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ICT's Impact on Labour Productivity Towards Achieving Golden Indonesia 2045 Vision

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Abstrak

- **Tujuan:** Penelitian ini bertujuan untuk menganalisis variabel-variabel yang memengaruhi produktivitas tenaga kerja di Indonesia, dengan fokus pada peran teknologi informasi dan komunikasi (TIK) dalam mendukung pertumbuhan ekonomi yang inklusif dan berkelanjutan menuju Visi Indonesia Emas 2045.
- **Desain/metodologi/pendekatan:** Penelitian ini menggunakan data panel dari 34 provinsi selama periode 2015–2022. Model estimasi yang digunakan adalah Feasible Generalized Least Squares (FGLS). Variabel yang dianalisis meliputi modal fisik, modal manusia, keterbukaan perdagangan, upah riil, kepemilikan ponsel, dan akses internet.
- **Temuan:** Hasil menunjukkan bahwa modal fisik, modal manusia, keterbukaan perdagangan, upah riil, dan akses internet berpengaruh positif signifikan terhadap produktivitas tenaga kerja. Sebaliknya, kepemilikan ponsel memiliki pengaruh negatif signifikan, yang mengindikasikan pemanfaatan TIK untuk produktivitas masih belum optimal.
- **Batasan penelitian/dampak:** Penelitian terbatas pada data level provinsi dan indikator TIK kuantitatif, sehingga belum menangkap aspek kualitas dan perilaku pengguna. Studi lanjutan dapat menggali interaksi antar variabel dan pengaruh jangka panjang pemanfaatan TIK.
- **Implikasi praktis:** Pemerintah perlu mendorong pemerataan infrastruktur internet, peningkatan literasi digital, serta kebijakan yang mampu mengurangi dampak disruptif TIK terhadap pekerja, guna mengoptimalkan potensi digitalisasi secara inklusif.
- **Keaslian/nilai:** Penelitian ini menawarkan kontribusi baru dengan menggunakan data panel provinsi 2015–2022 dan menganalisis perbedaan dampak TIK antara wilayah barat dan timur Indonesia, serta mengintegrasikan indikator TIK secara eksplisit dalam model analisis.
- **Jenis makalah:** Makalah penelitian.

Kata Kunci: Produktivitas tenaga kerja; TIK; FGLS; internet; panel.

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Abstract

- ***Purpose:*** *This research aims to analyse the variables that influence labour productivity in Indonesia, with a focus on the role of information and communication technology (ICT) in supporting inclusive and sustainable economic growth towards the Vision of Golden Indonesia 2045.*
- ***Design/methodology/approach:*** *This study uses panel data from 34 provinces over the period 2015–2022. The estimation model used is Feasible Generalised Least Squares (FGLS). The variables analysed include physical capital, human capital, trade openness, real wages, mobile phone ownership, and internet access.*
- ***Findings:*** *The results show that physical capital, human capital, trade openness, real wages, and internet access have a significantly positive impact on labour productivity. On the contrary, mobile phone ownership has a significant negative impact, indicating that the utilisation of ICT for productivity is still not optimal.*
- ***Research limitations/implications:*** *The research is limited to provincial-level data and quantitative ICT indicators, thus it has not captured the aspects of quality and user behaviour. Further studies can explore the interactions between variables and the long-term effects of ICT utilisation.*
- ***Practical implications:*** *The government needs to promote the equitable distribution of internet infrastructure, enhance digital literacy, and implement policies that can reduce the disruptive impact of ICT on workers, in order to optimise the potential of digitalisation inclusively.*
- ***Originality/value:*** *This research offers a new contribution by using provincial panel data from 2015–2022 and analysing the differences in the impact of ICT between the western and eastern regions of Indonesia, as well as explicitly integrating ICT indicators into the analysis model.*
- ***Paper type:*** *Research paper.*

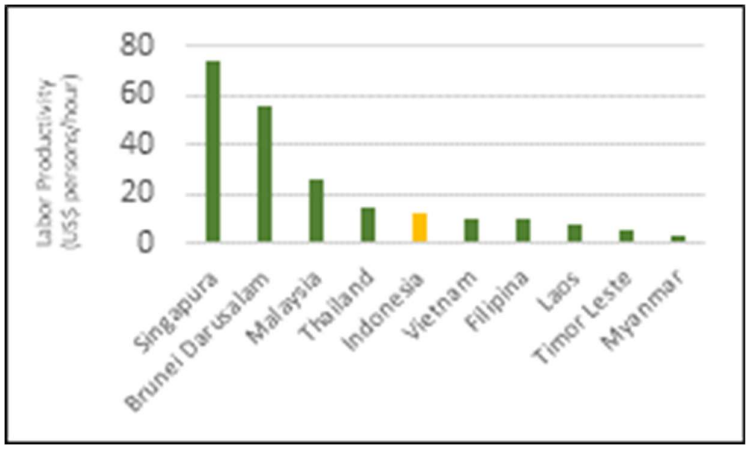
***Keywords**: Output Gap, NTB, Potential RGDP, R-Statistics.*

Introduction

As part of the Indonesia Emas 2045 initiative, Indonesia hopes to rank among the top five countries in the world in terms of GDP by that year. Indonesia is expected to achieve this goal with sustainable economic growth. Labor productivity is one of the key factors that determines the extent of economic growth in a country (Masso & Tiwari, 2024; Yasin et al., 2024). The workforce plays an important role in the economy, and worker productivity has always been a key factor in economic growth (Yu et al., 2024).

