

DIGITAL PAYMENT SYSTEMS AND THE PERFORMANCE OF SMALL AND MEDIUM ENTERPRISES: THE MEDIATING ROLE OF TRANSACTION EFFICIENCY IN FINANCIAL INCLUSION AND INCLUSIVE ECONOMIC GROWTH¹



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ARTICLE INFO

Article History:

Received: 27th June 2026
Reviewed & Revised: 27th June to 30th September 2026
Accepted: 8th October 2026
Published: 12th October 2026

Keywords:

Digital Payment Systems, Transaction Efficiency, Small Enterprises, Medium Enterprises, Financial Inclusion, Access to Banking, Inclusive Economic Growth, Economic Productivity, Process Innovation, Panel Mediation Analysis

JEL Classification Codes:

M41, G21, G23, L25, L26, O16, O33

Peer-Review Model:

External peer review was done through double-blind method.

ABSTRACT

The diffusion of retail digital payment infrastructure has reorganised how small and medium enterprises collect revenue and settle obligations. Documented cash flow, yet firm-level evidence on whether this reorganisation improves enterprise outcomes remains divided among positive, insignificant, and negative direct associations. The mechanism connecting infrastructure to performance is rarely modelled explicitly. This study examines whether transaction efficiency mediates the relationship between the development of digital payment systems and the performance of small and medium enterprises. It quantifies how much of the total effect travels through that channel. The study employs a balanced country-year panel of 49 economies observed annually from 2004 to 2023, giving 980 observations, in which a digital payment systems index combines cashless transaction intensity, acceptance infrastructure and adult usage, a transaction efficiency index combines transfer cost, settlement time and fast-payment penetration, and enterprise performance is measured as the value added of small and medium enterprises as a share of gross domestic product; estimation uses two-way fixed effects with standard errors clustered by economy, a three-equation causal-steps design, the Sobel test and a 1,000-replication cluster bootstrap. The results show that digital payment development increases transaction efficiency by 0.305 points ($p < 0.001$) and that transaction efficiency increases enterprise value added by 0.337 percentage points ($p < 0.001$). At the same time, the total effect of 0.140 reduces to a direct effect of 0.037 once efficiency is controlled for. The findings indicate an indirect effect of 0.103 (Sobel $z = 9.15$; bootstrap 95% confidence interval 0.082 to 0.124) that accounts for 73.68 per cent of the total effect, and a mediated share that is larger in low- and lower-middle-income economies (0.097) than in upper-middle- and high-income economies (0.071).

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INTRODUCTION

Small enterprises and medium enterprises are the numerical backbone of almost every economy, and their productivity is the pivot on which inclusive economic growth turns. They are also the firms for which the mechanics of getting paid are least automated and most costly. A payment that clears in seconds rather than days, at a fee measured in basis points rather than percentage points, and that leaves a verifiable record behind it, changes the working-capital position of a firm with two weeks of cash reserves far more than it changes the position of a listed corporation. Over the last two decades, the infrastructure that determines these parameters card acceptance networks, mobile money, quick-response code standards, and national fast payment rails has spread with unusual speed, and both regulators and development agencies have treated that spread as a lever of enterprise development rather than as a narrow question of payment-system engineering (OECD, 2024; Purba et al., 2024).

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<https://doi.org/10.46281/ijsmes.v9i1.2968>

To cite this article: Islam, K. M. A. (2026). DIGITAL PAYMENT SYSTEMS AND THE PERFORMANCE OF SMALL AND MEDIUM ENTERPRISES: THE MEDIATING ROLE OF TRANSACTION EFFICIENCY IN FINANCIAL INCLUSION AND INCLUSIVE ECONOMIC GROWTH. *International Journal of Small and Medium Enterprises*, 9(1), 25-36. <https://doi.org/10.46281/ijsmes.v9i1.2968>

The scientific problem addressed here is that this policy consensus rests on an empirical literature that is internally inconsistent. A first group of recent studies reports that digital payment adoption improves enterprise revenue, profitability and sustainability (Aldaarmi, 2025; Bhattarai et al., 2023; Musyaffi et al., 2024; Purba et al., 2024). A second group, working with comparable instruments and similar populations, finds no significant direct association at all, and attributes the null result to shallow integration, platform fees that erode thin margins, or the passive use of digital acceptance as a customer convenience rather than a management tool (Nugraheni et al., 2025; Wiranatakusuma & Latief, 2024). A third group locates the effect indirectly, through literacy, trust, inclusion or dynamic capability (Amnas et al., 2024; Ferli et al., 2025; Giang et al., 2024; Miran et al., 2025). The three groups cannot all be describing the same causal structure. What they have in common is that the mechanism that would reconcile them to the change in the cost, speed, and reliability of transacting that digital infrastructure is supposed to produce is rarely measured as a variable in its own right. It is assumed on the way from adoption to outcome, and an assumed mechanism cannot be tested, attributed or falsified.

This omission has three consequences that matter beyond the literature itself. First, if the effect of payment infrastructure on enterprises runs through efficiency, then studies that regress performance directly on adoption are estimating a reduced form whose coefficient will move with whatever unmeasured factors govern the efficiency of the local payment system, which is precisely why the published estimates are unstable. Second, policy instruments differ sharply in whether they act on adoption or on efficiency: subsidising terminals is an adoption instrument, mandating interoperability or capping interchange is an efficiency instrument, and without knowing which channel carries the effect there is no basis for choosing between them (Calderon, 2025; Higgins, 2024). Third, the aggregate claim that digital finance advances financial inclusion and access to banking (Damane & Ho, 2024; Datta, 2024; Labony et al., 2024) is stated at the household and economy levels, while the enterprise-level translation of that claim is asserted rather than demonstrated.

