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Research article

The Role of Information and Communication Technology on Tax Revenue in Indonesia

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ABSTRACT

Taxes are a fundamental component of the economy, serving as a primary resource of revenue for governments across the globe. Tax revenues are essential for financing public expenditures such as education, healthcare, and infrastructure. This study aims to analyze the indirect relationship between information and communication technology (ICT) and tax revenue in Indonesia, specifically through tax compliance. We select ICT due to its established role as an integral part of society and helps streamline tax administration, including payment, reporting, and auditing. The data used in this study comprise panel data at the provincial level from 2018 to 2022. The tax indicator used is the tax ratio, while the ICT indicators include base transceiver station (BTS) infrastructure, and internet penetration. Utilizing the two-stage least squares (TSLS) method, this study finds that ICT has a positive correlation with the compliance ratio, and the compliance ratio, in turn, has a positive correlation with tax revenue. The implications of this study suggest the expansion of telecommunications infrastructure coverage across all regions of Indonesia and the utilization of technology in disseminating tax information to continually improve tax compliance and tax revenue mobilization.

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1. INTRODUCTION

Taxes are the primary source of revenue for countries worldwide, serving as a crucial means to finance government expenditures and support national development. Indeed, the core objective of taxation is to bolster revenue streams, allowing governments to invest in vital sectors like education, healthcare, social welfare, and infrastructure. These investments, as highlighted by Halim & Rahman (2022); and Rahman (2023), are fundamental for fostering sustainable development, while Arvin et al. (2021); Ho et al. (2023); and Segura (2017) emphasize their role in driving economic growth. Despite the critical importance of tax revenue, Indonesia faces persistent challenges, evident in its relatively low tax-to-GDP ratio (see Figure 1). This figure consistently falls short of the World Bank's 15% benchmark. This shortfall can be attributed to a confluence of factors, including limited access to technology, difficulties in tax compliance, complex regulations, the prevalence of informal economic activities, insufficient financial transparency, a lack of tax education and awareness, and the persistent issues of corruption and tax evasion (Sukarno, 2024). Importantly, a higher tax ratio also serves as a mechanism for reducing inequality through the redistribution of welfare (Duncan & Peter, 2016; and Scheuer & Slemrod, 2021). Consequently, Indonesia must implement diverse strategies to enhance its tax ratio, thereby bolstering its fiscal capacity and advancing the achievement of the Sustainable Development Goals (SDGs).

Tax revenue is essentially influenced by tariff and administrative factors (Basri et al., 2021). This fundamental principle underscores the delicate balance required in taxation. While tariffs

contribute to revenue, excessively high tax rates can, paradoxically, distort economic activity and ultimately reduce overall tax revenue, a phenomenon illustrated by the Laffer curve (Lin & Jia, 2019). The efficiency of tax collection is further determined by two key aspects: the policy gap and the compliance gap (Keen, 2013). The policy gap represents the difference between the potential tax revenue under existing policies, considering factors like tax rates, incentives, and exemptions. The compliance gap, on the other hand, highlights the discrepancy between the tax legally owed by taxpayers and the amount actually paid. This emphasizes the critical role of tax administration in bridging this compliance gap. Beyond revenue generation and collection efficiency, tax policy also aims for ease of administration and simplification, both of which are intrinsically linked to the effectiveness of the tax collection process (Tresch, 2015).