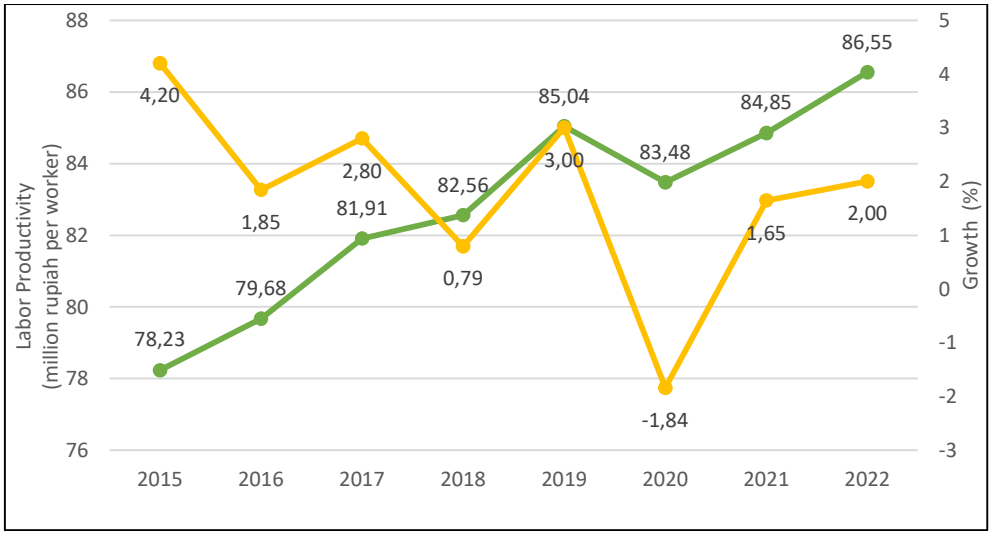
From 2015 to 2022, the growth of Indonesia's labor productivity showed a positive trend. However, labor productivity fell by 1.84 percent in 2020. In 2021 and 2022, Indonesia's GDP grew by 1.65% and 2% respectively after the pandemic ended, but it still grew slowly. Meanwhile, the government has set an annual growth target of 5.12% for worker productivity in the National Medium-Term Development Plan (RPJMN) 2020–2024. This indicates that the growth of Indonesian worker productivity has not yet reached the expected level.

Figure 1. Labor productivity of ASEAN member countries in 2022



Source: ILOSTAT (2022)

Figure 2. Achievements and Growth of Labor Productivity in Indonesia from 2015-2022

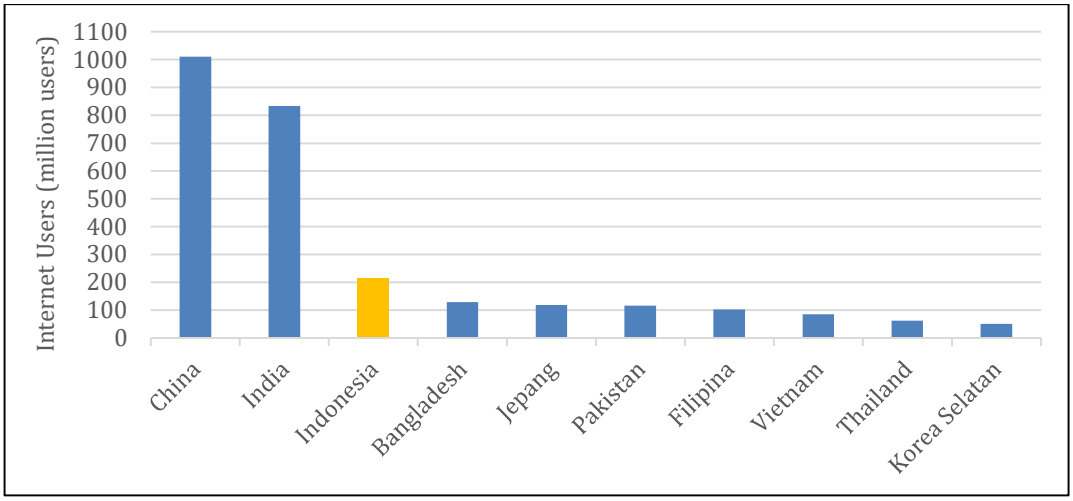


Source: BPS (2022)

To improve productivity, it is important to understand the elements that impact productivity. Connectivity is an important factor that can enhance productivity because it requires continuous interaction between individuals to maintain connections. One of these connectivities is inseparable from the role of ICT. Digital transformation is a crucial element in achieving the vision of Indonesia Gold 2045, particularly in enhancing labor productivity. The significant impact of ICT on economic growth comes from the extensive integration of technology into the lives of individuals and economic enterprises (Ferdy Firmansyah et al., 2021). The

internet is an important component of Information and Communication Technology (ICT), as declared by Kominfo in 2023. The utilization of the internet and ICT devices can streamline business processes, enhance communication and collaboration, thereby accelerating decision-making (Grimes and Ren, 2009). According to Internet World Stats (2023), Figure 3 shows that Indonesia ranked third globally in terms of internet users in 2022, with approximately 123.5 million users. According to the Central Statistics Agency, the projected proportion of the working-age population in Indonesia in 2022 was 69.25% of the total population, equivalent to 190.98 million people (BPS, 2023). Based on Susenas data from the same year, it was found that 47.64% of internet users in Indonesia are in the age range of 25-49 years. The presence of a large number of internet users in the age group capable of high productivity presents a potential opportunity to enhance overall productivity.

Figure 3. The ten countries with the largest number of internet users in the world in 2022



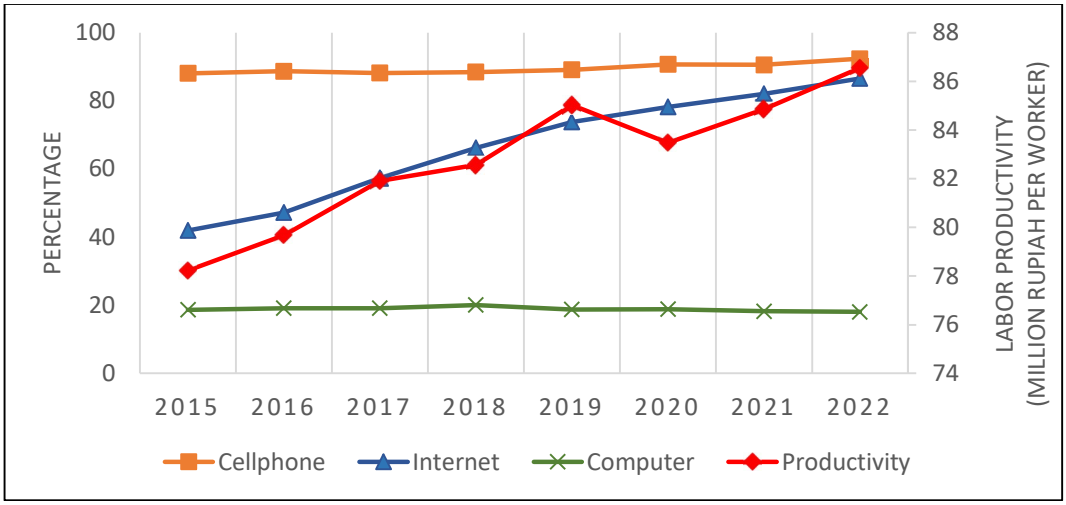
Source: Internet World Stats (2022)