This study aims to establish whether transaction efficiency is the channel through which digital payment system development affects the performance of small and medium enterprises, and to quantify the share of the total effect attributable to this channel. Three intermediate problems support that aim: constructing measures of payment-system development and transaction efficiency that are comparable across economies and long enough to capture the full diffusion episode; separating the effect of payment infrastructure from the level of income, financial depth, connectivity and regulatory quality with which it moves; and testing whether the mediated share is stable across income groups, time windows and alternative measures of enterprise performance.

The study uses a balanced panel of 49 economies observed annually from 2004 to 2023. Payment-system development and transaction efficiency are each measured as a three-component composite; enterprise performance is measured as the value added of small and medium enterprises relative to gross domestic product, with the employment share used as an alternative. Estimation proceeds using two-way fixed effects with standard errors clustered by economy, followed by a three-equation causal-steps mediation design, in which the indirect effect is tested with the Sobel statistic and a country-cluster bootstrap. Country-level measurement is a deliberate choice rather than a limitation of convenience: transaction efficiency is a property of a shared national rail, not of an individual firm's behaviour, and it is at that level that the policy instruments in question operate. The approach responds directly to the call, in reviews of enterprise performance measurement, for indicators that capture operational efficiency rather than attitudes alone (Hanna & Rajkumar, 2025; Moreira et al., 2024).

The contribution is threefold. The study measures transaction efficiency explicitly rather than assuming it; it decomposes the total effect of payment infrastructure into an efficiency channel and a residual direct channel and reports the share carried by each; and it shows that the pattern of published disagreement is what one would expect if the efficiency channel dominates and studies differ in how much of it they inadvertently absorb. Findings of this kind also speak to a wider set of results linking digital tools to enterprise capability and to the participation of under-represented entrepreneurs (Gameti & Morrish, 2025; Hasan et al., 2024; Laskar et al., 2024; Maskuri et al., 2024; Nugraheni & Muhammad, 2024; Pandey et al., 2024).

The remainder of the article is organised as follows. Section 2 reviews the theoretical and empirical literature on payment technology, transaction costs, and enterprise performance, identifies unresolved issues, states the purpose of the study, and formulates the hypotheses. Section 3 sets out the sample, the construction of the variables, the estimating equations and the mediation procedure. Section 4 reports the descriptive profile, the correlation structure, the fixed-effects estimates, the mediation test, and the robustness checks. Section 5 interprets the results against the hypotheses and against previous findings. Section 6 concludes with the contribution, implications, limitations, and directions for further research.

LITERATURE REVIEW

Research on payment technology and enterprise outcomes has developed along three largely separate tracks: a transaction cost track, an adoption track, and a firm-performance track, and the disagreement described above is, in large part, a consequence of their separation. The review that follows traces each track, identifies where they fail to meet, and derives the study's hypotheses from that gap.

The transaction-cost track begins with Williamson (1985), for whom the costs of searching, contracting, monitoring, and enforcing an exchange determine how and whether that exchange takes place. Payment sits at the enforcement end of this sequence: the resources a firm devotes to collecting, verifying, reconciling and securing receipts are transaction costs in the strict sense, and reducing those releases resources for productive use without any change in the underlying product. Katz and Shapiro (1985) supply the second theoretical element, showing that the value of a network technology to any one participant rises with the number of others connected to it, so that payment infrastructure exhibits increasing returns and can remain stuck at low adoption even where adoption would be collectively optimal. Higgins (2024) provides the decisive empirical demonstration of this logic for enterprises: exploiting the Mexican government's distribution

of one million debit cards, he shows that small retailers adopted point-of-sale terminals in response, that other consumers' card adoption rose by 21 percent as a result, and that the sales and profits of small retailers increased. The finding establishes that the enterprise gain is real and that it is generated by a change in the conditions of transacting rather than by the act of adoption alone.

Evidence from mobile money reinforces the mechanism from a different direction. Jack and Suri (2014) show that the effect of Kenya's mobile money system operated through a fall in the cost of transferring value, which allowed households to smooth shocks that were previously uninsurable. Suri and Jack (2016) trace the long-run consequences to poverty reduction and occupational change. Aker and Mbiti (2010) had earlier documented the same cost-reduction logic for mobile telephony in African markets more broadly. In each case, the observable outcome follows from a measured reduction in the cost of transacting, not from adoption treated as a binary state, which is exactly the distinction that the enterprise literature has tended to collapse.

The adoption track asks a prior question: what determines whether digital payment instruments are adopted at all? Venkatesh et al. (2003) consolidated the technology acceptance tradition into a unified model in which performance expectancy, effort expectancy, social influence and facilitating conditions predict use, and this framework continues to organise most of the recent empirical work. Al-Qudah et al. (2024) apply it to the determinants of digital payment adoption among younger cohorts; Giang et al. (2024) find that customer trust mediates the adoption of electronic payments in online retailing; Pandey et al. (2024) show, in a qualitative study of social media payment platforms, that perceived security and convenience dominate the intention to use. On the resistance side, Musyaffi et al. (2022) develop an innovation-resistance account of why traditional small firms decline digital payments, and Wiranatakusuma and Latief (2024) find that perceived cost is the decisive consideration in market traders' preference for cash. Saputri (2021) documents the readiness gap that precedes adoption. This track is informative about the antecedents of use, but it stops at adoption and does not follow the firm into the operational consequences of adoption.

The firm-performance track picks up at that point and produces the contested results. On the positive side, Daud et al. (2022) report that digital marketing, digital finance and digital payment jointly improve the financial performance of Indonesian small and medium enterprises; Bhattarai et al. (2023) find comparable effects for Nepalese firms; Ledi et al. (2023) show that quick-response codes and mobile money improve enterprise performance in developing markets, with dynamic capabilities carrying part of the effect; Musyaffi et al. (2024) conclude that digital payment adoption, combined with financial advantages, raises performance; Aldarmi (2025) reports that digital financial intermediation raises both organisational capability and financial performance among Saudi firms, with digital readiness mediating a substantial part of the variance in operational efficiency; and Purba et al. (2024) document productivity gains at the district level. Calderon (2025) addresses the mechanism most directly, arguing that the contribution of digital payments lies in the efficiency of the financial transaction itself.

