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Quantitative Impact Assessment of Digital Payment Solutions on Small Business Revenue Panel Data Analysis From 1,200 U.S. SMES

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Abstract

This study assessed the revenue impact of Digital Payment Solutions (DPS) using a longitudinal panel dataset of 1,200 U.S. small and medium-sized enterprises (SMEs) observed over 14,400 firm-period observations. The sample included SMEs from retail (30.0%), food service (20.0%), personal services (17.5%), professional services (16.7%), and repair-based industries (15.8%), with 70.0% employing fewer than 20 employees. Descriptive results showed mean logged revenue of 10.42 (SD = 0.88) and an average digital sales share of 49.6% (SD = 24.3%). DPS adoption increased from 68.0% in the early period to 85.0% by the final period. Reliability analysis confirmed strong internal consistency for the main constructs, including DPS intensity (a = 0.86), breadth (a = 0.79), and integration (a = 0.82). Two-way fixed effects regression models controlling for firm size, age, sector, location, channel mix, and competitive density indicated that DPS adoption was positively associated with revenue ($\beta = 0.082$, $p < 0.001$), corresponding to an average revenue increase of approximately 8.2% relative to pre-adoption levels. Usage intensity demonstrated the strongest effect ($\beta = 0.214$, $p < 0.001$). Payment breadth was also significant ($\beta = 0.036$, $p = 0.010$), while integration showed a moderate positive effect ($\beta = 0.051$, $p = 0.020$). Dynamic models confirmed revenue persistence (lagged revenue $\beta = 0.641$, $p < 0.001$) and maintained coefficient stability. The baseline model explained 42% of within-firm revenue variation (within $R^2 = 0.42$). Overall, findings provided robust quantitative evidence that DPS adoption, particularly when used intensively and integrated operationally, was positively associated with SME revenue performance in the U.S. context.

Keywords

Digital Payments, SMEs, Revenue, Panel Data, Adoption.

INTRODUCTION

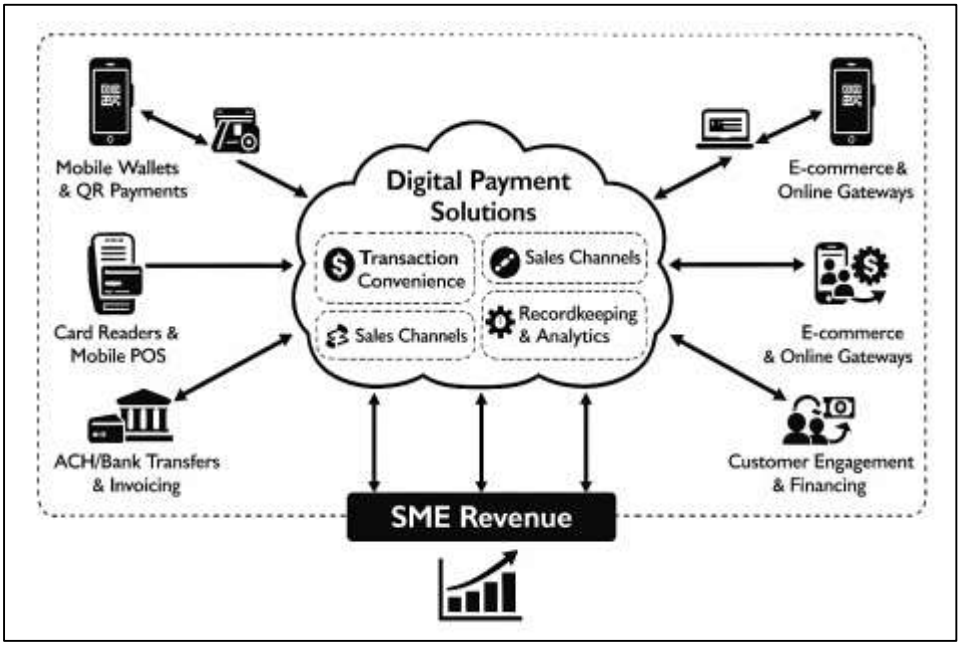
Digital payment solutions refer to electronically mediated methods of transferring monetary value between buyers and sellers using digital infrastructure rather than physical cash. In small-business settings, this term commonly includes debit and credit card acceptance, mobile wallet payments, online payment gateways, contactless point-of-sale transactions, peer-to-merchant transfer systems, automated clearing house transfers, QR-based payments, and integrated invoicing systems that allow customers to pay through embedded links (Hassan et al., 2020). Digital payment solutions also include the hardware and software ecosystem that supports acceptance, such as card readers, mobile POS devices, terminal software, gateway APIs, fraud screening systems, and accounting integration tools. For small and medium-sized enterprises (SMEs), digital payment acceptance is not only a transactional method but also a business capability that influences customer convenience, purchasing speed, transaction documentation, and the ability to participate in both physical and digital commerce. Revenue, in quantitative terms, refers to the total sales receipts generated by a firm over a given period, usually measured before expenses and operating costs. When revenue is observed across multiple time periods for the same firms, it becomes a dynamic outcome shaped by demand, pricing, competition, seasonal patterns, and operational capacity . The quantitative relationship between digital payment solutions and SME revenue is therefore anchored in the idea that payment mechanisms affect both customer-side behaviors and firm-side operational processes. At the customer level, payment convenience can reduce friction during checkout, increase the probability of purchase completion, and support higher average transaction values when buyers are not constrained by cash availability. At the firm level, digital payments can reduce the administrative burden of cash handling, improve recordkeeping accuracy, and enable more consistent sales reporting (Faysal & Shamsunnahar, 2022; Maurer et al., 2018).