Nevertheless, this demographic group is vulnerable to the negative impacts of ICT disruption, which poses significant problems. Policy design must align with the demands of dynamic technological growth. Equal distribution of ICT utilization across regions is also important, as uneven internet access and the quality of digital human resources can lead to imbalanced labor productivity. By increasing its digital maturity, Indonesia has a significant opportunity to maximize its economic potential and successfully achieve the Golden Indonesia goal by 2045 (Kominfo, 2023).

On the other hand, labor productivity in Indonesia showed an increasing trend during the observation period from 2015 to 2022, as depicted in Figure 4. However, it experienced a significant decline in 2020 as a result of the pandemic. Nevertheless, despite the pandemic, ICT metrics consistently show an upward trend, exemplified by the percentage of households with internet connections. Among the three ICT indicators used, the most notable increase occurred in the proportion of households utilizing the internet between 2015 and 2022 (Figure 4). This indicates the increasing prevalence of internet connectivity and penetration in society. The

adoption of mobile phones also shows a positive trend. Nevertheless, computer penetration seems to be declining. ICT is believed to facilitate productivity and connectivity for individuals during the pandemic, allowing them to engage in activities despite social restrictions (Papaioannou, 2023).

Figure 4. Development of Indonesia's ICT Productivity and Its Indicators 2015-2022



Source: BPS (2022)

Various empirical studies have shown that information and communication technology (ICT) plays a significant role in enhancing labor productivity. Lee et al. (2020) and Shahnazi (2021) highlight the positive impact of ICT on production improvement, while Laddha et al. (2022) found a significant correlation between telephone subscriptions, broadband subscriptions, and overall labor productivity. In Indonesia, Martami and Dartanto (2020) revealed that internet penetration has a positive impact on national labor productivity. However, most previous studies are still limited to certain regions or narrow time frames, and have not comprehensively examined the impact of ICT on labor productivity across all provinces in Indonesia in the long term. Therefore, this research is important as it positions ICT at the intersection of digital transformation, regional development, and human capital strengthening as a foundation towards achieving the Vision of Golden Indonesia 2045. Using secondary data from 34 provinces in Indonesia during the period 2015–2022, this study aims to identify the variables that influence labor productivity, with a particular focus on the role of ICT. The novelty of this research lies in the use of provincial panel data from 2015-2022 and the comparative analysis of the impact of ICT between the western and eastern regions of Indonesia, as well as incorporating ICT variables into the model to observe their influence on labor productivity. Thus, the optimal utilization of ICT is expected to increase labor productivity evenly, especially if supported by the equitable distribution of digital infrastructure, improvement in digital literacy, and strengthening of human and physical capital across all regions of Indonesia.

Literature review and hypothesis development

According to the Solow economic growth model theory, labor productivity is one of the main components that affects the output of an economy in the long run. In this study, productivity analysis can be approached mathematically through the Cobb-Douglas production function, which is a general functional form to describe the relationship between input factors of production and output.

$$Y = F(K, L)$$

$$F(K, L) = AK^{\alpha}L^{1-\alpha}$$

Figure 5. Cobb-Douglas production function

Assuming a production function with constant returns to scale, this equation can be derived as follows (Mankiw, 2019):

$$zY = F(zk, zl) \; where \; z = \frac{1}{L}$$

$$\frac{Y}{L} = F\left(\frac{K}{L}, 1\right)$$

Figure 6. Production function with constant returns to scale

With the information that Y is the output, K is capital, and L is labor, if equation on Figure 6 is substituted into the Cobb Douglas function, we obtain the equation that can be written as follows.

$$\frac{Y}{L} = \frac{AK^{\alpha}L^{1-\alpha}}{L} = A\left(\frac{K}{L}\right)^{\alpha}$$

$$y = Ak^{\alpha}$$

Figure 7. Production function

Where y represents $\frac{Y}{L}$ or worker productivity, then k is $\frac{K}{L}$ or capital per worker. Where : K : *capital*; L: *labor*; α : *capital's share of income* (he amount of income received by capital providers); Y: output; A: *total factor productivity* (TFP); k : capital per worker.

Based on Figure 7, the solution to the Cobb-Douglas production function must be transformed into a linear function. To convert it into a linear form, the production function can be transformed into a natural logarithm, resulting in an equation.

$$\ln(y) = \ln(A) + \alpha \ln(k)$$

Figure 8. Linear function of transformed Cobb-Douglas production function

Statistics Indoesia (BPS) defines labor productivity as the ability of the workforce to produce output in the form of goods and services within a certain period, which is technically measured as the ratio of the value of output to the paid labor input. This definition aligns with the methodological standards set by the International Labour Organization (ILO, 2022), which underscores the importance of measuring productivity as an indicator of labor efficiency within the economic system. In practice, BPS calculates labor productivity by dividing the Gross Regional Domestic Product (GRDP) at constant prices by the number of people employed in a region. This method provides an estimate of productivity in terms of rupiah per worker per year, allowing for comparisons of labor efficiency between regions and across time periods. The use of constant prices in the calculations aims to eliminate the influence of inflation, so that changes in productivity reflect real changes in output, not just the result of price fluctuations.

$$Labor\ Productivity = \frac{\text{GRDP at Constant Prices}}{Number\ of\ Labor}$$

Figure 9. Labor productivity function

Based on Figure 7, the amount of capital per worker and the level of technology availability, also known as total factor productivity (A), have an impact on productivity. Based on Mankiw (2019), total factor productivity accounts for all variations in the measurement of inputs and outputs. Hutami & Riani (2022) state that the two types of capital in this scenario are fixed/physical capital and human capital. Thus, the availability of capital for each worker, both human and material capital, also affects labor productivity. The explanation shows that initiatives to improve productivity can be analyzed from the perspective of physical and human capital per worker. Wages, health, and education are three factors that can be used to approach human capital.

