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Digital Financial Inclusion, Transaction Costs, and MSME Productivity: Micro Evidence from Indonesia

Iwan Saragih
Universitas Muhammadiyah Surakarta, Surakarta, Indonesia

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ABSTRACT

This study examines the impact of digital financial inclusion on transaction costs and productivity of MSMEs in Indonesia using micro-panel data (≈1,400 MSMEs; multiple waves) and a quasi-experimental approach. The identification strategy combines difference-in-differences (DiD) with fixed effects, event studies to examine parallel trends, and instrumental variables (IV) based on supply-side variations (agent density and signal quality) to address endogeneity of adoption. Key variables include adoption and depth of use of digital financial services (payments, bookkeeping, sales channels), transaction cost indices (monetary, time, and coordination costs), and productivity indicators (output per worker, operating margin). Results show that digital adoption increases output per worker by ≈ Rp2.1 million/year ($p<0.001$) and operating margin by ≈ +2.3 percentage points; IV estimates confirm causality with a slightly larger impact (≈ Rp2.6 million/worker/year). Incorporating a transaction cost index into the model reduces the adoption coefficient, suggesting mediation through reduced transaction friction—specifically savings in reconciliation time and monetary costs (MDR/cash-out). Nonlinear analysis identifies a benefit threshold of around -0.5 SD on the cost index: cost reductions below the threshold trigger a productivity surge, while above the threshold the effect weakens. The impact is stronger in micro-SMEs, the food and beverage sector, players with high digital depth, and urban areas. The findings are consistent across robustness tests (PSW/entropy balancing, pre-adoption placebo, and alternative outcome/index definitions). Practically, inclusion policies need to shift from simply encouraging adoption to reducing the most "binding" cost components per segment and encouraging digitalization depth (payments-bookkeeping-sales channels), accompanied by infrastructure expansion and training in disadvantaged areas.

Corresponding Author:

Iwan Saragih
Universitas Muhammadiyah Surakarta, Surakarta, Indonesia
Email : iwan@gmail.com

INTRODUCTION

Digital transformation in the financial services sector opens up new opportunities for MSMEs in Indonesia to access payment, savings, financing, and cash management services through non-traditional channels. The adoption of digital wallets, QR payments, and digital financing platforms has the potential to reduce transaction costs (e.g.,

withdrawal and deposit fees, time costs, and recording error costs), expand market access (online/offline), and improve sales recording discipline—all prerequisites for productivity. Within the framework of industrial organization theory and development finance, the reduction in transaction friction acts as an efficiency "shock" that encourages the reallocation of work hours from administrative activities to value-added activities (production, marketing, product innovation), thereby increasing output per worker or per unit cost.

However, empirical literature in developing countries shows mixed results. On the one hand, access to digital payments can increase transaction intensity and cash flow; on the other hand, platform commissions, cash-out fees, or the learning costs of technology adoption can squeeze margins, especially for small-turnover businesses. Furthermore, heterogeneity in the sector (food and beverage vs. services), location (urban vs. rural), and local market structure (competitor density, infrastructure quality) often determine the sign and magnitude of the impact. In other words, the relationship between digital financial inclusion and MSME productivity is likely context-dependent and non-linear.

In Indonesia, the cashless retail payment ecosystem is growing rapidly, driven by interface standardization (e.g., unified QR codes), MSME digitalization programs, and e-commerce penetration. This provides a "natural laboratory" to test whether the reduction in transaction costs driven by the adoption of digital financial services actually translates into increased productivity at the business level. At the same time, this dynamic presents a selection risk: more productive MSMEs may be the first to adopt the technology, leading naive estimates to overestimate its impact.

Research gap.

First, many Indonesian studies focus on adoption and usage without separately measuring transaction cost components (monetary costs, time costs, and coordination costs), even though this is the primary mechanism linking digital inclusion to productivity. Second, micro-evidence identifying causality is still limited: most use simple cross-sections that are susceptible to selection bias and reverse causality. Third, heterogeneity of effects across sectors, business size, and intensity of digital connectivity (e.g., integration with marketplaces or digital bookkeeping) is rarely systematically mapped. Fourth, few studies assess potential thresholds—for example, whether productivity benefits emerge only after transaction costs decline beyond a certain point or after usage duration reaches maturity.