In a modern commerce environment, payment solutions also function as access infrastructure because many consumer channels require digital payment acceptance, including e-commerce marketplaces, delivery platforms, subscription billing, and online ordering systems. This makes digital payment solutions particularly significant for SMEs, which often operate with limited staff, limited technology capacity, and constrained financial buffers. The international significance of digital payments emerges from the role of payment digitization in shaping economic participation, transaction formalization, and the expansion of digital commerce (Habibullah & Zaheda, 2022; Jahangir & Shahab, 2022). Many economies have observed measurable relationships between payment modernization and retail growth, enterprise formalization, and improved transactional efficiency. The U.S. SME market provides a particularly meaningful context because of its diversity in sector composition, the high prevalence of card and wallet usage among consumers, and the strong competitive environment among payment service providers (Hassan et al., 2021; Ratul, 2022; Ratul & Subrato, 2022). These conditions create measurable variation in adoption, intensity of usage, and performance outcomes. The title of this study positions the research within a quantitative impact assessment framework, meaning the objective is to estimate how changes in digital payment adoption and usage relate to changes in revenue over time. The use of panel data from 1,200 U.S. SMEs is central to the methodological strength of the research because it allows the analysis to track within-firm changes across time rather than relying only on cross-sectional comparisons.

Digital payment solutions influence SME revenue through multiple behavioral and operational pathways that can be formalized into measurable constructs for quantitative analysis. One foundational mechanism is transaction convenience, which affects purchase completion and customer satisfaction. In many retail and service environments, customers increasingly expect to pay electronically, and the absence of digital payment options can function as a demand barrier. When SMEs adopt card acceptance, mobile wallets, or digital invoicing, they reduce the likelihood of abandoned purchases caused by insufficient cash or inconvenience (Caliskan, 2020; Jahangir & Mohiul, 2023; Bhuya & Rebeka, 2022). Another pathway relates to transaction speed and queue management. Faster payment processing can increase throughput during peak hours, allowing firms to serve more customers within the same time window, which can translate into revenue gains in high-volume contexts. Digital payment solutions also enable omnichannel selling, allowing SMEs to generate sales through online stores, social media commerce, delivery platforms, and remote invoicing. These channels are often

impossible to operate effectively without digital payment infrastructure, making adoption a structural requirement for participation. Additionally, digital payments provide systematic transaction records. This recordkeeping can reduce revenue leakage caused by manual errors, improve reconciliation accuracy, and strengthen internal controls. For SMEs, which often rely on simplified accounting practices, automated payment records can improve the completeness of revenue reporting and reduce administrative overhead (Jinnat & Rakib, 2023; Khaled & Mosheur, 2023). Digital payment systems also connect to customer relationship mechanisms. Many payment solutions provide customer-level data, digital receipts, and loyalty integration. When SMEs use these features, they can increase repeat purchasing, personalize offers, and strengthen customer retention, which is a revenue-relevant outcome. Payment digitization also interacts with business financing (Shahab & Aditya, 2023; Mostafa, 2023). Digitally recorded revenue streams can be used by financial institutions and fintech lenders to evaluate creditworthiness. Improved access to working capital can enable inventory expansion, service capacity increases, or marketing investments, all of which can influence revenue trajectories. Another important mechanism involves consumer spending psychology (Aziz & Naima, 2021).