The variables of human capital stock and physical capital stock in this study follow the research conducted by Yuniasih et al., (2013). The variable for the physical capital stock is proxied through the data on the proportion of real PMTB to real GDP. The variable for the stock of human capital is proxied using data on the proportion of the population aged 15 and above who are employed and have at least completed high school. The variables of physical capital and human capital in this study are limited to a depreciation rate of 0.05, referring to the research conducted by Firdaus and Yusop (2009) which assumes this depreciation rate. Referring to the assumption g_{it}+δ_{it} value of 0.05 from Firdaus and Yusop (2009), this value is used as a divisor for the physical capital and human capital variables. This is also done by Wang (2024) and Carnevali et al. (2024) by emphasizing the optimal allocation of

resources between the accumulation of physical capital and human capital, which develops a growth model using a stock-flow approach.

The efficiency wage theory states that wages can be used as a driver of productivity and strengthen the working relationship between employers and employees in the long term (Mankiw, 2019). According to this theory, labor productivity will depend on the level of wages received because the wage level is the goal that motivates the workforce. The increase in workers' income will increase their ability to meet needs and increase domestic consumption so that economic growth can increase.

In economic theory, the Cobb-Douglas production function states that production is influenced by technology, labor and capital. According to theory, the more advanced the technology available, the more efficient production will be and the amount of production can be increased (Mankiw, 2019). The technology used in this research refers to the components of the ICT Development Index. BPS has compiled an index that describes Indonesia's ICT development with the name ICT Development Index referring to (ITU, 2018).

ICT and Labour Productivity

Various empirical research provide inconclusive evidence on the impact of ICT on labor productivity. Studies by Lee et al., (2020) and Shahnazi (2021) demonstrate the influence of ICT on enhancing production. ICT has a favorable impact on worker productivity. Laddha et al., (2022) conducted a study that revealed a noteworthy correlation between telephone subscriptions, broadband subscriptions, and the overall labor productivity. Martami & Dartanto (2020) found that internet penetration in Indonesia has a beneficial impact on labor productivity.

Nevertheless, there is research indicating that the correlation between ICT and worker productivity is not substantial (Abramova & Grishchenko, 2020). According to Erumban (2023) the internet does not have a substantial impact on enhancing labor productivity. This discovery corroborates the findings of Markhaichuk & Panshin (2020) who assert that the process of digitization, including the utilization of cell phones, has a direct adverse impact on labor productivity. The use of the internet, particularly through mobile devices equipped with various applications, can diminish productivity levels due to its potential for entertainment and other non-work-related activities Erumban (2023). Similarly, as stated byPanshin & Yares (2021) in addition to the practical advantages, there exists a "Productivity Paradox" which suggests that the first investment in ICT may not result in an instant boost in production.

Research Method

Data collecting technique and variables

The data used in this research is panel data, which is a combination of cross-sectional data and time series data. The cross-section data in this study covers 34 provinces in Indonesia with a research period from 2015 to 2022, resulting in a total of 272 observation units with balanced panel characteristics. This data is secondary data sourced from the Central Statistics Agency, specifically the publication on Labor

Force/Employment Conditions in August across 34 Provinces from 2015 to 2022, the publication on Regional Gross Domestic Product by Expenditure in Indonesian Provinces from 2015 to 2022, and the publication on Indonesian Telecommunications Statistics from 2015 to 2022. Data on the population aged 15-64 years who are employed and use the internet via mobile phones and computers is also required, obtained from the weighted raw data of KOR Susenas March 2022. The raw data used is in Block 7 details 2 and 4 regarding employment and Block 8 details 7, 9, and 11 regarding Information and Communication Technology.

Table 1. Variables and Indicators

No.	Variable	Explanation	Operational Definition
1	Prod	Labor productivity	Real GDP value divided by the number of people aged 15-64 years who work in units of millions of rupiah per worker.
2	PHYSICAL	Stock of physical capital	The proportion of real PMTB to real GRDP divided by the depreciation level variable.
3	HUMAN	Stock of human capital	The proportion of the working population aged 15-64 years who have at least completed high school is divided by the depreciation level variable.
4	TO	Trade openness	Real exports plus real imports divided by real GDP in percentage units.
5	WAGES	Wages	The wage value of residents aged 15-64 years who work with their main job status as laborers in rupiah units.
6	INTERNET	Internet penetration	Percentage of households that access the internet.
7	CELLPHONE	Cellphone penetration	Percentage of households that own/control a cell phone.
8	COMPUTER	Computer penetration	Percentage of households that own/control a computer.

