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Digital Technology Access and Income Inequality: A Labour Market Behaviour Perspective in Rural Indonesia

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ABSTRACT

The importance of digital technology for inclusive economic development is becoming increasingly evident. This paper examines the impact of digital access and productive internet use on the individual labor income of rural Indonesians across different income percentiles, taking into account the heterogeneity of rural digital infrastructure and the high level of informality in the rural sector. By utilizing the 2024 National Socioeconomic Survey and the National Labour Force Survey, this paper employs the quantile regression technique to examine the effects of digital access and internet engagement at the 25th, 50th, and 75th income percentiles. The results indicate that digital access has a significant benefit for lower-middle-income individuals, with decreasing returns at higher income levels. Conversely, productive internet usage is associated with increased income, particularly at the upper quantiles, suggesting that digital skills enable rural individuals to capitalize on economic opportunities. Additionally, the proxies for job-searching behaviors do not demonstrate a relationship with income in any quantile, which indicates structural issues with the rural labor market. Thus, policymakers need integrated digital inclusion strategies that focus both on capability and institutional constraints to ensure fair economic access for rural residents.

INTRODUCTION

Over the last twenty years, a wave of digital technologies has swept the world, reshaping the global economy and redefining the ways people produce, communicate, and exchange value. Not merely a temporal trend, digital transformation has become a transformative current that addresses all aspects of industry competition, institutional development, and social engagement

In low- and middle-income areas, digitalisation is positioned as a great social leveller, which may reach people in the backwoods and connect them to big markets, offer multiple earnings options, and open the way from handicrafts to high production or service rendition, thereby preventing the entrenchment of poverty (Jamil, 2021; Kumar, Verma, & Mirza, 2024). Indonesia offers an instructive example in this context. With one of the most dynamic digital economies globally, the Indonesian government has allocated substantial resources to broadband, digital literacy, and inclusive finance, as planned in the Indonesia Digital Roadmap 2021-2024. Nevertheless, while digitalization is one of the nation's most vital missions, the disparities between rural and urban areas remain substantial. Hence, the issue is not simply one of access but one of capacity disparity. Indeed, capability, or the ability to use the technology efficiently and effectively for earning a living, job transition, and entrepreneurship, is a significant concern.

Rural labor markets are burdened with numerous structural impediments that severely impede economic mobility and equality, including inadequate internet coverage, low educational attainment, and the prevalence of informal employment. These structural challenges, therefore, severely limit the rural laborers' ability to capitalize on the financial benefits of digitalization. Therefore, the pertinent question that arises is to what extent the digital economy provides a level playing field for individuals of varying socioeconomic backgrounds. This study aims to investigate the effects of digital access and productive internet usage on individual labor earnings across different quantiles of the income distribution in rural Indonesia. Utilizing high-quality microdata from the 2024 wave of the National Socioeconomic Survey and the National Labor Force Survey, this study employs quantile regression analysis to reveal differences in earnings patterns among low-, middle-, and high-income earners, rather than just average effects. The goal is to identify the extent to which the digital divide may act as either a leveling or exacerbating force in the labor market. Furthermore, this study aims to examine the extensive and distinct behavioral channels of influence at the individual level, including online job searching, the utility of digital tools in the workplace, and the continuation of informal employment.

LITERATURE REVIEW

Digital Access and the Promise of Inclusive Development

Digital access had become the key enabler of development, and its inclusiveness was becoming a defining criterion. This implies not only the availability of the internet and digital devices as such but also their ability to function for productive purposes. With the widespread use of digital connectivity, it has contributed to increased access to the labour market, productivity increases, and income growth (Kelikume, 2021; Mhlanga, 2021). Several studies highlight that digital access can lower transaction costs, reduce information asymmetries, and unlock new economic opportunities, particularly for marginalised populations (Saini & Kharb, 2025). However, the inclusive potential of digitalisation depends on its equitable distribution and the absorptive capacity of users to integrate technology into their livelihoods. Without addressing disparities in digital literacy, affordability, and institutional support, digital access risks reproducing the very inequalities it is meant to mitigate (Srinivasan, 2025). The notion of *"digital dividends"*, the social and economic returns of digital adoption, thus varies significantly across contexts, requiring careful examination of who benefits and who remains excluded.

