitalization on tax revenues.

It may be hard for policymakers to maintain broad support for new digital taxes when tax revenues are already seen to be stable or rising, particularly when digital firms with market power can pass the burden of new taxes completely on to users. If digitalization does indeed pose a threat to tax bases, governments must ensure the best possible data is available to support this argument.

5. Policy Conclusions and Research Perspectives

The present paper contributes to the literature by placing a specific focus on OECD countries and examining macroeconomic determinants of tax revenues in a departure from previous contributions to the literature. It is found that digitalization may indeed have a negative impact on developed and highly digital countries' tax revenues, possibly supporting the position of national governments in seeking to find a new multilateral solution to the tax challenges of digitalization. However, results should be interpreted with caution considering the effect found in the static and dynamic analyses.

The findings lend support to previous findings in the literature that a country with high GDP per capita, a low share of inward FDI in relation to gross fixed capital formation, a sizeable industrial sector relative to the agricultural sector, an urbanized and growing population and the protection of civil liberties and democratic institutions is more likely to be in a position to generate higher tax revenues. Meanwhile, high levels of unemployment and the existence of a banking crisis may have a negative effect on tax revenue generation.

While digitalization and its impact on tax revenues have been to the forefront of national and international discussions on public revenues in recent years, previous studies which have considered large samples of developed and developing countries have found that ICT (usually based on Internet intensity) is positively related to tax revenues – providing evidence against Tanzi's fiscal termite outlook and against the focus placed on digitalization and tax by policymakers, nationally, at an EU level and at the global level (OECD/G20). However, these results may be affected by the heterogeneity of these larger samples of developed and developing countries in terms of level of economic development, tax capacity and the extent of digitalization with the marginal gains for less developed countries possibly masking the effects for more developed and digitalized firms. Future research could consider to expand the sample of countries considered here, to include non-OECD countries which are highly digitalized.

Appendix

Table 4: **Definition and Source of Variable Used in the Analysis**

Variable	Definition	Source
$TaxRev_{it}$	Tax revenue as a percentage of Gross Domestic Product (GDP)	OECD
$lnGDPpc_{it}$	Log of GDP per capita of country i in year t in 2010 International Dollars	World Bank / World Development Indicators
$TradeGDP_{it}$	Sum of exports and imports of goods and services as % of GDP	World Bank / World Development Indicators
$AgriGDP_{it}$	Agriculture, forestry and fishing value-added as a % of GDP	World Bank / World Development Indicators
$IndustGDP_{it}$	Industry (including construction) value-added as a percentage of GDP	World Bank / World Development Indicators
$GovtDebtGDP_{it}$	General government gross debt as % GDP	World Bank / World Development Indicators
$UrbanPop_{it}$	Urban population as % of total population	World Bank / World Development Indicators
$inFDIGCF$	Inward FDI as a % of Gross Fixed Capital Formation	Own calculation using data from World Bank / World Development Indicators
$Unemployment_{it}$	Unemployment, total (as % of total labor force)	World Bank / World Development Indicators
$Inflation_{it}$	Annual consumer price inflation in percent	World Bank / World Development Indicators
$PolRights_{it}$	Political rights	Freedom House (2020)
$CivLib_{it}$	Civil liberties	Freedom House (2020)
$POPgrowth_{it}$	Growth rate of the total population in percent	Own calculation using data from World Bank / World Development Indicators
Banking Crisis	Dummy variable on annual basis if respective country experienced a banking crisis. Crises over 5 years are truncated at 5	Laeven and Valencia (2018, 2020)
SovCrisis	Dummy variable which takes the value of 1 in years when a country is experiencing a sovereign debt crisis. Crises over 5 years are truncated at 5	Laeven and Valencia (2018, 2020)
Digital	Digital penetration/intensity – allocation of IP addresses per capita	Own calculation based on data provided by APNIC

Source: Own representation.

Table 5:   **IP Allocations per Capita 2018**

Country	IP Allocations Per Capita 2018
Iceland	50.1452426
Sweden	41.3802219
Luxembourg	34.0464056
Netherlands	26.314549
Australia	25.4440285
Norway	24.9034517
Switzerland	21.3199972
United Kingdom	19.6373991
Germany	15.3133055
Denmark	14.7342418
Estonia	14.1491191
United States	13.8604189
France	13.1182164
Finland	12.5364134
Ireland	12.4845324
Czechia	11.3123851
Austria	11.0702509
Slovenia	10.3860394
Italy	9.17202016
Korea	8.8472736
Belgium	8.78872828
Poland	7.75557301
Latvia	7.06380967
Japan	6.63836143
Spain	6.22539814
Lithuania	5.57558953
Slovakia	5.46876682
New Zealand	4.43992795
Israel	3.89469461
Canada	3.10869289
Hungary	3.02623417
Portugal	2.82440967
Greece	2.13103752
Turkey	1.4729257
Chile	1.07825706
Mexico	0.4276671

Source: Own representation and calculations based on APNIC data.

Table 6: **Correlation Matrix**

Variables	TaxRev	Ln GDPpc	Trade GDP	Agri GDP	Indust GDP	Govt Debt GDP	Urban Pop	Unemp-loyment	inFDI GFCF	Infla-tion	Pol Rights	Civ Lib	POP growth	Banking Crisis	Sov Crisis	Digital
TaxRev	1.000															
LnGDPpc	0.465	1.000														
TradeGDP	0.189	0.149	1.000													
AgriGDP	-0.316	-0.586	-0.237	1.000												
IndustGDP	-0.356	-0.350	-0.179	0.123	1.000											
GovtDebtGDP	0.164	0.217	-0.261	-0.223	-0.254	1.000										
UrbanPop	0.092	0.432	-0.102	-0.126	-0.288	0.114	1.000									
Unemployment	0.061	-0.400	-0.050	0.175	-0.151	0.190	-0.253	1.000								
inFDIGFCF	0.067	0.159	0.459	-0.150	-0.160	-0.074	0.100	-0.046	1.000							
Inflation	-0.243	-0.408	-0.098	0.618	0.157	-0.173	-0.185	0.041	-0.053	1.000						
PolRights	-0.471	-0.477	-0.148	0.523	0.201	-0.088	-0.098	0.047	-0.101	0.621	1.000					
CivLib	-0.399	-0.540	-0.229	0.481	0.173	0.033	-0.101	0.157	-0.134	0.559	0.739	1.000				
POPgrowth	-0.166	0.368	-0.018	-0.017	-0.048	-0.162	0.407	-0.390	0.085	0.100	0.155	0.099	1.000			
BankingCrisis	-0.005	-0.002	0.072	-0.054	-0.125	0.108	-0.062	0.127	0.082	0.090	0.010	-0.009	-0.065	1.000		
SovCrisis	0.034	-0.046	0.030	0.010	-0.053	0.168	-0.001	0.218	-0.026	-0.050	0.069	0.015	-0.115	-0.011	1.000	
Digital	0.098	0.398	0.079	-0.270	-0.154	0.030	0.239	-0.242	-0.077	-0.151	-0.146	-0.242	0.205	-0.099	-0.010	1.000

Source: Own calculations

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