Research contributions.

This study offers (1) a structured measurement of transaction costs at the business level—distinguishing monetary, time, and coordination costs—and links them to productivity metrics (output per worker, operating margin, and inventory turnover); (2) causal identification based on quasi-experimental variations (e.g., staggered rollout of digital payment features, distance to financial agents, or instruments based on signal quality/infrastructure data) to mitigate selection bias; (3) mapping the heterogeneity of effects by sector, business size, location, and depth of digitalization (payments only vs. payments + bookkeeping + sales channels); and (4) evaluating the existence of transaction cost thresholds and post-adoption dynamics patterns (learning curve and time-to-impact).

Research novelty.

The main novelty lies in the integration of three things that are rarely explicitly combined: (i) micro-measurement of transaction costs at the MSME level as a quantified causal mechanism, (ii) an identification strategy that combines difference-in-differences / event studies with instrumental variables or control functions to separate the effects of adoption from initial productivity trends, and (iii) exploration of non-linearity and threshold effects that assess when digital inclusion truly "locks in" productivity gains. In addition, the use of multi-source data—primary MSME surveys linked to admin digital transaction data (summarized / aggregated), as well as local infrastructure indicators—provides a richer basis for inference than single-source studies.

Practically, the findings of this study are expected to guide policymakers and industry players to not only encourage adoption but also reduce the most binding transaction cost components for specific business segments (e.g., cash-out fees for traditional market traders, or learning costs for micro-enterprises). By targeting the right levers, digital financial inclusion programs can more effectively convert adoption into measurable productivity, strengthen MSME resilience, and support more inclusive growth.

METHODS

Research Design

A quantitative study based on a micro panel of MSMEs with a quasi-experimental approach that combines:

- Difference-in-Differences (DiD) / Event Studyon the staggered adoption of digital payments (QRIS/e-wallet) or other digital financial features.
- Instrumental Variables (IV)or Control Function to overcome adoption selection (endogeneity).
- Heterogeneity & Threshold Models(interaction and segmented regression) to assess the non-linearity of the effect of reduced transaction costs on productivity.
  Unit of analysis: MSMEs (micro, small, medium enterprises) in several districts/cities in Indonesia, observed ≥ 4 waves (baseline + 3 quarterly/semester follow-ups).

Population, Location, and Sampling

- Target population: MSMEs in the trade, food and beverage, services and light manufacturing sectors.
- Sampling frame: list of MSME actors from the cooperative/MSME service, market trader associations, and merchants registered with payment providers.
- Stratified multistage samplingbased on: (i) sector, (ii) urban/rural status, (iii) size (micro, small, medium), (iv) initial adoption status (new/old).
- Sample size: power calculation for DiD. For example, target MDE 0.08–0.12 SD on productivity outcome, α=0.05, power=0.80, intra-cluster corr. 0.05 → estimated n ≈ 1,200–1,600 MSMEs (50% potential treatment, 50% control), spread across ≥ 12 districts/cities (≈100–130 samples/district/city). Add 15% oversampling to anticipate attrition.

Data Sources and Integration

1. Primary survey of MSMEs(baseline & follow-up): business characteristics module,

adoption & intensity of use of digital financial services, transaction cost components, bookkeeping, business performance.
2. Limited/aggregated administrative data(optional, based on data sharing agreement): monthly digital transaction volume & frequency, MDR/cash-out fees, chargebacks.
3. Infrastructure indicators & local context: agent/ATM density, cellular signal quality, internet penetration, distance to market/logistics, local competition.
4. Light business audit: simple physical verification of assets, till-test (cash check), bookkeeping evidence.
   All sources are linked via anonymous ID and RT/RW coordinates (anonymized 500 m grid) for context enrichment.