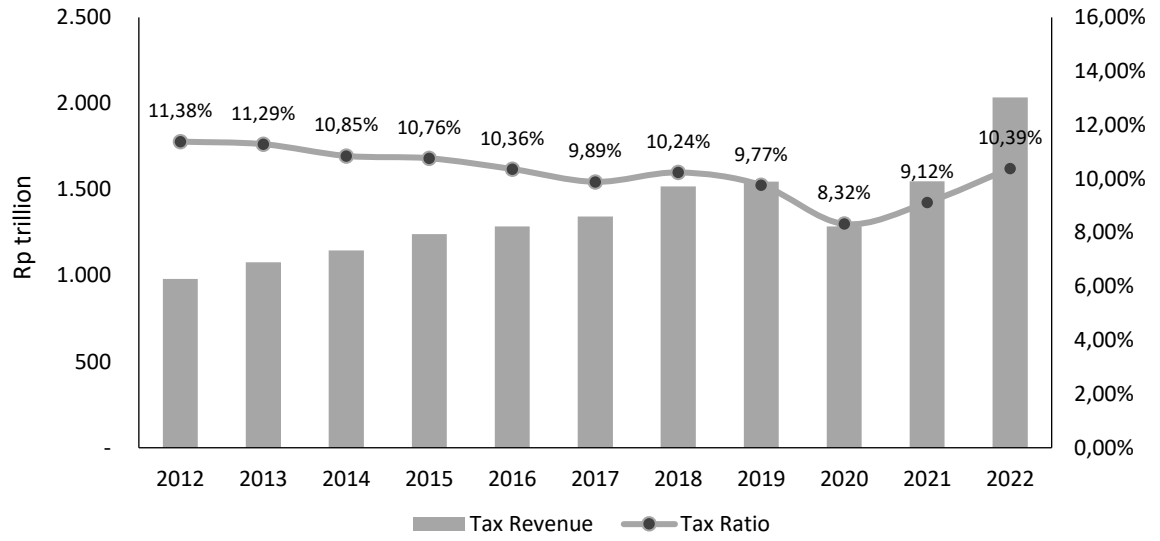


Figure 1. Tax Revenue and Tax Ratio in Indonesia
Source: Ministry of Finance

In the global literature, previous studies on the determinants of tax revenue have indicated that structural factors—such as GDP per capita, the share of the agricultural sector, the share of the mining sector, and the export-import ratio to GDP—significantly influence tax revenue (Anastasiou et al., 2024; Castro & Camarillo, 2014; Ha et al., 2022; and Rodríguez, 2018). However, relying solely on these factors presents challenges. Structural factors typically evolve slowly, making rapid revenue growth through their manipulation unlikely in the short term. Furthermore, simultaneously analyzing multiple structural factors requires careful consideration to avoid issues of overlap and multicollinearity (Bahl, 1971). Given these limitations, increasing tax revenue often requires exploring alternative approaches, particularly to non-structural factors or administrative issues (Akitoby et al., 2020). As governments worldwide face escalating fiscal pressures and rising demands for public services, finding effective strategies to strengthen their revenue bases is paramount. This issue holds particular relevance for Indonesia, where addressing these challenges is crucial for ensuring sustainable fiscal policy.

Against this background, one approach to simplifying tax administration and enhancing tax revenue is through the utilization of information and communication technology (ICT) (Bellon et al., 2022; Gnangnon & Brun, 2018, 2019; and Jemiluyi & Jeke, 2023). This approach is bolstered by the pervasive and rapid growth of ICT, which has become an integral part of modern society (Clercq et al., 2023; and Dufva & Dufva, 2019) and has significantly improved government capacity (Kochanova et al., 2020). Technology offers substantial benefits in this regard, including reducing costs, enabling the monitoring of diverse transactions, and streamlining critical processes such as payment, reporting, and auditing (Agrawal & Wildasin, 2020; and Ofori et al., 2022). Moreover, the widespread use of the internet has been shown to facilitate tax reform (Gnangnon, 2020), and effectively bridging internet access gaps can optimally enhance revenue generation (Gnangnon & Brun, 2018).

Additionally, technology plays a critical role in defining, monitoring, and facilitating compliance (Okunogbe & Santoro, 2023b). Indeed, technological advancements have demonstrably improved tax compliance and enhanced the reporting of sales, purchases, and Value-Added Tax (VAT) duties for businesses (Bellon et al., 2022; and Mascagni et al., 2021). For instance, Li et al. (2020) found that adopting modern information technology could increase corporate income tax compliance by a significant 25%. With robust systems in place, tax administrators can swiftly identify suspected tax evasion (Uyar et al., 2021). Consequently, leveraging technology is expected to provide governments with opportunities to achieve higher tax revenue with existing tax rates or maintain current revenue levels with reduced rates (Gupta et al., 2017).

Empirical evidence regarding the relationship between Information and Communication Technology (ICT) and tax revenue is varied. Some studies highlight a positive impact of ICT on tax revenue mobilization (Adegboye et al., 2022; Apeti & Edoh, 2023; and Ofori et al., 2022), emphasizing the need for supplementary measures such as policy collaboration and technical, logistical, and financial support to broaden ICT access and utilization. These studies also suggest that ICT indicators must reach specific thresholds and be integrated with other policies to maximize their effect on tax revenue (Adegboye et al., 2022). Conversely, Mallick (2021) found a negative impact of ICT on tax revenue, attributing this to factors like the digital divide and weak institutional frameworks. Existing studies on ICT and taxation in Indonesia are often limited to specific tax offices (Winoto et al., 2022; and Sadress et al., 2019), thus failing to capture the broader national context. While Priambodo et al. (2024) linked ICT to tax revenue, their focus on local taxes and retribution does not fully reflect the dynamics of central tax revenue in Indonesia. These discrepancies and mixed results highlight the complexity of the ICT-tax revenue nexus, particularly in cross-country studies with varying ICT adoption levels and socioeconomic conditions. Furthermore, most existing research directly analyzes this relationship without clearly explaining the mechanisms through which ICT influences tax revenue.