The Rural Digital Divide in Low- and Middle-Income Countries

In rural areas of low- and middle-income countries (LMICs), including Indonesia, the optimistic narrative that digital connectivity benefits all has been increasingly contested (Fuchs, Tesfamichael, Clube, & Tomei, 2024; Madon & Masiero, 2025). Despite the rapid expansion of infrastructure and the proliferation of mobile devices, access remains uneven between core and

peripheral regions. Rural communities, particularly those outside Java and major urban centres, often encounter *multi-layered exclusion* stemming from infrastructural deficits, weak educational systems, and entrenched informality in the labour market (Faizah, Isbah, & Azca, 2025; Permana, 2025). These constraints limit not only the adoption of technology but also its translation into economic outcomes. For instance, rural internet users may rely on digital tools primarily for social communication rather than productive activities, reflecting both skill gaps and opportunity deficits. Consequently, the rural digital divide should be viewed as a structural and behavioural phenomenon, influenced by economic geography, institutional quality, and social capital.

Digital Skills as Adaptive Human Capital in Evolving Labour Markets

Recent theoretical developments position digital skills as a critical dimension of *adaptive human capital*, enabling workers to navigate technological disruption and shifting employment landscapes (Cai, Chen, Wang, & Di, 2025; Moore et al., 2024; Țarcă, Luca, & Țarcă, 2024). In this perspective, digital competence not only enhances employability but also increases resilience in volatile labour markets. Workers with advanced digital skills can transition more effectively into hybrid or remote employment, benefiting from flexible work arrangements and platform-based opportunities. Nevertheless, empirical evidence suggests that access to digital tools does not automatically result in equitable economic returns. Digital skills are unevenly distributed, often mirroring pre-existing socio-economic hierarchies. Rural workers, in particular, face cumulative disadvantages: lower exposure to technology, limited institutional support, and weaker social networks that facilitate skill development (Jia, Du, & Yan, 2024; Yu & Cai, 2025; Zhao & Weng, 2024). These disparities underscore the dual nature of digitalisation as both a vector of empowerment and a potential amplifier of inequality.

Structural Segmentation and Institutional Mediation in Labour Markets

The structural segmentation of labour markets mediates the relationship between digitalisation and labour outcomes. Empirical studies indicate that workers in informal or precarious employment remain disconnected mainly from digital labour opportunities, even when they possess basic technological access (Scully & Moyo, 2021; Tang & Hao, 2025). This persistence of structural dualism reflects institutional weaknesses, limited enforcement of labour protections, and unequal bargaining power within digital economies (Anner, Fischer-Daly, & Maffie, 2020; Graham, Hjorth, & Lehdonvirta, 2017). From an institutional economics standpoint, digital inclusion is thus contingent upon the interplay between technology and governance. Where institutional mechanisms such as training systems, labour regulations, and digital ecosystems are weak, technology adoption may entrench informality rather than alleviate it. Hence, understanding the digital economy's impact requires integrating both micro-level behavioural factors and macro-level institutional dynamics.

Empirical Insights: Digital Technology, Productivity, and Income Effects

A growing body of empirical literature has examined the economic implications of digital technology. Studies in Sub-Saharan Africa, for instance, reveal that broadband access significantly increases employment rates and firm productivity, particularly in service-oriented industries (Cao, Zhang, & Cui, 2024; Harrathi & Alshogeathri, 2025). Similarly, in high-income economies such as Germany, internet penetration enhances job-search efficiency, facilitates regional labour mobility, and supports more efficient matching in the labour market (Bella et al., 2024; F. Chen, Shi, & Chen, 2024; Xiong & Yu, 2024). In LMICs, digital technologies such as mobile phones have enabled smallholders to access agricultural markets, obtain price information, and develop informal entrepreneurial ventures (Marion et al., 2024). However, these benefits accrue disproportionately to wealthier, urban-connected, and better-educated individuals (Ho, Ngoc, & Ho, 2025; Tian & Xiang, 2024). This pattern suggests that while digitalisation can enhance productivity and inclusion, its gains are conditional on pre-existing socio-economic endowments.