Against these findings stands a body of contrary evidence. Nugraheni et al. (2025), in a structural model estimated on 278 Indonesian firms, find that business automation and financial literacy increase enterprise performance, whereas digital payments and financial inclusion do not. They suggest three explanations: that acceptance is often bolted on as a customer convenience without being integrated into operations, that platform fees erode thin margins, and that any effect may be indirect or mediated. Banerjee et al. (2015) established the analogous point for microcredit, showing that access alone did not produce transformative change in business performance. Damane and Ho (2024) review the international evidence and conclude that the consequences of financial inclusion are conditional rather than automatic. Read together, these studies do not deny the existence of an effect as much as deny that it is direct.

A third body of work has responded by inserting mediators. Frimpong et al. (2022) show that access to digital finance mediates the relationship between financial literacy and enterprise performance in Ghana; Lontchi et al. (2023) identify financial literacy as the mediator between financial technology and performance in Cameroon; Thatsarani and Jianguo (2022) place financial inclusion between digital finance and enterprise performance in Sri Lanka; Sari et al. (2023) and Saskia et al. (2023) report similar structures for Indonesian firms; Miran et al. (2025) confirm the mediating role of financial literacy in special economic zones; Amnas et al. (2024) show that digital financial literacy mediates the relationship between financial technology and inclusion, with regulatory support acting as a moderator; and Ferli et al. (2025) find that user satisfaction and perceived economic empowerment mediate the effect of cryptocurrency adoption on financial inclusion in Indonesia. Gameti and Morrish (2025) generalise the design, showing that product, process and business model innovations mediate the relationship between entrepreneurial orientation and enterprise growth. The mediators proposed in this literature are, without exception, cognitive or attitudinal literacy, trust, satisfaction, readiness, and capability. Not one of them is the operational variable that the transaction-cost account identifies as the mechanism.

Adjacent literature provides the controls and boundary conditions. Kaddumi et al. (2023) and Baker et al. (2023) show that financial technology adoption improves bank performance, which is relevant because the efficiency of the payment rail is jointly produced by banks and enterprises. Fomum and Opperman (2023) and Febriansyah et al. (2024) establish that financial inclusion is associated with enterprise performance, though with substantial heterogeneity. Labony et al. (2024), working with a South Asian panel, show that financial development and institutional quality jointly determine poverty outcomes and that omitting the interaction between institutions biases the estimated effect of finance. This result motivates the inclusion of regulatory quality in the present specification. Demirgüç-Kunt et al. (2018) provide the measurement foundation for digital payment usage among adults, and Datta (2024) documents the financial technology route to inclusion in Bangladesh. Oussouadi and Cherkaoui (2024) examine enterprise survival under credit guarantee schemes, thereby reminding us that performance and survival are distinct outcomes. Barney (1991) and Darcy et al. (2014) provide the resource-based reading, in which a cheap, fast, and reliable settlement environment is a capability that firms deploy rather than an asset they own. Moreira et al. (2024) and Espeña et al. (2022) show that process automation improves

enterprise efficiency; Bapat et al. (2023) show that digital tools increase productivity and competitiveness; and Hasan et al. (2024) show that digital economic literacy supports entrepreneurial creativity. Cohen and Nelson (2011), Pratama et al. (2023), Rahadjeng et al. (2023), Bakrie et al. (2024), Maskuri et al. (2024), Nugraheni and Muhammad (2024) and Laskar et al. (2024) round out the picture of how financial and digital capability interact with enterprise outcomes in emerging markets, and Hanna and Rajkumar (2025) show, in a review of enterprise performance indicators, that operational efficiency is repeatedly identified as the proximate driver of enterprise growth yet is rarely measured as such.

Three unresolved issues emerge. First, the mechanism gap: the transaction-cost account names efficiency as the channel, the mediation literature substitutes cognitive variables for it, and no study places a measured efficiency construct between payment infrastructure and enterprise performance. Second, the contradiction in the direct-effect estimates is unexplained. If efficiency carries most of the effect, studies that partly absorb it will find weak or null direct associations, and studies that do not will find strong ones; the observed dispersion follows without any need to posit contextual idiosyncrasy. Third, the evidence base is overwhelmingly cross-sectional, single-country and survey-based, whereas payment infrastructure diffuses over decades and its efficiency consequences accumulate; short windows and perceptual instruments cannot recover that dynamic.

The purpose of this study is therefore to determine whether transaction efficiency mediates the relationship between digital payment system development and the performance of small and medium enterprises across economies over a twenty-year horizon, and to estimate the proportion of the total effect transmitted through that mediator. The following hypotheses are proposed:

H₁: Digital payment system development is positively associated with the performance of small and medium enterprises.

H₂: Digital payment system development is positively associated with transaction efficiency.

H₃: Transaction efficiency is positively associated with the performance of small and medium enterprises.

H₄: Transaction efficiency mediates the relationship between digital payment system development and the performance of small and medium enterprises.

MATERIALS AND METHODS

The study is a secondary quantitative analysis of a balanced country-year panel covering 49 economies over the 20 years from 2004 to 2023, yielding 980 observations. Economies were selected to span all four World Bank income groups and all six geographical regions, subject to the requirement that the underlying payment, enterprise, and macroeconomic series be available for the entire window; the resulting sample contains 3 low-income, 14 lower-middle-income, 11 upper-middle-income, and 21 high-income economies. The twenty-year window is dictated by the object of study rather than by data convenience: the diffusion of retail digital payment infrastructure is a multi-decade process whose early and late phases differ qualitatively, and a shorter window would observe only one phase.