This underscores the need for a comprehensive study in Indonesia, a country characterized by its unique ICT infrastructure, regional disparities, and specific tax administration challenges. Therefore, this study aims to examine the relationship between ICT and tax revenue in Indonesia, addressing prior research gaps in several ways. Firstly, it introduces novelty by investigating the indirect relationship between ICT and tax revenue through the intermediary role of the tax compliance ratio. This indirect approach is based on the premise that ICT influences tax compliance (Li et al., 2020; and Mascagni et al., 2021); however, existing research has not extended this mechanism to assess its impact on tax revenue, especially within the Indonesian context. Secondly, this study utilizes BTS infrastructure and internet penetration as proxies for ICT, encompassing both the supply and demand sides. BTS infrastructure is chosen for its foundational role in telecommunications, enhancing mobile connectivity and internet access in Indonesia, and its novel application in taxation studies constitutes a key aspect of this research. Internet penetration is also selected due to its rapid growth in Indonesia (Badan Pusat Statistik, 2022). Finally, by employing the Two-Stage Least Square (TSLS) methodology, this study ensures a robust empirical analysis that mitigates endogeneity concerns and offers a clearer understanding of the pathways through which ICT contributes to tax revenue. Through these analyses, this study is expected to provide actionable policy implications for stakeholders on how ICT can serve as a key factor in improving tax compliance and increasing tax revenue in Indonesia. The remainder of this paper is structured as follows: the subsequent section outlines the research methods, followed by the results and discussions in the third section, and the conclusions in the final section.

2. RESEARCH METHODS

2.1. Data

This study utilized panel data from 33 provinces in Indonesia, spanning the period from 2018 to 2022. All data were secondary, sourced from various national institutions and surveys, including the Directorate General of Taxes (DJP), the Ministry of Communications and Informatics (KOMINFO), Statistics Indonesia (BPS), the Ministry of Public Works and Housing (PUPR), and the National

Socioeconomic Survey (SUSENAS). The dependent variable in this study is the tax ratio, a crucial measure for depicting a region's taxation performance as it accounts for the size of its economy. Our primary focus is on central taxes collected by the DJP. Given that the original unit level for this data is the Tax Service Office (KPP), it was necessary to aggregate KPP locations to align with their respective provinces. Consequently, the tax ratio for each province is calculated as its tax revenue divided by its Gross Regional Domestic Product (GRDP).

Table 1. The Description of Variables

Variables	Descriptions	Unit measurement	Source
TR	Tax revenue for each region	% of GRDP	DJP
COMPL	Ratio between the number of Annual Tax Returns (SPT) and the number of registered taxpayers who are required to submit SPT at the beginning of the year	%	DJP
BTS	Number of BTS for each region	Unit per 1 million population	KOMINFO
4G BTS	Number of 4G BTS for each region	Unit per 1 million population	KOMINFO
INT	Number of people who accessed the internet in the last three months for each region	% population	SUSENAS
LMI	Number of large and medium-scale industries for each region	Unit	BPS
GRDPC	Gross regional domestic product per capita	Rp million	BPS
FW	Number of formal workers for each region	Person	BPS
ROAD	Road length for each region	Km	PUPR
POPGR	Population growth for each region	%	BPS
COVID	Dummy of COVID-19 for each region	0: before 2020 and 1: after 2020	

For this analysis, we excluded the Special Capital Region of Jakarta (DKI Jakarta) due to observed anomalies. Taxes collected in DKI Jakarta do not entirely reflect the economic activities of Jakarta residents. This discrepancy arises because the registered residence locations of taxpayers are not always within DKI Jakarta, while most income tax payments are directed to Tax Service Offices (KPPs) based on company locations. Consequently, the analysis in this study spans 33 provinces. The independent ICT variables in this study are BTS (Base Transceiver Station) infrastructure and internet penetration. To standardize comparisons and account for regional population sizes, the BTS variable is transformed into BTS per 1 million population, thereby reducing potential bias in the analysis. We specifically focus on 4G BTS due to its strong correlation with internet access and its rapid expansion, making it a particularly relevant area for in-depth examination. Furthermore, to mitigate omitted variable bias, we incorporate multiple sets of control variables.