Many national-level studies, however, still treat digital inclusion as a single aggregated measure, overlooking its differentiated effects across income strata or occupational groups (Jia et al., 2024; Shah & Krishnan, 2024).

Indonesia's rural economy presents a paradoxical case; while digital infrastructure has expanded significantly, functional digital literacy and labour protections remain limited. Rural workers operate within informal institutions where digital technologies are often underutilised for income generation or career advancement. The behavioural responses to digital access, whether through online job search, e-commerce participation, or digital upskilling, are therefore profoundly shaped by structural and institutional constraints (Duan, Exter, & Li, 2024; Mwansa, Ngandu, & Mkwambi, 2025; Yang, Zhang, & Wang, 2025). Empirical research on the *distributional effects* of digitalisation in rural Indonesia remains sparse. Few studies have examined how the benefits of digital access vary across income groups or how behavioural mechanisms mediate its impact on labour outcomes (Guarascio, Reljic, & Stöllinger, 2025; Xiao, Xu, Skare, Qin, & Wang, 2024; Xiong & Sui, 2025). Moreover, the rural context, characterised by high informality, income volatility, and geographical isolation, poses unique challenges for equitable digital inclusion. Accordingly, this study contributes to the literature by adopting an income-stratified analytical framework to investigate the heterogeneous impacts of digital access and productive internet use on labour income in rural Indonesia. By integrating behavioural and institutional dimensions, it extends existing digital economy research toward a more *distribution-sensitive* understanding of technological transformation and its role in shaping inclusive rural development.

METHODS

Research Design and Empirical Strategy

This study employs a cross-sectional econometric design to investigate the impact of digital access (DA), productive internet use (PI), and labour market behaviour (LMB) on individual labour income (Y) across the income distribution in rural Indonesia. Unlike conventional mean-based regression, this study employs the quantile regression (QR) method, initially proposed by (Koenker, R., & Bassett, G., 1978), which enables the estimation of covariate effects at different points (quantiles) of the conditional income distribution.The quantile regression model is specified as follows:

$$Y_{(i,\tau)} = \beta_{(0,\tau)} + \beta_{(1,\tau)}DA_i + \beta_{(2,\tau)}PI_i + \beta_{(3,\tau)}LMB_i + \varepsilon_{(i,\tau)}, \quad 0 < \tau < 1$$

where $Y_{(i,\tau)}$ denotes the income of individual i at quantile τ, DA_i represents digital access, PI_i captures productive internet use, and LMB_i indicates labour market behaviour. The parameters β_τ are estimated for three quantiles: 0.25 (lower income), 0.50 (median), and 0.75 (upper income), capturing heterogeneous marginal effects across the income distribution.

Data Source and Variable Measurement

The analysis draws on nationally representative microdata from the 2024 National Socioeconomic Survey (SUSENAS) and the 2024 National Labour Force Survey (Sakernas), conducted by Statistics Indonesia (BPS). These datasets provide comprehensive information on individual labour income, employment characteristics, and household digital access.

Dependent Variable

- Individual monthly labour income (in Indonesian Rupiah, IDR).

Independent Variables

- Digital Access (DA): Ownership of internet-enabled devices and household connectivity.

- Productive Internet Use (PI): Frequency of using the internet for productive activities such as online business or education.
- Labour Market Behaviour (LMB): Patterns of job-seeking and employment formality.

Quantile Regression Model

The quantile regression technique estimates conditional quantiles rather than conditional means, thus capturing heterogeneity and non-linear effects across the income distribution (Koenker, R., & Bassett, 1978). The quantile estimator solves:

$$\min_{(\beta_\tau)} \Sigma_i \rho_\tau (Y_i - X_i'\beta_\tau),$$
$$\text{where } \rho_\tau(u) = u(\tau - I(u < 0))$$

This minimises the weighted sum of absolute residuals, assigning τ and $(1-\tau)$ weights to positive and negative errors, respectively. The model is estimated at $\tau = 0.25$, 0.50, and 0.75 to explore income heterogeneity among low-, middle-, and high-income groups.