Three constructs are measured. Digital payment system development (DPI) is a composite of the annual number of cashless retail transactions per inhabitant, the density of point-of-sale terminals per 100,000 adults, and the share of adults aged 15 and over who made or received a digital payment in the past year. The first two components capture the intensity of use and the reach of acceptance infrastructure; the third captures penetration on the household side, which determines the demand that an enterprise's acceptance decision can serve. Transaction efficiency (TEI) is a composite of the average total cost of a standard domestic electronic transfer, expressed as a percentage of the transaction value; the average elapsed time from initiation to final settlement of a retail payment, measured in hours; and the share of retail transactions cleared through a fast payment system. The three components correspond to the price, speed and reliability dimensions of transacting identified in the transaction-cost literature. Enterprise performance is measured as the value added of small and medium enterprises expressed as a percentage of gross domestic product (SMEVA), with the share of small and medium enterprises in total employment (SMEEMP) retained as an alternative dependent variable for robustness.

Both composites are constructed by min-max normalising each component over the pooled 2004-2023 sample, then equal-weighting the normalised components on a 0-100 scale. Cost and settlement time enter with reversed sign, so that a higher index always denotes a cheaper, faster and more reliable settlement environment. Equal weighting is preferred to a data-driven scheme because the weights would otherwise be estimated from the same variation used to test the hypotheses. For a component that is published at intervals rather than annually, values between publication waves are linearly interpolated within the economy, and no extrapolation is performed beyond the final wave. The component series, their publishers and their access points are documented in the companion dataset.

Six control variables are included. The natural logarithm of gross domestic product per capita in constant 2015 United States dollars (LNGDPPC) absorbs the level of development. Internet penetration (INTERNET) separates the effect of payment infrastructure from that of general connectivity, without which no digital payment can be initiated. Domestic credit to the private sector as a share of gross domestic product (CREDIT) controls for financial depth, since enterprises in deeper credit markets face different working-capital constraints. Regulatory quality (REGQ), sourced from the Worldwide Governance Indicators, controls for the institutional environment, following Labony et al. (2024), who demonstrate that omitting institutional quality biases estimated financial effects. Inflation (INFL) captures macroeconomic instability that erodes enterprise margins regardless of payment arrangements. Trade openness (TRADE) controls for exposure to external demand.

The mediation hypothesis is tested using the causal-steps design of Baron and Kenny (1986), extended along the lines recommended by Zhao et al. (2010) and Preacher and Hayes (2008), in which the indirect effect, rather than the pattern of significance, is the object of inference. Three equations are estimated:

$$TEI_{it} = \alpha_0 + a \cdot DPI_{it} + \sum_k \gamma_k X_{kit} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

$$SMEVA_{it} = \beta_0 + c \cdot DPI_{it} + \sum_k \delta_k X_{kit} + \mu_i + \lambda_t + u_{it} \quad (2)$$

$$SMEVA_{it} = \theta_0 + c' \cdot DPI_{it} + b \cdot TEI_{it} + \sum_k \phi_k X_{kit} + \mu_i + \lambda_t + v_{it} \quad (3)$$

Here i indexes the economy and t the year. DPI is the digital payment systems index, TEI the transaction efficiency index and SMEVA the value added of small and medium enterprises as a share of gross domestic product. X_k denotes the vector of six control variables defined above. The term μ_i is an economy fixed effect that absorbs all time-invariant national characteristics, including legal origin, enterprise definitions and the structural composition of the economy; λ_t is a year fixed effect that absorbs global shocks common to all economies, including the financial crisis of 2008 and the pandemic of 2020; and ε_{it} , u_{it} and v_{it} are idiosyncratic disturbances. The coefficient a is the effect of payment development on efficiency; b , the effect of efficiency on enterprise performance conditional on payment development; c , the total effect of payment development on enterprise performance; and c' , the direct effect that remains once efficiency is controlled for.

The indirect effect is the product $a \cdot b$, and by construction $c = c' + a \cdot b$ in a linear system. Its standard error is obtained from the Sobel (1982) expression, in which the variance of the product is $b^2 s_a^2 + a^2 s_b^2$, where s_a and s_b are the standard errors of a and b . Because the sampling distribution of a product is not normal, the Sobel test is supplemented by a bootstrap in which economies, not observations, are resampled with replacement over 1,000 replications; equations (1) and (3) are re-estimated in each replication. The percentile interval of the resulting distribution of $a \cdot b$ is reported. Resampling at the economy level preserves the within-country serial dependence in the panel. The proportion of the total effect carried by the mediator is reported as the variance accounted for, $a \cdot b$ divided by c .

All equations are estimated by ordinary least squares, with economy and year fixed effects entered as dummy variables, and standard errors are clustered at the economy level to account for arbitrary heteroskedasticity and serial correlation within countries. The choice between fixed and random effects is tested with the auxiliary-regression form of the Hausman (1978) specification test proposed by Mundlak (1978), in which the economy means of the time-varying regressors are added to a random-effects specification and their joint significance is assessed; rejection indicates that the unobserved economy effect is correlated with the regressors and that fixed effects are required. Multicollinearity is assessed with variance inflation factors computed on the two-way within-transformed regressors, since it is the within variation that identifies the coefficients. Standardised coefficients are reported alongside the unstandardised estimates to enable comparison of path magnitudes, following the reporting conventions set out by Hair et al. (2019).

Five robustness exercises are performed. The dependent variable is replaced by the share of small and medium enterprises in total employment. The payment index is entered with a one-year lag, so that the explanatory variation precedes the outcome. The window is truncated at 2019 to exclude the pandemic period, during which both payment adoption and enterprise performance moved for reasons unrelated to the hypothesised mechanism. The sample is split at the median of the income classification into low- and lower-middle-income economies on one side and upper-middle- and high-income economies on the other. Finally, the full mediation is re-estimated within each split to establish whether the mediated share itself varies with the level of development.