2.2. Model Specification

This study employs a two-stage least squares (TSLS) modeling procedure using instrumental variable-general methods of moment (IV-GMM), given that ICT may not directly influence tax revenue. IV-GMM is notable for producing asymptotically efficient errors (Baum et al., 2003). In the first-stage regression, we use ICT and lag of tax compliance ratio to be employed to assess the tax compliance ratio. The inclusion of ICT variables is well warranted, as previous studies have demonstrated that technology utilization contributes to tax compliance (Bellon et al., 2022; and Li et al., 2020). The inclusion of lag of tax compliance ratio is also a strategy to handle endogeneity; as the lagged variable is typically correlated with current values, precedes the current time, and cannot be directly influenced by the error term (Bellemare et al., 2017). In the second-stage regression, we utilize the predicted value of the tax compliance ratio to be regressed against the tax ratio. The model in this study can be expressed in equations (1) and (2) as follows:

$$COMPL_{i,t} = \alpha_0 + \alpha_1 ICT_{i,t} + \alpha_2 COMPL_{i,t-1} + \sum_{i=3}^{n} \alpha_i X_{i,t} + v_{i,t} \quad (1)$$

$$TR_{i,t} = \beta_0 + \beta_1 \widehat{COMPL}_{i,t} + \sum_{i=2}^{n} \beta_i X_{i,t} + \varepsilon_{i,t} \quad (2)$$

where, TR represent the tax ratio of province-i in period-t; $COMPL$ represents SPT reporting compliance; ICT denotes BTS and internet penetration; $COMPL_1$ *i*s the lag of tax compliance ratio; α and β are parameters; X represents control variables that are considered to take into account, such as (i) tax base (the number of large and medium scale industries (LMI)); (ii) economic development (GRDP per capita); (iii) employment (formal workers), (iv) public service delivery (road length); (v) demography (population growth); and (vi) COVID-19; the notation of $v_{i,t}$ and $\varepsilon_{i,t}$ are error components.

Several diagnostic tests will be conducted on the constructed model. First is the under-identification test, which examines the relevance of the instruments, with the null hypothesis being that the model is under-identified. Second is the weak identification test using the Cragg-Donald statistic. The IVs are considered suitable and strong if their statistics surpass the Stock and Yogo critical value of 10. Third, when using multiple IVs, the over-identification test using Hansen J-statistic should be performed to assess the validity of the instruments and whether they can be jointly utilized. The null hypothesis for this test is that the model is over-identified.

3. RESULTS AND DISCUSSION

3.1. Results

This sub-section is started with descriptive statistics for all dependent and independent variables, based on 132 observations across regions in Indonesia. As shown in Table 2, the highest tax ratio is 8.90% in Banten Province, while the lowest is 0.67% in North Kalimantan Province. If the Special Capital Region of Jakarta (DKI Jakarta) were included in the analysis, it would be an outlier with a tax ratio of 35.50%. Meanwhile, the province with the highest tax compliance is Bengkulu Province, at 98.92%, while the lowest is West Papua Province, at 51.59%.

Table 2. The Result of Descriptive Statistics

Variable	Obs	Mean	Std Dev	Min	Max
TR (%)	132	2.93	1.28	0.67	8.90
COMPL (%)	132	82.65	9.97	51.59	98.92
BTS	132	16,271.15	21,421.50	1,132.00	108,025.00
4G BTS	132	8,343.15	11,556.51	422.00	72,982.00
INT (%)	132	49.81	12.24	19.72	77.22
LMI	132	873.55	1,898.61	14.00	8,724.00
GRDPC (Rp Million)	132	61.29	38.36	19.63	245.52
FW	132	1,536,593.48	2,321,593.80	162,138.00	10,912,668.00
ROAD	132	16,342	10,045.75	4,338.00	42,521.00
POPGR (%)	132	1.32	3.36	-8.29	27.35

According to historical statistics from DJP and BPS, tax revenue increased to IDR 2,034.55 trillion by 2022, indicating an economic recovery from COVID-19, compared to the decline of 17.05% in 2020 when it fell to IDR 1,248.42 trillion." This recovery highlights a significant rebound in Indonesia's fiscal health. Domestic taxes, including excise, constituted the vast majority of this total at 95.53%, with international trade taxes making up the remainder. Within domestic tax revenue (excluding excise), the primary contributions came from Income Tax (PPh), which encompasses both Non-Oil and Gas Income Tax and Oil and Gas Income Tax, as well as Value-Added Tax (VAT) and Luxury Goods Sales Tax (PPnBM). Property Tax (PBB) contributed minimally to central tax revenue, largely because most of its authority has been delegated to provincial and municipal governments. Specifically, the central government manages the Property Tax for Plantation, Forestry, and and Mining (PBB P3), while regional governments oversee the Rural and Urban Property Tax (PBB P2).