Data Analysis

Using panel data analysis, the final equation to be used in the regression model is as follows:

$$LnProd_{it} = \alpha + \beta_1 LnPHYSIC_{it} + \beta_2 LnMHUMAN_{it} + \beta_3 LnTO_{it} + \beta_4 WAGES_{it} + \beta_5 INTERNET_{it} + \beta_6 CELLPHONE_{it} + \beta_7 COMPUTER_{it} + \varepsilon_{it}$$

Figure 10. Panel equation

In this study, the steps in conducting panel data regression analysis are as follows: Choosing the best model using the Chow Test. If H0 is rejected, the testing continues with the Hausman Test. If H0 is not rejected, then the Breusch Pagan-Lagrange Multiplier (BP-LM) test is conducted. If the Hausman test result rejects H0, then the best model to use is FEM. If H0 is not rejected, then the chosen model is REM. If the Breusch Pagan-Lagrange Multiplier (BP-LM) test rejects H0, then the model used is REM. If H0 is not rejected, then the most appropriate model to use is CEM. If the chosen model is CEM and FEM, then a residual variance-covariance structure test is conducted to determine the best estimation method. The residual variance-covariance structure test is conducted using the LM test and the LM test. If the LM test results in a decision to reject H0, then the residual variance-covariance structure is heteroskedastic, and continue the examination with. If the LM test fails to reject H0, then the residual variance-covariance structure is homoskedastic, so the best model to use is FEM with the OLS estimation method. If the test rejects H0, then there is cross-sectional correlation, so the model used is FEM with the SUR estimation method. If H0 is not rejected, then there is no correlation between individual residuals, so the appropriate model to use is FEM with the cross-section weight estimation method; Perform estimation using the chosen model and estimation method, then conduct classical assumption testing; Perform model interpretation and analysis.

The Chow test is a statistical test used to determine whether a fixed effects model or a pooled effects model is more suitable for panel data regression. The Chow test hypothesis examines whether the coefficients of the model are the same. The F-test is a statistical test that determines whether to reject the null hypothesis (H0) or use the fixed effects model with an F probability less than α. The Hausman test, a statistical test, is designed to determine the appropriate panel data regression method between the random effects model and the fixed effects model. This hypothesis test determines whether there is a correlation between cross-sectional effects and other regressors (using the fixed effects model rather than the random effects model). In this statistical test, chi-square is used to see if the F probability is less than or equal to the confidence level. It is very important to determine whether the parameters used in regression-based studies meet the BLUE (Best Linear Unbiased Estimator) criteria. To meet these conditions, multicollinearity and autocorrelation are tested and heteroskedasticity is assessed. After conducting the three tests mentioned above to assess autocorrelation, heteroscedasticity, and multicollinearity, it was found that the fixed effects model regression analysis is susceptible to heteroscedasticity. To address this issue, here is the model for the regression analysis. Feasible Generalised Least Squares is an additional framework that will be used in this project.

Result and discussion

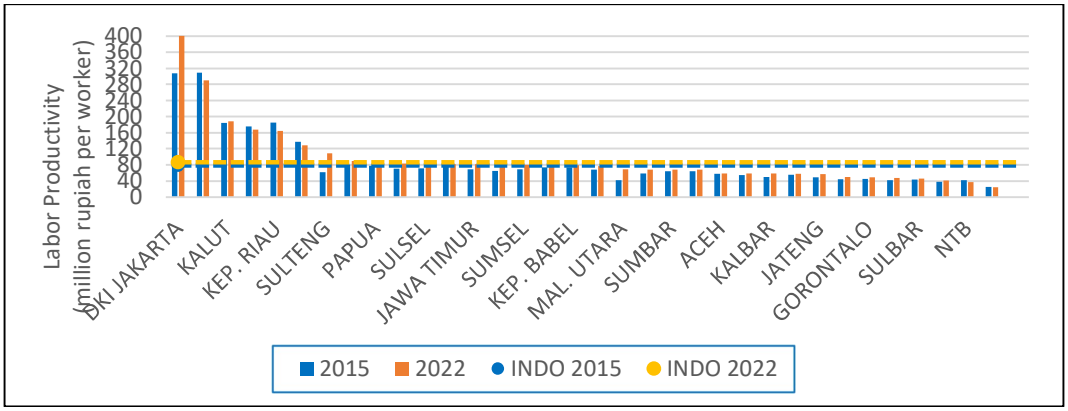
Labour Productivity in Indonesia

Based on 2015 data, there were only six provinces with labor productivity above the national average, whereas in 2022, that number increased to nine provinces. This shows that although there has been a national increase in

productivity, the growth in productivity is still concentrated in certain provinces. The DKI Jakarta province consistently holds the top position with a productivity of 400.70 million rupiah per worker, far exceeding the national average. Followed by provinces rich in natural resources such as East Kalimantan, North Kalimantan, and the Riau Islands, which also show high productivity compared to other regions. This increase reflects the development of leading sectors in the region that drive labor efficiency.

However, there is a significant gap between provinces in terms of labor productivity. The comparison between the province with the highest productivity, namely DKI Jakarta, and the province with the lowest productivity, namely Nusa Tenggara Timur (NTT), shows a very sharp difference of more than sixteen times. This disparity indicates that the distribution of economic development and the quality of the workforce are not yet geographically balanced.

Figure 11. Labor Productivity by Province in Indonesia 2015-2022



Source: BPS (2015 & 2022)

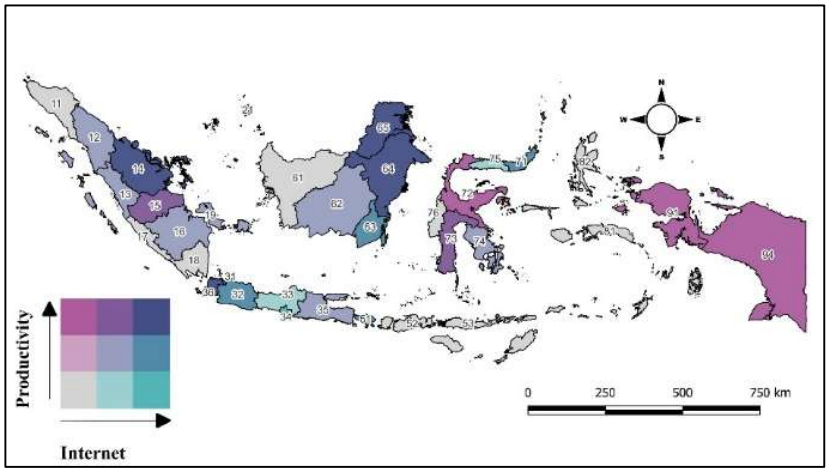
ICT Indicators in Indonesia

Information and communication technology (ICT) has become a significant driver of productivity improvement and economic growth in a country (Jorgenson & Stiroh, 1999; Ceccobelli et al., 2012). One important indicator of ICT utilization at the household level is access to the internet. During the period from 2015 to 2022, there was a significant increase in the percentage of households with internet access across all provinces in Indonesia, as shown in Figure 6. This increase reflects progress in the penetration of digital infrastructure and the adoption of technology by the community, which serves as an important foundation in strengthening labor productivity.