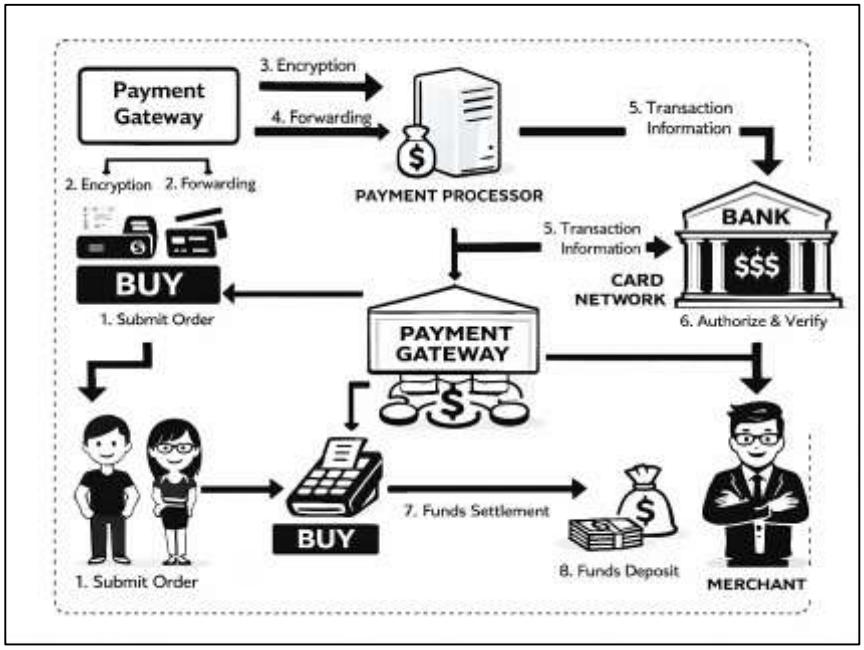
Figure 1: Digital Payments Drive SME Revenue



A central motivation for quantitative impact assessment is the recognition that SMEs do not adopt digital payment solutions randomly. Adoption decisions are shaped by managerial preferences, business maturity, customer demand, competitive pressure, and technological readiness. This creates selection effects that can bias simple comparisons between adopters and non-adopters. Firms that adopt earlier may already have higher growth potential, better operational systems, or more digitally oriented customer bases (Diniz et al., 2019; Mostafa & Bhuya, 2023; Ratul & Aditya, 2023). A panel data framework is particularly well suited to addressing these challenges because it allows the researcher to compare firms to themselves over time, isolating the association between adoption changes and revenue changes within the same enterprise. The use of panel data also allows the inclusion of time fixed effects that capture common macroeconomic shocks, sector-level shifts, and seasonal patterns affecting all firms. This is essential for SMEs because revenue can fluctuate due to macroeconomic cycles, inflation, regional demand changes, and industry-specific conditions. Panel models can also include firm fixed effects, which control for unobserved time-invariant factors such as location advantages, baseline customer loyalty, long-run pricing strategy, and managerial competence. These methodological features strengthen the credibility of the estimated relationships between digital payment adoption and revenue. Another advantage of panel data is the ability to model dynamic effects. Revenue is not only influenced by current adoption status but also by past performance,

customer retention, and lagged operational adjustments. Firms may experience adoption learning curves in which benefits emerge gradually as employees become familiar with the system, as customers adjust to new payment options, and as the firm integrates payments into broader workflows. Panel methods can capture such dynamics through lagged variables or event-time specifications. The panel structure also enables the modeling of adoption intensity. Many SMEs adopt digital payments in stages, beginning with basic card acceptance, then adding contactless payments, then integrating online invoicing, and later adopting e-commerce gateways or subscription billing tools (Saiedi et al., 2021). These staged changes create variation that can be exploited statistically to estimate marginal revenue impacts. Measurement of digital payment solutions can therefore be operationalized through binary adoption indicators, usage share metrics, transaction counts, or the number of enabled payment channels. The title of this study emphasizes "digital payment solutions" rather than a single instrument, suggesting a broader conceptualization that captures this layered adoption process. The sample size of 1,200 SMEs provides sufficient statistical power for modeling heterogeneity and for testing whether revenue effects differ across firm categories. Heterogeneity is central because adoption may be more beneficial for firms with higher customer turnover, higher reliance on impulse purchases, or greater online channel potential. Another key issue in impact assessment is endogeneity. Firms may adopt digital payments in response to revenue declines, changes in customer demand, or competitive threats (Goodell et al., 2022). This can produce reverse causality where revenue changes drive adoption rather than adoption driving revenue changes. Panel econometrics provides tools to address this through fixed effects, lagged adoption variables, and robust inference strategies. The quantitative focus of this study therefore aligns with the broader need for evidence-based understanding of how payment modernization affects SME performance in real market conditions.