Regarding ICT infrastructure, it was observed that certain areas, particularly in the regencies of Papua, lacked any 4G BTS until 2020. However, by 2021, every regency/city had at least one 4G BTS,

indicating a significant, albeit recent, expansion of coverage. In terms of internet penetration, two regions—Intan Jaya Regency and Deiyai Regency in Papua—still had no internet access at all in 2022. Conversely, the Riau Islands Province demonstrated the highest internet penetration at 77.22%, while Papua Province recorded the lowest at 19.72%, further highlighting the stark regional disparities in internet access across Indonesia.

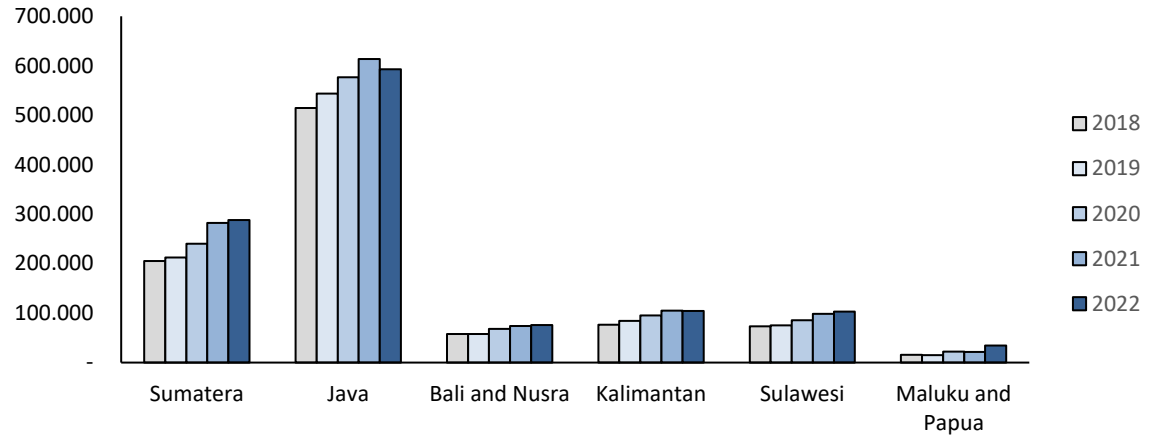


Figure 1. Number of BTS in Indonesia
Source: KOMINFO

Without adequate infrastructure, the public may struggle to use the internet effectively, as reliable internet access is heavily dependent on the availability of strong signals. As illustrated in Figures 1 and 2, infrastructure development, particularly of Base Transceiver Stations (BTS) in Indonesia, remains heavily concentrated on the islands of Java and Sumatra. This uneven distribution underscores the persistent digital divide in telecommunications infrastructure across the country. In response, the Ministry of Communications and Informatics (KOMINFO) has initiated a policy to gradually phase out 3G BTS, prioritizing upgrades to 4G and 5G. While 3G technology is considered obsolete, 2G services are being maintained to meet essential public communication needs via telephone, especially given its continued stability in remote areas.

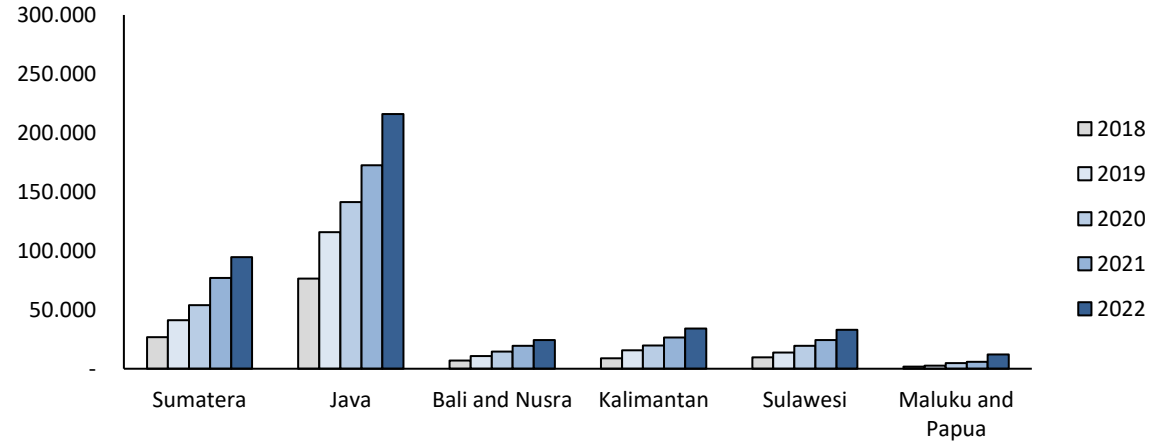
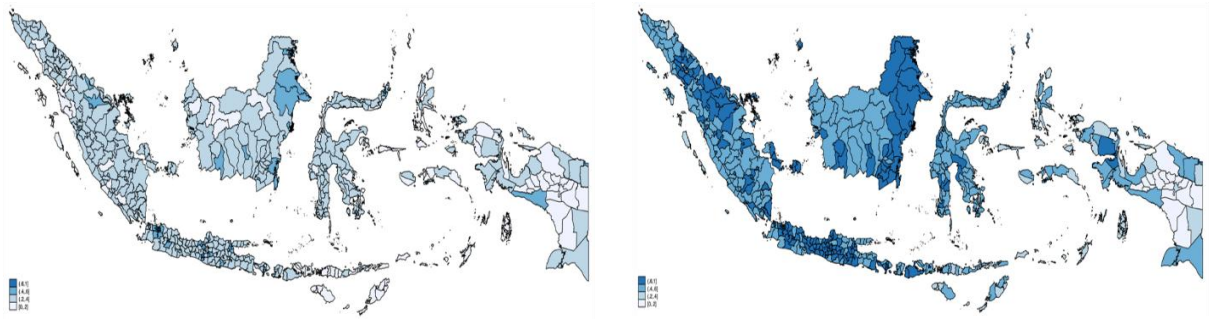