The choropleth map in Figure 12 illustrates the relationship between internet penetration and labor productivity at the provincial level. There are several provinces that stand out with high performance in both aspects, including DKI Jakarta, Riau, Kepulauan Riau, West Kalimantan, Central Kalimantan, and North Kalimantan. These provinces show a combination of a high percentage of households accessing the internet and high labor productivity, indicating that

effective utilization of ICT can strengthen labor efficiency and support regional growth.

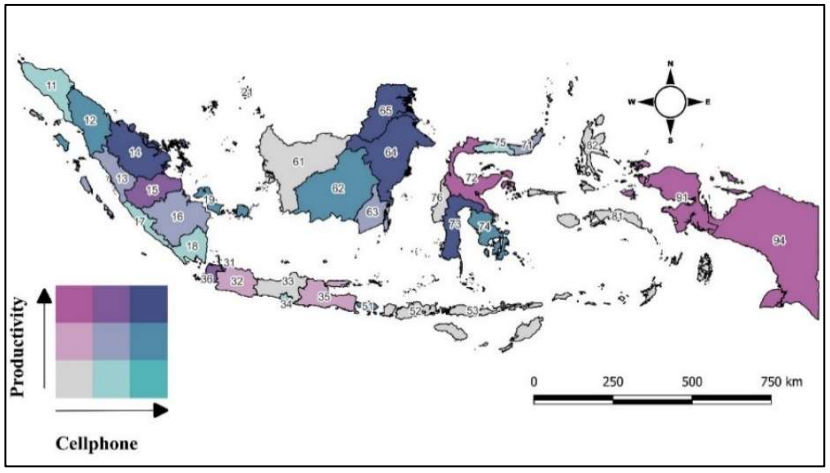
Figure 12. Bivariate choropleth map of labor productivity and the percentage of households accessing the internet in Indonesia 2015-2022



Source: BPS (2015-2022)

Conversely, several provinces such as East Nusa Tenggara and Aceh occupy lower positions in terms of internet access and labor productivity. This condition indicates the persistence of a digital divide that has implications for productivity disparities between regions.

Figure 13. Bivariate choropleth map of labor productivity and the percentage of households with/controlling mobile phones in Indonesia 2015-2022



Source: BPS (2015-2022)

The utilization of communication technology through mobile phone ownership has seen a significant increase across all provinces in Indonesia since

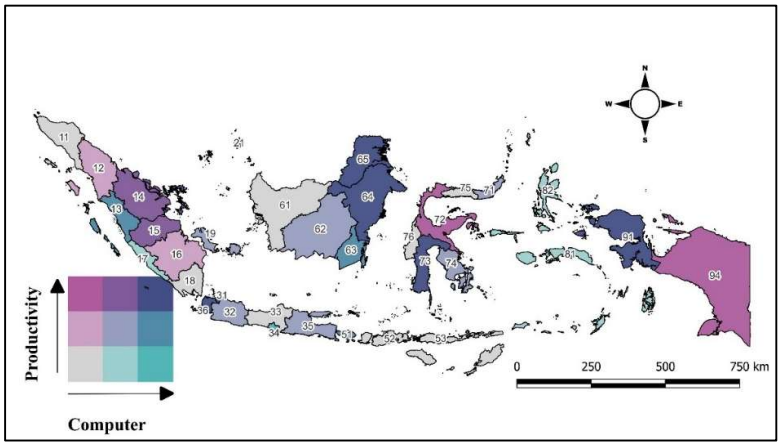
2015. Almost all regions show a high percentage of households that own or control mobile phones, except for Papua, which is still lagging in this regard. In 2022, data showed that all provinces experienced an increase in mobile phone ownership, reflecting the increasingly even penetration of technology at the household level. This shows that mobile devices have become the primary means for the public to access information and communicate in the digital era.

Figure 13 maps the relationship between mobile phone ownership and labor productivity at the provincial level. Several provinces such as the Riau Islands, East Kalimantan, North Kalimantan, Bali, and DKI Jakarta stand out due to their high levels of mobile phone ownership and labor productivity. The color distribution in the map illustrates a positive correlation between the two variables in those regions. This indicates that under certain conditions, high mobile phone ownership can drive productivity, especially if the devices are used for work-supporting activities, such as professional communication, information access, or digital economy activities.

However, some provinces show high mobile phone ownership but do not have high labor productivity. This may indicate suboptimal use of technology, such as using mobile phones more for consumptive activities rather than productive ones. Therefore, although the ownership of digital devices is becoming more widespread, their positive impact on productivity greatly depends on how the technology is used.

Unlike the high penetration of the internet and mobile phone ownership across provinces, the percentage of households that own or control a computer in 2022 remains relatively low. This phenomenon can be explained by several factors, including the rapid development of mobile phone technology, which has been able to replace most of the functions of computers, such as internet access, work productivity, and light data processing. In addition, the price of computer devices is relatively more expensive compared to mobile phones, making them unaffordable for all segments of society, especially in areas with low purchasing power (Kartiasih et al., 2023; Kartiasih, 2023a; Kartiasih, 2023b).

Figure 14. Bivariate choropleth map of average labor productivity and the percentage of households with computer ownership/usage in Indonesia 2015-2022



Source: BPS (2015-2022)

Based on the data visualized in Figure 14, the relationship between household computer penetration and labor productivity levels in Indonesia generally shows a not very strong correlation. Some regions, such as Maluku and North Maluku, are recorded to have a moderate level of household computer penetration but relatively low labor productivity. This indicates that computer ownership has not automatically translated into increased productivity, possibly due to limitations in user skills, access to productive applications, or the relevance of the devices to the dominant types of work in the region.