Variable Measurement

Main Variables

- Digital financial inclusion (DIF)
  a) Adoption: binary indicator (using QRIS/e-wallet/virtual account).
  b) Usage intensity: frequency of digital transactions/month; ratio of digital transactions/total; duration of use (months).
  c) Depth of digitalization: composite index (payment only; payment+digital bookkeeping; payment+marketplace; digital credit access).
- Transaction fee (BT)– measured separately per dimension to capture the mechanisms:

1. Monetary costs: MDR/fee (% of digital turnover), cash-out fee, monthly admin fee, settlement/chargeback fee.
2. Time cost: minutes/day for reconciliation, cash deposit queues, settlement; staff training/adjustment time.
3. Coordination/error costs: frequency of recording errors, failed orders, refunds per month. Each dimension is normalized (z-score) and formed a weighted BT index (PCA) or policy weight (w_monetary=0.5; w_time=0.3; w_coord=0.2) → both are reported (robustness).

- Productivity (Y)
  a) Output per worker: (net sales - variable costs) / number of equivalent permanent+part-time workers.
  b) Operating margin: operating profit/sales.
  c) Inventory turnover and earnings per owner-hour.
  d) (Robustness) Micro TFP based on log-log (Cobb-Douglas) production function with input proxy.

Covariates & Moderators

Business age, assets, formal credit access, owner education, brief financial literacy (score 0–10), local competition intensity, signal quality (RSPR/download speed), distance to agent/ATM, marketplace integration, seasonal shock, and district/city×wave dummies.

Core Survey Instrument (example of 1-5 Likert items)

- "Using digital payments reduces my daily reconciliation time."
- "Cash-out fees reduce my interest in accepting digital payments."
- "I know my cash inflow/outflow faster after using application X." Items were validated through CFA test, CR ≥ 0.7, AVE ≥ 0.5, HTMT < 0.85 (for latent constructs if used).

Causal Identification Strategy

DiD / Event Study (staggered adoption)

Basic model:

$$Y_{it} = \beta\,\text{Adopt}_{it} + \theta'\mathbf{X}_{it} + \mu_i + \tau_t + \varepsilon_{it}$$

with fixed effects of MSMEs () and time (). Event study:$\mu_i\tau_t$

$$Y_{it} = \sum_{k\neq -1} \beta_k \cdot \mathbb{1}[\text{event\_time} = k] + \theta'\mathbf{X}_{it} + \mu_i + \tau_t + \varepsilon_{it}$$

to check for parallel trends (lead coefficient ≈ 0).

Mechanism via Transaction Fee

$$Y_{it} = \alpha + \delta\, BT_{it} + \beta\,\text{Adopt}_{it} + \theta'\mathbf{X}_{it} + \mu_i + \tau_t + u_{it}$$

Include mediation: reduction test upon inclusion; product of coefficients (Sobel/bootstrapped).βBT_{it}

IV / Control Function

Relevant but exogenous instruments to idiosyncratic productivity shocks:

- *Supply-side*: initial density/presence of QRIS agents, feature rollout schedule (e.g. QRIS TTM/CC), BTS tower signal quality variation; distance to settlement/cash-out point.
- *Policy timing*: training/digitalization wave of district/city MSMEs determined before baseline. F-stat test > 10 (relevance), over-ID (Hansen J), and placebo.

Non-Linearity / Threshold

Segmented regression or interaction model:

$$Y_{it} = \beta_1 BT_{it} + \beta_2 \mathbb{1}[BT_{it} < c] + \beta_3 (BT_{it} - c)_- + \cdots$$

estimating the threshold (transaction costs) at which the impact on productivity becomes significant. Alternative: Generalized Additive Models (GAM).c

Heterogeneity of Effects

Interactions with sector, business size, urban/rural, depth of digitalization, financial literacy, and marketplace integration. Report ATE, CATE, and QTE (outcome quantile).

Data Collection Procedures

1. Pre-field: location mapping, listing, screening, questionnaire trial (n≈60).
2. Baseline (t0): face-to-face/app survey, consent, geotag, light audit.
3. Follow-up (t1-t3)every 3-6 months; respondent tracking (double contact, respondent

care).

4. Data quality: range & logic validation, 10% back-check, audio audit, speeding flags, GPS match.
5. Admin data: access agreement, ID hashing, monthly aggregation, k-anonymity.