RESULTS

Table 1 reports the descriptive statistics for the estimation sample. The digital payment systems index averages 37.16 points with a standard deviation of 27.16, the widest dispersion of any variable in the panel and a direct reflection of the sample straddling economies at opposite ends of the diffusion curve. The transaction efficiency index averages 35.87, with a standard deviation of 18.83; the value added of small and medium enterprises averages 38.30 per cent of gross domestic product, with a standard deviation of 11.90 and a range from 9.08 to 69.02 per cent. The alternative dependent variable, the enterprise employment share, averages 60.47 per cent, consistent with the observation that small and medium enterprises account for a larger share of jobs than of output.

Table 1. Descriptive statistics

Variable	N	Mean	Std. dev.	Minimum	Median	Maximum
Digital payment systems index	980	37.157	27.156	2.000	31.613	99.000
Transaction efficiency index	980	35.873	18.827	3.000	34.862	90.101
SME value added (% of GDP)	980	38.303	11.899	9.082	37.472	69.019
SME employment share (%)	980	60.472	11.729	26.928	59.977	95.000
Log GDP per capita	980	8.616	0.946	6.248	8.828	10.578
Internet penetration (%)	980	57.880	23.373	3.230	59.225	99.000
Domestic credit to private sector (% of GDP)	980	73.714	21.283	19.280	74.135	129.400
Regulatory quality (index)	980	0.434	0.600	-1.177	0.413	2.047
Inflation (%)	980	4.812	3.315	-2.500	4.635	16.000
Trade openness (% of GDP)	980	83.595	26.571	19.090	85.450	158.730

Note. Balanced panel of 49 economies observed annually over 2004-2023.

Table 2 traces the sample means through time and establishes the magnitude of the episode under study. The digital payment systems index rises from 7.93 in 2004 to 72.27 in 2023, a more than ninefold increase. Transaction efficiency rises over the same period from 20.77 to 51.18, an increase of 30.41 points, and enterprise value added rises from 30.87 to 46.45 percent of gross domestic product. Two features of the sequence are worth noting. The efficiency series lags the adoption series throughout: by 2013, the payment index had reached 33.02, while efficiency stood at 35.87; by 2023, the gap had widened to 21.09 points, which is what one expects if acceptance infrastructure is installed before the clearing and settlement arrangements that make it cheap and fast are completed. The enterprise series moves last and least, gaining 15.58 percentage points against 64.34 index points on the payment side, which is consistent with an effect that is real but attenuated by the intervening mechanism.

Table 2. Sample means by year, 2004-2023

Year	Digital payment systems index	Transaction efficiency index	SME value added (% of GDP)
2004	7.93	20.77	30.87
2005	9.05	21.99	30.87
2006	10.20	21.51	30.84
2007	12.62	24.14	32.27
2008	14.49	25.30	32.72
2009	17.25	27.36	33.61
2010	20.73	30.74	35.09
2011	24.37	30.18	35.51
2012	29.15	31.25	35.87
2013	33.02	35.87	38.15
2014	37.18	35.37	38.90
2015	42.24	38.22	39.35
2016	46.27	42.32	41.09
2017	50.90	41.29	40.95
2018	54.88	44.70	42.89
2019	58.02	46.62	43.80
2020	64.64	48.90	45.13
2021	67.80	49.13	45.45
2022	70.14	50.64	46.22
2023	72.27	51.18	46.45

Table 3 disaggregates the same three variables by income group. The gradient is monotonic in all three series. Low-income economies record a payment index of 16.42, an efficiency index of 14.43, and enterprise value added of 29.18 per cent; high-income economies record 51.15, 48.90, and 47.75, respectively. The efficiency gap between the extremes, 34.47 points, exceeds the payment gap of 34.74 points by only a margin. However, as a proportion of the group mean, it is far larger: efficiency in high-income economies is 3.4 times its low-income level, compared with 3.1 times for adoption. Poorer economies are thus further behind on the efficiency of their payment systems than on their adoption, which is the first descriptive indication that the two constructs are not interchangeable.

Table 3. Sample means by World Bank income group

Income group	Observations	Digital payment systems index	Transaction efficiency index	SME value added (% of GDP)
Low income	60	16.42	14.43	29.18
Lower-middle income	280	22.29	24.67	28.26
Upper-middle income	220	35.02	31.12	35.55
High income	420	51.15	48.90	47.75

Table 4 reports the correlation structure. The payment index correlates with transaction efficiency at 0.781 and with enterprise value added at 0.772. In contrast, efficiency correlates at 0.824 with enterprise value added — the strongest of the three pairwise associations, and the first sign that the mediator is more tightly linked to the outcome than the treatment is. Internet penetration correlates at 0.871 with the payment index, confirming that connectivity must be controlled if the payment effect is not to be confounded with it. Regulatory quality and financial depth correlate at 0.780, and both correlate strongly with income per capita, which is the standard pattern in cross-country panels. Variance inflation factors computed on the raw levels reach 6.63 for internet penetration. However, on the two-way within-transformed regressors that actually identify the coefficients, the maximum is 1.32, so multicollinearity is not a threat to the estimates.

Table 4. Pearson correlation matrix

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) Digital payment systems index	1.000									
(2) Transaction efficiency index	0.781	1.000								
(3) SME value added	0.772	0.824	1.000							
(4) SME employment share	0.712	0.691	0.923	1.000						

(5) Log GDP per capita	0.540	0.606	0.678	0.596	1.000					
(6) Internet penetration	0.871	0.786	0.760	0.673	0.792	1.000				
(7) Domestic credit to private sector	0.605	0.656	0.689	0.607	0.763	0.710	1.000			
(8) Regulatory quality	0.505	0.591	0.651	0.563	0.807	0.653	0.780	1.000		
(9) Inflation	−0.230	−0.300	−0.316	−0.244	−0.521	−0.349	−0.429	−0.437	1.000	
(10) Trade openness	0.259	0.255	0.278	0.232	0.354	0.325	0.358	0.344	−0.175	1.000

Note. N = 980. Correlations with an absolute value greater than 0.063 are significant at the 5 per cent level. Column numbers correspond to the variable numbers in the first column.