However, there are also regions that show a positive relationship between computer penetration and labor productivity, although their numbers are limited. For example, the Province of Bali and several areas in Java Island, which have low household computer penetration and also low labor productivity levels. These findings indicate that the role of computers in supporting labor productivity is still selective and uneven across regions.

Regression Model

The empirical results are presented in Table 2 and are based on the panel regression methodology. The Chow Test results show that the p-value is less than the 5 percent significance level, so the decision that can be made is to reject the null hypothesis. Thus, FEM is better than CEM. Next, a Hausman test was conducted, and the p-value was less than the 5 percent significance level, leading to the decision to reject the null hypothesis. This means that the Fixed Effect Model is a more appropriate model to use than the Random Effect Model.

After determining the best research model, the estimator in the research model has met the BLUE (Best Linear Unbiased Estimator) property. The multicollinearity test uses VIF and the heteroscedasticity test uses the Modified Wald Test for Groupwise Heteroscedasticity in the Fixed Effects Regression Model. However, since this study uses a fixed effects model, there is no need to conduct an autocorrelation test.

Here are the regression results. The LM test shows that there is heteroskedasticity in the residual variance-covariance structure, so the testing is continued with the The correlation test shows a rejection of the null hypothesis, indicating that there is a relationship between individuals. The multicollinearity test shows that there is no significant correlation among the independent variables in the model. Meanwhile, the heteroskedasticity test shows that the regression model contains heteroskedasticity properties. To address this issue, the Feasible Generalized Least Squares Model was used to eliminate the heteroskedasticity characteristic in the regression model.

The regression results below show the regression when the sample is divided between observations from provinces in western Indonesia and provinces in eastern Indonesia. In the regression results for the western and eastern Indonesian sample, it is evident that internet penetration is significant and positively impacts productivity. However, mobile penetration is significant and has a negative impact on productivity.

The regression coefficient results for internet penetration in Eastern Indonesia are higher compared to Western Indonesia. This may be due to the high

signal quality in cities in western Indonesia. So, when there is a change in signal quality, it will not significantly affect productivity.

This can also indicate that internet penetration in the eastern provinces of Indonesia is still low. So, when there is an increase in internet penetration, it will significantly affect productivity. These findings are consistent with previous regression analyses, which indicate that individuals with internet access and higher education levels may experience increased productivity.

Table 2. Research results on the impact of ICT on labor productivity

No.	Variable	Indonesia	West Indonesia	East Indonesia
1	C	3.1081 (0.000)***	4.3091 (0.000)***	1.256147 (0.2038)
2	lnPhysical	0,1077 (0,0102)***	-0,2663 (0,0027)***	0,1857 (0,0003)***
3	lnHuman	0,0421 (0,0100)***	0,0554 (0,0006)***	0,0284 (0,2058)
4	lnTO	0,0541 (0,000)***	0,0257 (0,1044)	0,0598 (0,000)***
5	lnWages	0,0990 (0,000)***	0,0735 (0,0053)***	0,2248 (0,0009)***
6	Internet	0,0020 (0,000)***	0,0014 (0.000)***	0,0024 (0,000)***
7	Cellphone	-0,0068 (0,000)***	-0,0072 (0,0015)***	-0,0097 (0,000)***
8	Computer	-0,0025 (0,2500)	-0,0039 (0,0958)*	-0,0009 (0,7667)
	Summary Statistics			
	R-squared	0.994022	0.994798	0.994372
	Adjusted R-squared	0.992987	0.993729	0.993217
	F-statistic	960.27	931.1846	860.4389
	Prob(F-statistic)	0	0	0

Standard error in parentheses; ***, **, *: significance level at 1%, 5% and 10%, respectively

The Impact of ICT on Labor Productivity

Labor productivity is positively and significantly influenced by physical capital, which is proxied by the real PMTB to real GDP divided by depreciation. The stock of physical capital will increase labor productivity. The regression coefficient of 0.1077 indicates that each one percent increase in physical capital stock raises labor productivity by 0.1077 percent, assuming other variables remain constant. This empirical conclusion supports Solow's hypothesis that capital accumulation drives large-scale manufacturing, which increases productivity. According to (Yuniasih et al., 2013) Indonesian: The stock of physical capital increases labor productivity. The labor capital ratio positively and significantly affects labor productivity (Erumban, 2023; Ismail, 2015).

The stock of human capital positively impacts labor productivity in Indonesia with a regression coefficient of 0.0421. Assuming other variables remain constant,

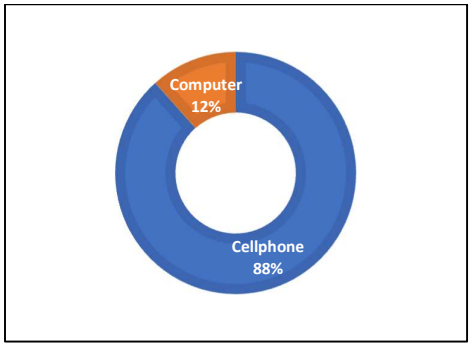
Indonesia's labor productivity increases by 0.0421 percent for every one percent increase in human capital stock. The positive and significant contribution of the regression model supports the human capital theory. Todaro & Smith (2012) that humans build new technology to increase labor productivity. High-performing workers with high school diplomas are considered human capital. Workers with higher education are more productive (Lee et al., 2020; Markhaichuk et al., 2022).

The regression coefficient for trade openness is 0.0541. Thus, trade openness drives the productivity of Indonesian labor. An increase in trade openness by 1% boosts labor productivity by 0.0541%, assuming other variables remain constant. According to Huchet-Bourdon et al. (2018) and Mireku et al. (2017), trade openness boosts economic growth.

The productivity of Indonesian workers is positively correlated with wages, with a regression coefficient of 0.0990. If all variables remain constant, the productivity of the Indonesian workforce will increase by 0.0990 percent for every one percent increase in worker wages. This research supports the efficiency wage theory, which states that higher wages increase productivity. (Mankiw, 2019). Otterby et al. (2024) and Zakaria (2022) found that higher wages increase productivity.