Figure 2. Number of 4G BTS in Indonesia
Source: KOMINFO

In terms of internet penetration, Susenas data from 2018 and 2022 also highlight the digital divide. As Figure 3 illustrates, while internet penetration has generally increased over the past five years, it remains heavily concentrated on Java, and to a lesser extent, Sumatra and Kalimantan. This uneven distribution is largely a result of Indonesia's diverse geographic conditions, leading to notably low internet penetration in many Disadvantage, Frontier, and Outermost (3T) regions. Within Sumatra, provinces situated near the Strait of Malacca exhibit high internet usage among

their populations. Similarly, in Kalimantan, high internet penetration is observed in North Kalimantan, East Kalimantan, and South Kalimantan provinces. Nearly all regions across Java demonstrate uniformly high internet penetration. Furthermore, Bali and the western part of Flores Island in East Nusa Tenggara (Labuan Bajo) benefit from spillover effects of the tourism sector, also showing high internet penetration. However, internet penetration remains relatively low across eastern Indonesia.



(a) 2018 (b) 2022

Figure 3. Internet penetration in 2018 and 2022
Source: SUSENAS

The next analysis is The TSLS procedure, which is conducted in two stages. The results of first-stage regression are presented in Table 3, and the second-stage regression results are presented in Table 4. Each table contains three columns: column (1) presents the regression for the ICT variable of BTS, column (2) presents the regression regarding the ICT variable of 4G BTS, and column (3) presents the regression for the ICT variable of internet penetration.

Table 3. The Result of First Stage Regression of TSLS Model

Variables	Dependent variable: COMPL		
	(1)	(2)	(3)
	BTS	4G BTS	INT
Log BTS	0.08726		
	(0.07051)		
Log 4G BTS		0.14355***	
		(0.04642)	
INT			0.69709***
			(0.20989)
COMPL (-1)	0.39435***	0.29194***	0.34654***
	(0.09439)	(0.10635)	(0.09702)
Control variables	yes	yes	yes
Observations	132	132	132
Groups	33	33	33

Note: ***, **, and * represent significance levels at 1%, 5% and 10%. Robust standard errors are in parentheses.

The empirical findings in Table 3 indicate that ICT serves as a good instrument for estimating the tax compliance ratio, with a positive correlation observed. However, only 4G BTS and internet penetration are statistically significant among the ICT variables at the significance level of 1%. The total BTS variable does not significantly affect the compliance ratio, likely due to the inclusion of 2G and 3G BTS, whose signals are possibly more utilized by non-taxpayer populations. Consequently, its impact may be statistically insignificant. For instance, internet penetration shows higher elasticity (0.69709) than 4G BTS (0.14355). It means that internet penetration directly enables taxpayers to access e-filing systems, online tax payment portals, or government websites. Meanwhile, BTS infrastructure is essential for internet and mobile connectivity but does not directly influence taxpayers unless paired with internet services or applications. Furthermore, the lag of compliance ratio in all columns is significant at 1% level. This indicates that the compliance ratio in the past is positively correlated with the compliance ratio in the current period.