Estimation Procedure and Diagnostic Tests

Estimation was carried out using the (Koenker, R., & Bassett, G., 1978) quantile regression procedure. Bootstrapped standard errors with 1,000 replications were computed to ensure robustness against heteroskedasticity and non-normal residuals. Diagnostic checks included pseudo R^2, coefficient stability across quantiles, and the Qu test for structural breaks (Davino, C., Furno, M., 2013).

Model Interpretation Framework

The quantile coefficients (β_τ) indicate the marginal effect of each independent variable on income at specific quantiles. A positive and significant coefficient at the 0.25 quantile suggests that digital access benefits lower-income individuals. In comparison, significance at the 0.75 quantile implies that digital utilisation yields higher income premiums for upper-income groups.

RESULTS

The quantile regression results presented in Tables 1–3 offer a nuanced understanding of how digital access (DA), productive internet use (PI), and labour market behaviour (LMB) influence labour income across the rural income distribution in Indonesia. By estimating coefficients at the 25th, 50th, and 75th percentiles, the model captures differential impacts between low-, middle-, and high-income earners, a methodological advancement over mean-based OLS estimations, which mask distributional heterogeneity. Overall, the pseudo-R2R^2R2 values, though relatively modest (ranging from 0.0135 to 0.0288), are consistent with micro-level behavioural data and support the argument that digital and behavioural factors exert subtle but meaningful effects on income disparities in rural labour markets characterised by informality and heterogeneity. At the 25th percentile, representing the bottom quartile of rural income earners, both digital access (DA) and productive internet use (PI) exhibit statistically significant and positive effects on income (Table 1).

Table 1. PERCENTILE 0,25

Income	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
DA	141666.67	67013.223	2.11	.035	10172.735	273160.6	**
PI	66666.667	32982.257	2.02	.044	1948.594	131384.74	**
LMB	-225000	262684.88	-0.86	.392	-740442.56	290442.57	ns
Constant	650000	91928.263	7.07	0	469617.56	830382.44	***
Mean dependent var		3186206.201	SD dependent var			15516305.098	

**** p<.01, ** p<.05, * p<.1*

The coefficient of DA (141,666.67; $p < 0.05$) confirms that expanding access to digital infrastructure, such as mobile broadband and internet-enabled devices, directly enhances income among low-income rural workers. Likewise, PI (66,666.67; $p < 0.05$) underscores that even limited engagement in productive online activities (e.g., online commerce, job searches, or e-learning) can yield measurable income gains. These results reflect a "connectivity dividend", wherein initial access to digital resources disproportionately benefits lower-income households by lowering transaction costs, improving information flow, and enabling participation in informal digital micro-economies. The insignificant coefficient of LMB ($p = 0.392$) suggests that structural labour market barriers such as limited job mobility, weak institutions, and low formality continue to suppress behavioural effects on income at this level. At the median quantile (0.50), both digital access and productive internet use continue to exhibit positive associations with income, although the magnitude and significance patterns shift, as shown in Table 2 below.

Table 2. 50% PERCENTILE

Pendapatan	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
DA	208333.33	93798.299	2.22	.027	24281.493	392385.17	**
PI	83333.333	46165.211	1.81	.071	-7252.447	173919.11	*
LMB	-280000	367679.59	-0.76	.447	-1001464.1	441464.11	ns
Constant	1500000	128671.84	11.66	0	1247519	1752481	***

Mean dependent var 3186206.201 SD dependent var 15516305.098

*** p<.01, ** p<.05, * p<.1

Source: BPS 2024 data processing

The higher magnitude of DA (208,333.33) relative to the lower quantile implies that improved digital connectivity yields increasing marginal returns as households move toward the middle of the income distribution. Meanwhile, the borderline significance of PI ($p = 0.071$) suggests that as digital literacy improves, internet utilisation transitions from basic access to productive engagement, amplifying returns among mid-income earners. The persistent insignificance of LMB reinforces that labour market behaviour alone, absent complementary institutional reforms, has limited explanatory power for income enhancement. Informality remains the defining feature of rural employment structures, constraining behavioural mechanisms like job-seeking from translating into real income gains. This finding aligns with (Shams, Chatterjee, & Chaudhuri, 2024; Shatila, Aránega, Soga, & Hernández-Lara, 2025), who argue that the transformative impact of digitalization depends not only on access but also on individuals' adaptive human capital, the capacity to integrate digital tools into productive and entrepreneurial practices. At the upper quantile (0.75), representing higher-income rural individuals, productive internet use (PI**)** becomes the strongest and most significant predictor of income, as shown in Table 3 below.