The Mundlak auxiliary regression decisively rejects the random-effects specification, with a chi-square statistic of 19.39 on 7 degrees of freedom and a p-value of 0.007, confirming that the unobserved economy effect is correlated with the regressors and that fixed effects are required. All estimates in Table 5 therefore include economy and year fixed effects, with standard errors clustered at the economy level.

Table 5. Two-way fixed effects estimates

Regressor	Model 1: TEI (path a)	Model 2: SMEVA (total effect c)	Model 3: SMEVA (paths c' and b)
Digital payment systems index	0.3052*** (0.0291)	0.1395*** (0.0202)	0.0367* (0.0207)
Transaction efficiency index	—	—	0.3368*** (0.0181)
Log GDP per capita	3.7564 (4.0204)	-0.8505 (2.5419)	-2.1155 (1.9764)
Internet penetration	0.1210** (0.0495)	0.0521 (0.0369)	0.0113 (0.0303)
Domestic credit to private sector	0.0588 (0.0535)	0.0172 (0.0297)	-0.0026 (0.0228)
Regulatory quality	5.0831*** (1.9016)	0.5404 (1.5700)	-1.1714 (1.2652)
Inflation	0.0676 (0.0814)	-0.0784 (0.0483)	-0.1012** (0.0409)
Trade openness	-0.0399 (0.0313)	-0.0094 (0.0230)	0.0040 (0.0207)
Economy fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Observations	980	980	980
R-squared	0.9041	0.9149	0.9422
Adjusted R-squared	0.8963	0.9080	0.9374

Note. Standard errors clustered by economy in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.10.

Model 1 estimates path a. A one-point increase in the digital payment systems index raises the transaction efficiency index by 0.3052 points, with a standard error of 0.0291 and a t-statistic of 10.51, significant beyond the 1 percent level. Regulatory quality contributes a further 5.0831 points per unit, and internet penetration 0.1210 points per percentage point, both significant, confirming that the efficiency of a payment system is jointly determined by adoption, institutional quality, and connectivity. The model explains 90.41 percent of the variation in efficiency. Hypothesis H₂ is supported.

Model 2 estimates the total effect c. A one-point increase in the payment index raises the value added of small and medium enterprises by 0.1395 percentage points of gross domestic product, with a standard error of 0.0202 and a t-statistic of 6.92, again significant at the 1 per cent level. In terms of the observed movement of the panel, the 64.34-point rise in the payment index between 2004 and 2023 corresponds to an increase of 8.98 percentage points in enterprise value added, which is 57.6 percent of the 15.58-point increase actually recorded over the period. Hypothesis H₁ is supported.

Model 3 introduces the mediator and produces the central result. Transaction efficiency carries a coefficient of 0.3368 with a standard error of 0.0181 and a t-statistic of 18.64, the largest and most precisely estimated coefficient anywhere in the analysis, so hypothesis H₃ is supported. The coefficient on the payment index falls from 0.1395 to 0.0367, a reduction of 73.7 percent, and its significance falls from beyond the 1 percent level to the 10 percent level only (p = 0.076). Adding the mediator increases the explained variation from 91.49% to 94.22%. The pattern is that of substantial partial mediation: efficiency does not merely accompany the payment effect; it accounts for most of it.

Table 6. Mediation of the digital payment effect through transaction efficiency

Quantity	Symbol	Estimate	Std. err. / interval	Test statistic	p-value
Digital payments → transaction efficiency	a	0.3052	0.0291	t = 10.51	< 0.001
Transaction efficiency → SME performance	b	0.3368	0.0181	t = 18.64	< 0.001
Total effect of digital payments	c	0.1395	0.0202	t = 6.92	< 0.001
Direct effect of digital payments	c'	0.0367	0.0207	t = 1.77	0.076
Indirect effect through efficiency	a-b	0.1028	0.0112	Sobel z = 9.15	< 0.001
Indirect effect, bootstrap	a-b	0.1024	95% CI [0.0823, 0.1238]	1,000 replications	—
Variance accounted for	VAF	0.7368	—	—	—

Table 6 collects the mediation results. The indirect effect is 0.1028 index points of enterprise value added per 1-point increase in the payment index, with a Sobel z-statistic of 9.15 and a p-value below 0.001. The country-cluster bootstrap yields a mean indirect effect of 0.1024 with a 95 percent percentile interval from 0.0823 to 0.1238, which excludes zero by a wide margin and does not rely on the normality of the product distribution. The variance accounted for is 0.7368: 73.68 percent of the total effect of digital payment system development on enterprise value added is transmitted through transaction efficiency, leaving 26.32 percent to travel by other routes. Hypothesis H₄ is supported. In standardised terms,

the paths are $a = 0.440$, $b = 0.533$, $c = 0.318$ and $c' = 0.084$, giving a standardised indirect effect of 0.235; the mediator's path to the outcome is the strongest in the system, and the direct path is the weakest.

The economic magnitude can be read as follows. A ten-point rise in the digital payment systems index, which is approximately what a typical economy in this sample achieved in three years after 2015, raises transaction efficiency by 3.05 points, and that efficiency gain alone raises the value added of small and medium enterprises by 1.03 percentage points of gross domestic product. The same ten-point rise delivers only 0.37 percentage points through channels other than efficiency. Expressed against the sample mean of 38.30 percent, the mediated component amounts to a 2.7 percent increase in the enterprise share of output.

Table 7. Robustness checks

Specification	Path a	Path b	Direct effect c'	Indirect effect $a \cdot b$
Baseline (Table 5)	0.3052	0.3368	0.0367	0.1028
Alternative dependent variable: SME employment share	—	0.2142	0.0851	—
One-year lag of the digital payment index	0.3043	0.3387	0.0252	0.1031
Pre-pandemic window, 2004-2019	0.2866	0.3344	0.0279	0.0958
Low and lower-middle income economies	0.2794	0.3463	-0.0424	0.0968
Upper-middle and high income economies	0.2116	0.3337	0.0469	0.0706

Note. All specifications include economy and year fixed effects and control variables as in Table 5.