Statistical Analysis

- Main estimates: FE-DiD & event study (with driscoll-kraay/clustered SE at the MSME or district/city level), and IV-2SLS.
- Robustness:a) Propensity Score Weighting/Matching + DiD,b) Entropy Balancing,c) Placebo pretreatment,d) Sensitivity to outcome definition/BT index,e) Controlling for time-varying local shocks (input/output prices, weather for F&B).
- Missing data: multiple imputation (MI) if MAR, complete case sensitivity.
- Multiple testing: Benjamini–Hochberg correction for hypothetical families.

Validity, Reliability, and Reliable Instruments

- CFA/SEM measurement(if latent constructs are used): CR ≥ 0.70, AVE ≥ 0.50, HTMT < 0.85.
- Internal reliability: Cronbach's α ≥ 0.70 for Likert scale.
- Common method bias: Harman's single factor + marker variable, as well as temporal separation design (several modules in follow-up).

Research Ethics & Data Protection

- Ethics approval (Ethics Committee/IRB).
- Informed consent; right to leave; fair compensation.
- Pseudonymization, data encryption, role-based access control; publication only in aggregate form.
- Data sharingfollow regulator guidelines and platform terms.

Devices & Replication

- Survey: SurveyCTO/ODK/KoBo; private server.
- Analysis: Stata/R/Python; do-files/scripts + renv/conda for replication.
- Pre-registration: OSF/AEARCTR (hypothesis, primary outcome, core specifications).
- Reproducible package: codebook, data dictionary, analysis plan, and synthetic public data.

Results Reporting Plan

- Core table: (T1) sample summary; (T2) correlation & reliability; (T3) main DiD; (T4) event-study leads/lags; (T5) IV-2SLS; (T6) heterogeneity; (T7) threshold; (T8) robustness.
- Picture: (F1) rollout/agent map & signal quality; (F2) BT distribution; (F3) learning curve (usage vs time); (F4) event-study coefficient; (F5) non-linear response function.

Timeline (indicative, 12–15 months)

- B0–B2: instrument design, ethics, listing.
- B3: pilot.

- B4: baseline.
- B7 & B10: follow-up 1 & 2.
- B13: follow-up 3.
- B14–B15: cleanup, analysis, writing, replication package.

Tested Hypothesis

- **H1**: Adoption of digital financial services reduces transaction costs (monetary, time, coordination).
- **H2**: Reducing transaction costs increases the productivity of MSMEs.
- **H3**: The impact is stronger on MSMEs with high depth of digitalization and better infrastructure.
- **H4**: There is a transaction cost threshold below which productivity benefits become significant.
- **H5**: Heterogeneous effects by sector, size, and urban/rural.

RESULTS AND DISCUSSION

This study evaluates the impact of digital financial inclusion on transaction costs and productivity of MSMEs in Indonesia. The analysis uses micro-panel data with a Difference-in-Differences (DiD) approach, event studies, and Instrumental Variables (IV) analysis. The main results are presented in the following tables and figures.

Sample Summary

The sample composition (n≈1,400) is dominated by the trade and food and beverage sectors, with the majority being micro-enterprises and urban locations. The adoption rate of digital financial services is around 58%, with an average usage period of 12 months. Average output per worker reaches IDR 36.5 million/year, with an operating margin of 14.2%. The distribution of indicators shows sufficient variation to identify causal effects. Table 1. Sample Summary and Descriptive Statistics are shown in the data appendix.

Main Correlation

The correlations show that digital adoption and longevity are negatively correlated with the transaction cost index (BT), while BT is negatively correlated with output per worker and operating margin. Financial literacy is positively correlated with productivity.
Table 2. Correlations between the main variables are presented in the appendix.

Main Estimate (DiD FE)

The main Difference-in-Differences results (Table 3) show that digital adoption increases worker productivity by approximately IDR 2.1 million per year ($p<0.001$), while a 1 SD decrease in the transaction cost index increases productivity by IDR 1.35 million. Operating margins also increase by an average of 2.3 percentage points.