Table 3. PERSENTILE 75%

Income	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
DA	250000	161737.43	1.55	.122	-67362.6	567362.6	
PI	218750	79603.178	2.75	.006	62551.949	374948.05	***
LMB	-843750	633993.94	-1.33	.184	-2087778.4	400278.45	
Constant	2500000	221870.26	11.27	0	2064644.2	2935355.8	***

Mean dependent var 3186206.201 SD dependent var 15516305.098

*** p<.01, ** p<.05, * p<.1

Source: olah data BPS 2025

The coefficient of PI (218,750; $p < 0.01$) indicates that the economic benefits of digital utilisation intensify as individuals ascend the income ladder. This pattern signifies a digital premium effect, where higher-income individuals leverage advanced digital capabilities, such as online entrepreneurship, remote work, and e-commerce platforms, to amplify their earnings. Conversely, AT ($p = 0.122$) becomes insignificant, implying that infrastructure access has reached a saturation threshold at the upper quantile. This transition from "access effect" to "capability effect" marks the second phase of digital transformation, where the quality and sophistication of digital engagement significantly influence income differentials. The negative, albeit insignificant, LMB coefficient (-843,750) highlights that behavioral factors, such as job-seeking, are overshadowed by capability-driven mechanisms at higher income levels. This finding resonates with (Okolo, Wen, & Susaeta, 2024; X. Zhang, Chang, Zhang, Zhang, & Lin, 2025) Documented that advanced digital use generates economic rents primarily for individuals possessing superior human capital and network capital.

DISCUSSION

Access to digital technology, such as smartphones, the internet, or computers, has a positive and statistically significant impact on income at the 25th and 50th percentiles, with marginal increases of IDR 141,667 and IDR 208,333, respectively. However, at the 75th percentile, this effect becomes statistically insignificant. This trend suggests that digital access is particularly beneficial for low- to middle-income individuals, likely due to increased opportunities for online employment, informal gig work, or improved access to market information. While the impact of productive internet use (PI) remains statistically significant at the 25th percentile, it loses significance at the median. Conversely, it becomes substantially more substantial and impactful at the 75th percentile (IDR 218,750, $p < 0.01$), suggesting that higher-income individuals derive greater benefits from digital entrepreneurship, remote service delivery, or high-skilled online work. Throughout all quantiles, the relationship between job-seeking behaviour in rural areas and income, as measured by LMB, is negative yet insignificant. This may indicate that job-seeking in rural areas does not necessarily correlate with higher wages, likely due to informal job structures, a scarcity of formal job openings, or inefficiencies in rural labour markets. Additionally, the pseudo R^2 increases with the quantile level, rising from 1.35% at the 25th percentile to 2.88% at the 75th percentile. This suggests that the model accounts for a greater proportion of income variation at the upper end of the distribution, which aligns with the more potent effects of PI observed at Q75. The findings of this study provide compelling evidence that access to digital technology has a differentiated impact on income distribution across rural areas in Indonesia. This aligns with and extends prior research emphasising the non-linear and distribution-sensitive nature of digital dividends in developing economies. (Ma & Kang, 2025; J. Zhang & Li, 2024; S. Zhang, Mingyue Gu, Sun, & Jin, 2024).

The positive and statistically significant effects of digital access on income for individuals in the lower (Q25) and middle (Q50) income brackets highlight the importance of digital infrastructure as a crucial enabler of income enhancement for economically vulnerable groups. The notable income gains associated with digital access for lower-income individuals (Q25) indicate that basic connectivity, such as internet-enabled phones or household internet, can promote labour participation in informal digital economies. These economies encompass micro-gig work, online resale, and access to agricultural price information, aligning with findings from low-income rural areas in South Asia and sub-Saharan Africa (Khan et al., 2024; Sarku & Ayamga, 2024). However, the diminishing and statistically insignificant effects of access at the 75th percentile reveal the saturation point of basic digital advantages. This suggests that in digital development, as access becomes widespread among higher-income groups, the differentiation of labour income fades, with success relying more on advanced digital skills and capital-intensive entrepreneurship(Hao, Ye, & Zhang, 2025; Hötte, Somers, & Theodorakopoulos, 2023).