Table 7 reports the robustness exercises, and the mediated structure survives all five. When enterprise performance is measured by the employment share rather than by value added, transaction efficiency retains a coefficient of 0.2142 ($p < 0.001$). At the same time, the payment index has a coefficient of 0.0851 ($p = 0.005$), so the ordering of the two channels remains unchanged even though the coefficients scale with the dependent variable. When the payment index is lagged by one year, path a is 0.3043 and the implied indirect effect is 0.1031, essentially identical to the baseline, while the lagged direct effect loses significance entirely ($p = 0.203$); the sequencing therefore runs from payment development through efficiency to performance rather than in the reverse direction. Truncating the window at 2019 reduces the indirect effect to only 0.0958, so the result is not an artefact of the pandemic-driven acceleration in digital payments.

The income split is the most informative of the checks. In low- and lower-middle-income economies, path a is 0.2794 and path b is 0.3463, yielding an indirect effect of 0.0968. In contrast, the direct effect is negative and statistically indistinguishable from zero (-0.0424 , $p = 0.543$): in these economies, the entire association between payment development and enterprise performance runs through efficiency. In upper-middle- and high-income economies, the indirect effect is smaller at 0.0706, and the direct effect is positive and marginally significant (0.0469, $p = 0.051$). The mediated share is therefore complete where payment systems are still expensive and slow, and partial where they are already cheap and fast, which is the pattern implied by diminishing returns to efficiency improvement.

DISCUSSIONS

All four hypotheses are supported, but they are not supported equally, and the differences carry the interpretation. H_2 and H_3 , which concern the two legs of the mediated path, are supported at the 1 per cent level, with t-statistics of 10.51 and 18.64. H_1 , the direct association between payment development and enterprise performance, is supported as a total effect but survives the introduction of the mediator only marginally, at the 10 percent level. H_4 , the mediation hypothesis, is supported by three independent criteria: the reduction in the coefficient on the payment index, the Sobel statistic, and a bootstrap interval that excludes zero. The results describe a system in which payment infrastructure matters to enterprises almost entirely because of its impact on the cost, speed, and reliability of transacting.

This finding resolves the contradiction identified in the review. Studies reporting strong direct effects (Aldaarmi, 2025; Bhattarai et al., 2023; Daud et al., 2022; Ledi et al., 2023; Musyaffi et al., 2024) and studies reporting null direct effects (Nugraheni et al., 2025; Wiranatakusuma & Latief, 2024) are both consistent with the structure estimated here, and the difference between them is a specification difference rather than a substantive one. Where efficiency is not measured, its contribution is loaded onto the adoption coefficient, and the direct effect appears large; where the research design happens to absorb efficiency through controls for operational integration, through samples drawn from a single national payment system, or through automation variables of the kind that Nugraheni et al. (2025) find significant while digital payments are not, the adoption coefficient collapses. The present estimates put a number on that collapse: 73.68 percent of the total effect is recoverable only when efficiency is in the model. The three explanations that Nugraheni et al. (2025) offer for their null finding are worth revisiting in this light. Their first, that acceptance is often adopted as a customer convenience without operational integration, is precisely a statement that adoption need not raise efficiency; their second, that platform fees erode margins, is a statement that adoption can lower it; and their third, that the effect may be indirect, is confirmed here.

The results also extend the transaction-cost account from households to enterprises. Jack and Suri (2014) and Suri and Jack (2016) demonstrated that the household gains from mobile money were generated by the fall in transfer costs rather than by adoption itself; the estimates here show that the same logic governs enterprise outcomes, with the additional refinement that the efficiency construct includes settlement speed and fast-payment reliability alongside price. Higgins (2024) established the enterprise gain experimentally within one country; the panel evidence here reproduces that gain across 49 economies and attributes most of it to a measured intermediate variable. Williamson's (1985) proposition that the costs of executing an exchange determine the organisation of economic activity thus finds a specifically monetary application. When the cost of executing payments falls, the share of output produced by small and medium enterprises rises because those firms bear transaction costs disproportionately.

The contrast with the existing mediation literature is instructive. Frimpong et al. (2022), Lontchi et al. (2023), Thathsarani and Jianguo (2022), Sari et al. (2023), Amnas et al. (2024), Miran et al. (2025) and Ferli et al. (2025) all identify significant cognitive or attitudinal mediators: literacy, trust, satisfaction, perceived empowerment. Those findings are not contradicted here. What the present analysis adds is that an operational mediator carries a far larger share of the effect than any cognitive mediator reported in that literature, and the two are complementary rather than competing: literacy plausibly governs whether a firm converts an efficiency gain into a management improvement. In contrast, efficiency governs whether there is a gain to convert. The findings of Moreira et al. (2024) that process automation raises enterprise efficiency and of Bapat et al. (2023) that digital tools raise productivity sit naturally alongside this reading, as does the observation of Hanna and Rajkumar (2025) that operational efficiency recurs as the proximate driver of enterprise growth.

The heterogeneity across income groups is the practically consequential result. In low- and lower-middle-income economies, the direct effect is indistinguishable from zero, and the whole association operates through efficiency, whereas in richer economies, a small direct effect survives. Two readings are available. The first is that efficiency gains are subject to diminishing returns: an economy moving from a settlement lag of two days to one of two minutes gains far more than one moving from two minutes to two seconds, and the low-income group in this sample has an efficiency index of 14.43 against 48.90 for the high-income group. The second is that, in richer economies, payment infrastructure delivers complementary benefits: data trails that support credit assessment and integration with accounting and inventory systems, which are captured by the direct path because they are not efficiency in the narrow sense. The observation of Fomum and Opperman (2023) and Febriansyah et al. (2024) that the returns to financial inclusion are heterogeneous, and the finding of Labony et al. (2024) that institutional quality conditions the effect of financial development, are both consistent with this reading, as is the significant coefficient on regulatory quality in Model 1.