Figure 2: Digital Payments Increase SME Revenue



The primary objective of the study titled "Quantitative Impact Assessment of Digital Payment Solutions on Small Business Revenue: Panel Data Analysis from 1,200 U.S. SMEs" is to quantitatively estimate the magnitude, direction, and statistical significance of the relationship between digital payment solution adoption and small business revenue performance over time by leveraging longitudinal observations from a large and diverse sample of U.S. small and medium-sized enterprises. This objective centers on producing a measurable impact estimate by comparing revenue trajectories within the same SMEs across multiple periods as their digital payment capabilities change in adoption status or usage intensity. The study aims to operationalize digital payment solutions as observable,

business-level payment acceptance and transaction-processing capabilities that may include card acceptance, contactless payments, mobile wallets, online payment gateways, digital invoicing, and integrated point-of-sale payment functions, and to translate these capabilities into quantifiable indicators suitable for panel modeling. A second component of the objective is to separate within-firm changes from between-firm differences by applying panel data techniques that control for stable firm characteristics such as location, baseline business model, managerial structure, and sector-specific operating norms, while also controlling for time-related shocks that influence all firms, including macroeconomic conditions, seasonal fluctuations, and sector-wide demand cycles. The study also seeks to evaluate impact heterogeneity by determining whether estimated revenue effects vary systematically across firm categories, such as industry sector, firm size group, channel structure (primarily in-person versus mixed or online-intensive operations), and transaction profile (high-frequency/low-ticket versus low-frequency/high-ticket sales), using interaction terms and subgroup estimations within the panel framework. Another objective embedded in the design is to assess the role of adoption intensity and channel breadth, distinguishing between simple adoption and expanded, integrated use of multiple payment methods and channels, in order to test whether incremental features are associated with additional revenue gains. The overarching objective remains to deliver a statistically grounded estimate of how digital payment solution adoption and usage correlate with revenue outcomes for SMEs in the U.S. context, using a structured panel approach that strengthens inference by accounting for unobserved firm-level stability and common time effects while preserving the empirical focus on revenue changes observed across the 1,200-firm dataset.

LITERATURE REVIEW

The literature review for "Quantitative Impact Assessment of Digital Payment Solutions on Small Business Revenue: Panel Data Analysis from 1,200 U.S. SMEs" synthesizes research streams that explain why and how digital payment solutions can alter small-business revenue and how those effects can be estimated credibly using longitudinal econometric designs (Hall & Schwartz, 2019). Because the study's outcome is small business revenue and the empirical design is panel data, the review is organized around (a) definitional clarity for digital payment solutions and revenue measurement in SME settings, (b) theoretical mechanisms linking payment acceptance to revenue-generating processes, (c) empirical evidence on merchant payment adoption and performance outcomes, (d) platform economics and pricing structures that shape both adoption and realized revenue effects, and (e) quantitative identification strategies used in prior work to address selection, endogeneity, and time-varying shocks in firm performance studies. The section also contextualizes the U.S. SME market as a setting characterized by high consumer adoption of electronic payments, heterogeneous merchant fee exposures, and rapid diffusion of integrated point-of-sale ecosystems, which jointly create measurable within-firm variation suitable for panel estimation (Cohen, 2018). Finally, the literature review establishes how the present study contributes by (1) using a large firm panel (1,200 SMEs) to observe within-firm revenue changes associated with adoption and intensity shifts, (2) modeling digital payment solutions as a multi-dimensional capability rather than a single adoption dummy, and (3) evaluating heterogeneity across sector, size, and channel structure using econometric specifications aligned with quantitative impact assessment. This structure ensures the review supports the study's core objective: estimating the magnitude and robustness of the revenue impact of digital payment solutions under real-world SME conditions using panel methods.