Unlike mere access, using the internet for productive purposes (PI), such as online business, learning, and job seeking, exhibits an increasing gradient across income levels, with the most potent positive effect at Q75. This reinforces the emerging view that digital usage intensity, not just access, is what drives economic returns in digitally transforming labour markets (Brunetti et al., 2020; Javaid, Haleem, Singh, & Sinha, 2024; Verhoef et al., 2021). The delayed significance of PI until the 75th percentile suggests that only those with sufficient human capital, likely with higher education, digital fluency, and market networks, can transform digital access into higher-income opportunities. This substantiates the argument that digitalisation may initially exacerbate inequality unless paired with investment in digital skills training, especially for rural youth and women (Y. Chen, Huang, Zeng, & Huang, 2024; Zamani & Rousaki, 2024).

The non-significant and negative coefficients for active job-seeking behaviour (LMB) across all quantiles challenge the conventional assumption that labour market agency (e.g., updating CVs or contacting employers) directly leads to income gains. This finding is consistent with earlier critiques of rural labour markets in Indonesia, where job matching mechanisms are weak, informal hiring is dominant, and job search efforts often fail to result in formal employment (Al Ayyubi, Pratomo, Prasetyia, & Susilo, 2025; Yulianti & Fitriansyah, 2024). In such fragmented labour markets, proactive behaviour may not translate into higher wages, particularly when low job quality or mobility constraints are high. This highlights the structural limitations within rural employment ecosystems, where individual agency is unable to overcome systemic barriers.Collectively, the results underscore a dual narrative: while digital access and internet usage can catalyse income gains, especially for the poor and middle-income groups, these benefits are not automatic nor evenly distributed. In its current form, digitalisation appears to augment pre-existing inequalities, favouring individuals with higher capabilities to leverage online opportunities (Hu, Chen, Liu, & Wang, 2024; Manning, 2024; Sulastri, Janssen, van de Poel, & Ding, 2024). The absence of significant returns to job-seeking behaviour suggests that technology alone cannot compensate for weak labour institutions or regional economic disparities. In the Indonesian context, this implies that national strategies on digital inclusion must go beyond hardware provision. Instead, tailored interventions that combine connectivity with targeted digital upskilling and access to relevant platforms are needed, particularly for rural micro-entrepreneurs and underemployed workers. Policy attention must also address the structural informality in rural labour markets, which may undermine the potential of digital technologies to serve as a true equaliser.

CONCLUSION

The economic impacts of digitalisation exhibit significant variability contingent upon socioeconomic status and the intensity of usage. Access to basic digital resources is a vital catalyst for individuals in lower and middle-income brackets, facilitating their engagement in informal economic activities. However, the benefits derived from such access tend to diminish at higher income levels, affirming the digital development threshold hypothesis. Conversely, productive utilisation of the internet is associated with escalating income gains, predominantly among higher-income individuals possessing advanced digital competencies. This observation underscores the critical role of digital skills and entrepreneurial engagement in realising economic benefits. Furthermore, the absence of a meaningful association between active job-seeking behaviours and income levels suggests the presence of structural impediments within rural labour markets. In these contexts, digital tools are insufficient to mitigate the challenges of inadequate institutional support and the prevalence of informal employment arrangements. These findings highlight the necessity for digital inclusion policies to transcend mere advancements in infrastructure; such policies must also integrate comprehensive strategies aimed at enhancing capabilities and instituting institutional reforms, particularly for marginalised populations in rural settings

LIMITATION

This study acknowledges several limitations. First, the use of cross-sectional data restricts causal inference between digital access, productive internet use, and income, suggesting the need for longitudinal analysis. Second, the indicators of digital inclusion may not fully capture qualitative aspects, such as literacy, institutional support, or social capital, that influence income outcomes. Finally, future research should incorporate multilevel and dynamic approaches to examine how digitalisation interacts with structural, spatial, and sociocultural factors in shaping inclusive rural development.

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