The influence of ICT is measured by internet penetration, mobile phones, and computers. Internet penetration significantly drives the productivity of the Indonesian workforce. If other variables remain constant, each one percent increase in households connected to the internet will boost labor productivity in Indonesia by 0.0020 percent. This study confirms Martami and Dartanto (2020). Research findings indicate that internet penetration can enhance the productivity of Indonesian workers. Several studies agree that the significant influence of the internet will affect productivity. (Laddha et al., 2022; Shahnazi, 2021). The varying penetration of mobile phones in Indonesia significantly reduces labor efficiency. If other variables remain unchanged, each one percent increase in households with mobile phones in Indonesia will reduce labor productivity by 0.0068 percent. Markhaichuk and Panshin (2020) found that digitalization, including the use of mobile phones, decreases labor productivity. According to Abramova and Grishchenko (2020), ICT does not permanently affect worker productivity.

Figure 15. Internet usage among working residents categorized by device in 2022

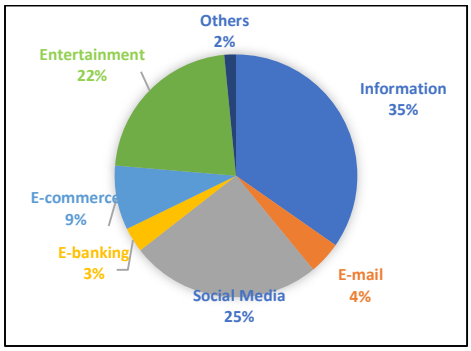


Source: BPS (2022)

The coefficient of the mobile phone penetration variable is negative and significant, supported by descriptive analysis results showing that 88% of the working-age population uses the internet via mobile devices, while only 12% use computers (Figure 15). People tend to prefer mobile phones because they are relatively affordable.

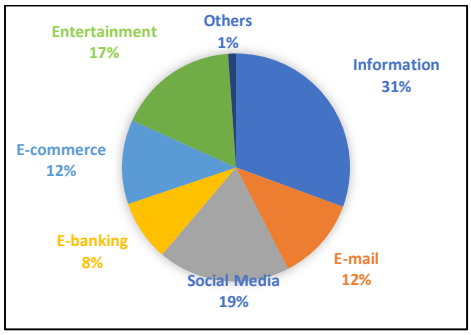
From these indications, it is also necessary to know the activities that mobile phone users engage in while working. In Figure 16, the primary use of mobile phones is accessing information/news, at 35%, followed by accessing social media at 25%, entertainment activities such as playing games, streaming videos, and YouTube at 22%, e-commerce for buying and selling transactions at 9%, e-banking at 9%, and email at 4%. The use of computers is more often for productive work activities compared to mobile phones. In Figure 17, it can be observed that the use of computers for accessing information, sending/receiving emails, e-commerce, and e-banking is 31%, 21%, 12%, and 12%, respectively. The figures are higher compared to the use of mobile phones for productive activities. The reason why its impact on productivity can be ignored can also be linked to the low penetration of computers.

Figure 16. Internet usage through mobile phones by working residents according to activities in 2022



Source: BPS (2022)

Figure 17. Internet usage through computer devices by working residents according to activities in 2022



Source: BPS (2022)

Individual Effect

Variation in individual effects is caused by differences in characteristics between provinces that are not included in the model (Table 3). The highest intercept is found in the DKI Jakarta Province, which means that if the independent variables used in the model are constant, DKI Jakarta Province has the highest labor productivity growth, while East Nusa Tenggara Province has the lowest labor productivity growth among all provinces, assuming all independent variables are constant.

Table 3. Individual impact for each province

ID	Province	Effect	ID	Province	Effect	ID	Province	Effect
11	Aceh	-0,270	32	Jawa Barat	-0,104 tahun	64	Kalimantan Timur	1.339
12	Sumatera Utara	0,062	33	Jawa Tengah	-0,329	65	Kalimantan Utara	0.891
13	Sumatera Barat	-0,114	34	DI Yogyakarta	-0,435	71	Sulawesi Utara	0,021
14	Riau	0.844	35	Jawa Timur	0,009	72	Sulawesi Tengah	0,016
15	Jambi	0.169	36	Banten	-0,015	73	Sulawesi Selatan	0.121
16	Sumatera Selatan	0.107	51	Bali	-0.210	74	Sulawesi Tenggara	-0,019 tahun
17	Bengkulu	-0,532	52	Nusa Tenggara Barat	-0,629	75	Gorontalo	-0,406
18	Lampung	-0,267	53	Nusa Tenggara Timur	-1.089	76	Sulawesi Barat	-0,458
19	Kepulauan Bangka Belitung	0,034 tahun	61	Kalimantan Barat	-0,235	81	Maluku	-0,617
21	Kepulauan Riau	0,765 tahun	62	Kalimantan Tengah	-0,038	82	Maluku Utara	-0,499
31	DKI Jakarta	1.526	63	Kalimantan Selatan	-0,172	91	Papua Barat	0.633
						94	Papua	-0,100

Conclusions

In this paper, it was found that labor productivity tends to show an increasing trend but its growth is slow. Furthermore, there is a significant gap in labor productivity across various provinces.

There are also indications of a relationship between labor productivity and physical capital, human capital, trade openness, wages, internet penetration, mobile phone penetration, and computer penetration. The results of the panel data regression show a positive and significant impact on labor productivity in Indonesia from the percentage of households with internet access, physical capital stock, human capital stock, and trade openness. On the other hand, the percentage of households that own/possess mobile phones has a negative and significant impact on labor productivity. Meanwhile, computer penetration does not significantly

affect productivity. The results were reinforced by further analysis stating that mobile phones are used more for accessing the internet compared to computers. However, workers use mobile phones more for entertainment than for activities that support productivity.

A recommendation for the government is to improve the equitable distribution of ICT infrastructure, particularly internet access, so that internet utilization can enhance labor productivity. In addition, improving digital maturity is also necessary to enhance the quality of human resources. Policies are needed to minimize the disruptive impact of ICT usage on workers, so that the potential utilization of ICT can be maximized.

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