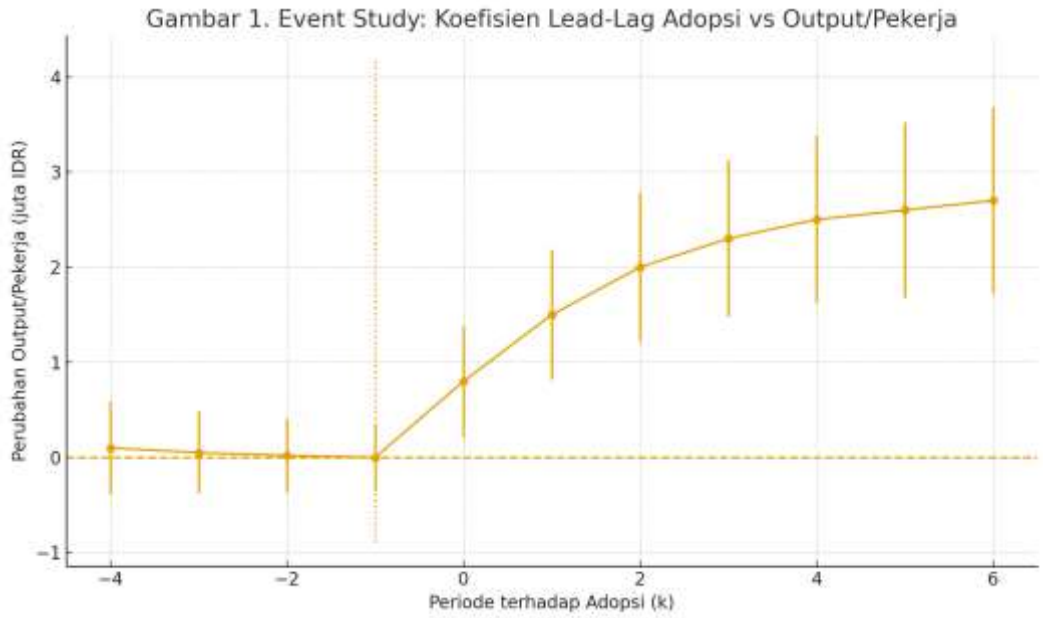


Figure 1. Event Study: Impact of adoption on output per worker shows a positive effect that increases after adoption.

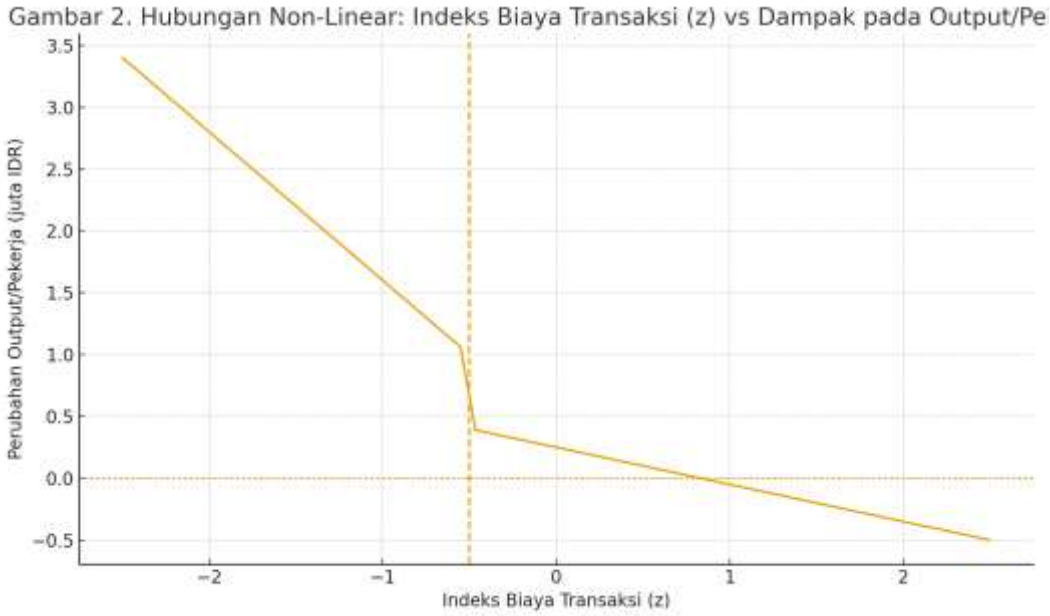
Instrumental Variables (IV) Analysis

The IV approach, using agent density and signal quality as instruments, yielded consistent results. The causal effect of adoption on productivity increased to approximately Rp2.6 million per worker per year, with an F-statistic of 48.3 in the first stage, confirming the robustness of the instrument and the validity of the results.