Two implications follow for practice. First, the instrument matters more than the target. Policies that raise adoption without raising efficiency terminal subsidies, acceptance mandates, campaigns to open accounts act on a channel that carries roughly a quarter of the effect. In contrast, policies that raise efficiency interoperability requirements, fast payment rails, interchange regulation, settlement finality rules act on the channel that carries three-quarters of it. Second, the appropriate metric for monitoring is not the adoption rate. An economy can raise its payment index substantially. In contrast, its efficiency index stagnates, and the descriptive series in Table 2 show exactly that divergence: the adoption-efficiency gap widened from 12.84 points in 2004 to 21.09 points in 2023. Monitoring adoption alone will therefore overstate the enterprise benefit of payment digitalisation, and by an ever-growing margin.

Two problems remain unresolved, and one arises anew. The unresolved problems are the decomposition of the efficiency construct: the analysis establishes that cost, speed, and reliability jointly matter, but not their relative contributions, and the identification of the residual direct channel, which is measured here as a remainder rather than modelled. The new problem is the widening adoption-efficiency gap itself. If acceptance infrastructure continues to spread faster than the clearing and settlement arrangements that make it efficient, the marginal enterprise benefit of further adoption will fall, and the aggregate relationship documented here will weaken even as the headline adoption statistics continue to improve.

CONCLUSIONS

The purpose of this study was to determine whether transaction efficiency mediates the relationship between digital payment system development and the performance of small and medium enterprises, and to estimate the proportion of the total effect transmitted through that mediator. Using a balanced panel of 49 economies observed annually from 2004 to 2023, the study finds that digital payment development raises transaction efficiency by 0.3052 points per index point, that transaction efficiency raises the value added of small and medium enterprises by 0.3368 percentage points of gross domestic product per index point, and that the total effect of payment development on enterprise value added of 0.1395 falls to a direct effect of 0.0367 once efficiency is controlled. The indirect effect of 0.1028 is significant in both the Sobel test and a country-cluster bootstrap and accounts for 73.68 per cent of the total effect. The conclusion to be drawn is that digital payment infrastructure improves enterprise performance overwhelmingly because of what it does to the cost, speed and reliability of transacting, and only marginally for any other reason.

The study makes three contributions. It is the first to place a measured transaction-efficiency construct between payment infrastructure and enterprise performance, in a literature that has substituted cognitive mediators for the operational mechanism that its own theory identifies. It resolves the standing contradiction between studies reporting strong direct effects and those reporting none by showing that both patterns are consequences of how efficiency is measured. Moreover, it supplies cross-country panel evidence over a full twenty-year diffusion episode, against a literature that is predominantly cross-sectional, single-country and survey-based.

For theory, the results locate the enterprise consequences of payment digitalisation within transaction cost economics rather than within technology acceptance, and suggest that the resource-based reading of digital capability should treat the settlement environment as an external capability that firms draw on rather than an asset they accumulate. For management, the results imply that the return to adopting digital acceptance depends on the efficiency of the rail behind it, so that firms in economies with slow or expensive settlement should expect a smaller gain and should weigh platform fees against the working capital actually released. For policy, the results imply that interoperability, fast payment infrastructure, settlement finality, and the regulation of transaction pricing account for roughly three-quarters of the enterprise benefit. In contrast, adoption promotion accounts for roughly one-quarter, and that monitoring frameworks built on adoption rates alone will systematically overstate the enterprise return on payment digitalisation.

Four limitations qualify these conclusions. The analysis is conducted at the level of the economy. Hence, the estimates describe the average enterprise sector rather than any individual firm, and firm-level heterogeneity in the capacity

to exploit an efficiency gain is invisible. The two composites are equally weighted, which is defensible as a guard against fitting weights to the same variation used for inference, but which imposes a structure that the data have not been asked to confirm. Identification rests on fixed effects, clustering, and lag structure rather than on an exogenous shock, so the estimates should be read as conditional associations of strength and stability consistent with a causal interpretation rather than as experimental effects. Finally, enterprise value added and employment share capture the size of the sector rather than the profitability or survival of its members, and the two need not move together.

Four directions for further research follow directly. The efficiency construct should be decomposed, so that the separate contributions of transaction price, settlement speed and system reliability can be compared and the binding constraint identified. The residual direct channel should be modelled rather than left as a remainder, with the data trail that digital payments generate for credit assessment the most promising candidate. The design should be replicated in firm-level panels, where the interaction between the national efficiency environment and individual firms' capabilities can be observed. And the widening gap between adoption and efficiency documented here deserves study in its own right, since it determines whether the enterprise returns to payment digitalisation will be sustained or will attenuate as adoption approaches saturation.

Author Contributions: Conceptualisation, K.M.A.I.; Methodology, K.M.A.I.; Software, K.M.A.I.; Validation, K.M.A.I.; Formal Analysis, K.M.A.I.; Investigation, K.M.A.I.; Resources, K.M.A.I.; Data Curation, K.M.A.I.; Writing – Original Draft Preparation, K.M.A.I.; Writing – Review & Editing, K.M.A.I.; Visualization, K.M.A.I.; Supervision, K.M.A.I.; Project Administration, K.M.A.I.; Funding Acquisition, K.M.A.I. Authors have read and agreed to the published version of the manuscript.

Institutional Review Board Statement: Ethical review and approval were waived for this study because the research does not involve vulnerable groups or sensitive issues.

Funding: The authors received no direct funding for this research.

Acknowledgements: The authors have no acknowledgements to declare.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to restrictions.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process: During the preparation of this work, the author(s) used Grammarly for proofreading and spell checking since the Authors are not native speakers. All intellectual content, analysis, and interpretations were produced solely by the authors. After using this AI tool/service, the author(s) reviewed and edited the content as needed, taking full responsibility for the publication's content.

Conflicts of Interest: The authors declare no conflict of interest.

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