Table 4. The Result of Second-Stage Regression using TSLS Model

Variables	Dependent variable: *TR*		
	(1)	(2)	(3)
	BTS	4G BTS	Internet
COMPL	0.01400*	0.01544**	0.02029***
	(0.00799)	(0.00626)	(0.00705)
Log LMI	0.00056	0.00037	-0.00014
	(0.00239)	(0.00235)	(0.00235)
Log GRDPC	0.00574	0.00581*	0.00533
	(0.00360)	(0.00349)	(0.00373)
Log FW	0.02081**	0.02080***	0.01989**
	(0.00810)	(0.00803)	(0.00819)
Log ROAD	0.03812**	0.03866**	0.03530*
	(0.01893)	(0.01856)	(0.01883)
POPGR	0.01318*	0.01326*	0.01398*
	(0.00785)	(0.00781)	(0.00803)
COVID	-0.00279***	-0.00292***	-0.00333***
	(0.00106)	(0.00096)	(0.00103)
Observations	132	132	132
Groups	33	33	33
R^2	0.42517	0.41511	0.36483
Diagnostic test			
Under-identification p-value	0.01063	0.00722	0.00023
Over-identification p-value	0.40696	0.68612	0.77285
Weak identification	11.82964	17.29958	19.10375

Note: ***, **, and * represent significance levels at 1%, 5% and 10%. Robust standard errors are in parentheses.

Table 4 presents the results of the second-stage regression, where the compliance ratio serves as the main independent variable, accompanied by various control variables. "Almost all variables are significant and correlated with tax ratio, except for the number of large and medium-scale industries." This widespread positive correlation highlights the intricate relationship between tax compliance, economic development, employment levels, public service delivery, and demographic factors in boosting the tax ratio. The sole variable exhibiting a negative relationship with the tax ratio is COVID, a finding that aligns with expectations. The pandemic-induced economic contraction across numerous sectors directly resulted in diminished tax revenue.

The results of the Two-Stage Least Squares (TSLS) procedure in this study generally meet the criteria for a robust TSLS model. "Based on the under-identification test, the p-values in Table 4, columns (1), (2), and (3) are 0.01063, 0.00722, and 0.00023, respectively." These values indicate that the Anderson canonical correlation LR statistic rejects the null hypothesis, as the p-values are significant at both the 5% and 1% levels. This confirmation means that all instruments used in the first-stage regression are relevant, thus allowing the estimated coefficients for the tax compliance ratio to be reliably employed in the second-stage regression. Following the under-identification test, the over-identification test was conducted. "The p-values of Hansen's J statistic in columns (1), (2), and (3) are 0.40696, 0.68612, and 0.77285, respectively, exceeding the 10% significance level." This outcome demonstrates that all instruments are valid and uncorrelated with the error term. Finally, the weak identification test results are presented. As shown in columns (1), (2), and (3), the Cragg-Donald Wald F statistics—11.82964, 17.29958, and 19.10375, respectively—all exceed the Stock-Yogo critical value of 10. This confirms that the instruments are strong predictors in the first-stage regression, further bolstering the reliability of the model.

3.2. Discussion

Our findings reveal that ICT has an indirect relationship with the tax ratio, primarily by influencing tax compliance. This relationship begins with both 4G BTS infrastructure and internet penetration exhibiting a positive correlation with the compliance ratio. Notably, internet penetration shows the largest estimated coefficient among the ICT variables. This outcome likely

stems from the government's direct use of the internet for widespread information dissemination and enhancement. Simultaneously, ICT is valuable for socializing the public about their tax filing and payment obligations, and also potentially improving tax compliance (Night & Bananuka, 2019; and Okunogbe & Santoro, 2023a). Leveraging ICT through digital platforms and mobile applications can provide taxpayers with timely reminders to file tax returns (Bhuasiri et al., 2016) and significantly lower compliance costs by eliminating the need for physical visits to tax offices (Okunogbe & Pouliquen, 2022). This proactive engagement fosters taxpayer education and highlights a learning and experience effect, wherein taxpayers become more efficient and compliant over time to avoid penalties or fines. Furthermore, the electronic systems implemented by Indonesia's Directorate General of Taxes (DJP) play a crucial role in enhancing taxpayers' willingness to file their Annual Tax Returns (SPT), thereby contributing to sustained compliance. The subsequent analysis involves the second-stage regression, which examines the relationship between compliance and other control variables with tax ratio. Table 4 exhibits that COMPL (derived from estimates in the first-stage estimation) is positively and significantly correlated with the tax ratio across all models. When taxpayers meet their reporting obligations, it enhances the accuracy and quality of reporting. Therefore, efforts to disseminate information, improve supervision, and enforce tax laws need to be intensified to further increase the SPT compliance ratio.