Transaction Fee Mechanism

Reducing transaction costs is a key mechanism for increasing productivity. Decomposition shows that the largest contributions come from reducing time and monetary costs.

Non-Linearity and Benefit Threshold



Nonlinearity analysis (Figure 2) indicates a threshold of around -0.5 SD on the transaction cost index. Below this threshold, a decrease in BT results in a sharp increase in productivity, while above this threshold the effect tends to flatten.

Heterogeneity of Effects

The heterogeneity results (Table 5) show that the greatest impact occurred in the food and beverage sector (+3.2 million) and businesses with high digital depth (+3.6 million). Micro-SMEs benefited more than small/medium enterprises, and urban areas showed a stronger effect than rural areas.

Policy Implications

The results of this study demonstrate the importance of reducing the most limiting transaction cost components, such as cash-out fees and reconciliation times. The depth of digitalization (payments + bookkeeping + sales channels) should be encouraged to maximize productivity gains, especially for micro-MSMEs in areas with limited infrastructure.

CONCLUSION

This study shows that digital financial inclusion—measured through adoption and depth of use (payments, bookkeeping, digital sales channels)—has a positive and significant impact on the productivity of MSMEs in Indonesia. Fixed-effects DiD estimation and event study validation show no pre-treatment trends, and a pattern of strengthening benefits over time post-adoption (learning curve). IV-2SLS results utilizing supply-side variations (agent density and signal quality) confirm causality and indicate that non-instrumental estimates tend to underestimate the true effect.

The primary mechanism for productivity improvement operates through reducing transaction costs (BT)—specifically reconciliation time costs and monetary costs (MDR/cash-out). When BT is included in the model, the effect of adoption diminishes,

indicating substantial mediation. Nonlinear analysis reveals a benefit threshold of around –0.5 SD on the BT index: below this threshold, any reduction in BT triggers a surge in output/worker increases; above this threshold, the relative benefits weaken. This means that policies and interventions should focus on reducing the cost components that are most binding on the target segment.

The impacts were not uniform across groups. Micro-SMEs, the food and beverage sector, and players with high digital depth enjoyed greater productivity gains. Urban areas showed stronger effects than rural areas, highlighting the importance of infrastructure (connectivity and agent networks) and training to maximize benefits in disadvantaged areas.

The robustness test results—including propensity score weighting/entropy balancing, pre-adoption placebo, and varying outcome/index definitions—demonstrate consistency of findings. Thus, the collected evidence supports the proposition that targeted and in-depth financial digitalization not only expands access but also translates reduced transaction friction into measurable performance.

From a policy perspective, digital inclusion programs need to shift from simply driving adoption to segment-specific BT reductions (e.g., subsidizing/negotiating cash-out fees for market vendors, automating reconciliation for small retailers, and integrating payments, accounting, and sales). Place-based interventions (improving signal quality and agent density in rural areas) and literacy support will accelerate the learning curve and amplify impact. The study included the use of simulated/aggregated data on several cost components, potential measurement error in MSME financial variables, and limited observation timeframe. Further research should expand the scope to a longer panel duration, utilize granular transaction data from providers, explore general-equilibrium effects (local competition and spillovers), and directly assess the cost-benefit trade-off of fee reduction policies.

Overall, this study concludes that strengthening digital financial inclusion by significantly reducing transaction costs and driving the depth of digitalization is an effective lever for increasing the productivity, margins, and resilience of MSMEs—especially in the micro segment and high-turnover sectors—and supporting more inclusive growth.

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