Regarding the control variables, we find that the large and medium-scale industries has a positive sign but insignificant effect on the tax ratio, as it yields an insignificant result. This finding can likely be attributed to the significantly smaller number of large and medium industries in Indonesia compared to micro and small enterprises. In 2022, BPS data only recorded a total the large and medium-scale industries of 31,776, while the total number of micro and small enterprises reached 4,339,228. This disparity further underscores Indonesia's continued reliance on the informal economy, where micro and small enterprises predominantly operate. To address this, the Indonesian government could implement various initiatives aimed at attracting industrial investment, such as offering tax incentives, simplifying regulations, and improving infrastructure. An increased number of large industries would directly translate into more taxable entities, including corporate taxes and individual income taxes levied on employees. Therefore, it is recommended to expand the tax base and formalization efforts, which not only potentially allows for a decrease in tax rates but also promotes overall revenue mobilization (Akitoby et al., 2020). The internet, as demonstrated by studies from Elgin (2013); and Ndoya et al. (2023), also plays a crucial role in reducing the prevalence of the informal economy.

GRDP per capita, as a measure of well-being, exhibits have a positive sign and significant effect on the tax ratio. This finding aligns with previous research by Castro & Camarillo (2014); Rodríguez (2018); and Adegboye et al. (2022). The positive relationship is attributable to the fact that higher income signifies greater economic well-being and enhances purchasing power. An increase in GRDP per capita reflects elevated economic activity and improved overall economic conditions, ultimately leading to higher tax revenues. Additionally, increased consumption naturally generates more tax revenue through sales tax or VAT transactions. Similarly, the number of formal workers has a positive sign and significant effect on the tax ratio. This indicates that they contribute significantly to central tax revenue, particularly through income tax (PPh). This finding aligns with studies by Andrejovská & Puliková (2018); Roudo (2024); and Nugrahani & Mahi (2022), which adopted similar labor force-based approaches. Formal workers are typically registered and receive reported wages, which simplifies the assessment and collection of income tax. To capitalize on this, the government could implement policies that encourage labor formalization. These might include offering incentives for companies to hire formally, strengthening labor regulations, and enhancing social protection programs. Promoting formal labor practices not only boosts tax revenue (Jara et al., 2023) but also simultaneously improves worker welfare and stimulates broader economic growth (Esteban-Pretel & Kitao, 2021).

Road length, as an aspect of public service delivery, has a positive sign and significant effect on the tax ratio. This connection highlights how improved infrastructure can positively impact fiscal outcomes. An increase in road length directly enhances accessibility and connectivity between regions, leading to more efficient distribution of goods and services and stimulating broader

economic activity. Furthermore, adequate road infrastructure facilitates worker mobility, which can boost productivity and income, ultimately contributing to higher tax revenues (Roudo, 2024). The same findings on the population growth rate demonstrates has a positive sign and significant effect on tax revenue. This finding aligns with Gnangnon & Brun (2018), which reflects governments' potential to collect more tax revenue in the setting of the growth of populations. An increase in population naturally leads to a higher volume of economic transactions. This expansion of the tax base subsequently enhances the potential for tax revenue generation.

4. CONCLUSIONS

This study investigated the relationship between information and communication technology and central tax revenue (tax ratio) in Indonesia from 2018 to 2022. Utilizing BTS infrastructure and internet penetration as ICT indicators, the analysis employed a Two-Stage Least Squares approach to explore their indirect relationship. Several control variables were included to prevent omitted variable bias, namely the number of large and medium-scale industries, GRDP per capita, formal workers, population growth, road length, and a dummy variable for COVID-19. Our empirical results reveal an indirect relationship between ICT and tax revenue (tax ratio) through the enhancement of the tax compliance ratio. In the first stage of the TSLS analysis, ICT serves as a strong and relevant instrument for improving the compliance ratio, with a positive correlation observed. This suggests that in the digital era, the government can effectively leverage ICT to encourage taxpayers to utilize government websites, such as e-filing, to fulfill their reporting obligations and improve overall compliance. Subsequently, in the second-stage TSLS analysis, the compliance ratio exhibited a significant positive correlation with the tax ratio. This implies that when taxpayers comply, their submitted reports are more likely to be correct and accurate, thereby enhancing tax revenue.

Several key policy implications emerge, first, improving tax compliance is essential for increasing tax revenue and requires targeted measures that leverage technology. Tax authorities should utilize ICT to disseminate tax-related information across multiple platforms, ensuring the public receives accurate and timely information, which potentially boosts tax reporting compliance. Second, expanding BTS infrastructure, particularly in rural and 3T regions, is recommended to achieve more equitable telecommunication coverage across Indonesia. This is beneficial as BTS signals significantly influence connectivity and internet access. Third, online tax systems should be developed or enhanced to identify potential taxpayers and broaden the tax base, particularly by promoting the formalization of businesses and workers.

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