Digital payment solutions (DPS)

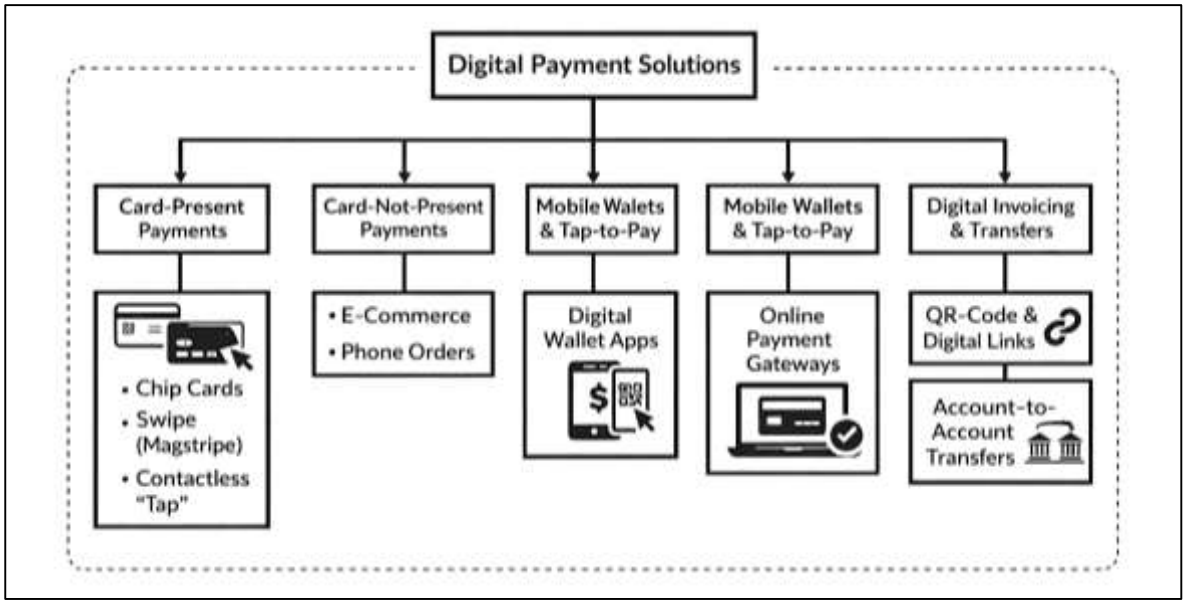
Digital payment solutions (DPS) are consistently described in the literature as merchant-facing systems that allow a business to accept electronic forms of payment and complete the full transaction cycle from customer authorization to settlement and reconciliation (Wolff et al., 2019). This merchant-side definition is important because it clarifies that DPS is not limited to a payment method, but includes the operational and technological infrastructure required to make the payment usable in day-to-day business practice. For SMEs, DPS is often implemented through a combination of point-of-sale hardware, payment processing software, acquiring relationships, transaction routing services, settlement rules, security layers, and accounting integration. The literature commonly categorizes DPS into several major types based on how the payment is initiated and processed. Card-present transactions represent a foundational category for in-person commerce, including chip-based

payments, magnetic stripe swipes, and contactless "tap" transactions. Each of these methods is associated with different authentication processes, transaction speeds, and risk-sharing arrangements, which influence merchant preferences and adoption decisions. Card-not-present transactions form a second category that includes e-commerce payments, phone orders, and other remote payment scenarios. This category is operationally distinct because it typically requires gateways, digital credential storage, and stronger fraud screening. A third category involves mobile wallets and tokenized tap-to-pay systems, which combine consumer convenience with merchant-side hardware compatibility and software enablement. Online payment gateways and hosted checkouts constitute another category, especially relevant for SMEs that sell through websites, marketplaces, and platform-based commerce (Elangovan & Sundaravel, 2021). Digital invoicing tools represent a separate DPS form, enabling SMEs to request payment through digital links, QR invoices, and embedded billing systems, which is particularly relevant for service-based and B2B SMEs. Account-to-account transfers also appear as a DPS category in the literature where bank-based electronic transfers or similar mechanisms are used for merchant payments. Across these categories, the literature stresses the importance of distinguishing between adoption, usage intensity, and feature breadth. Adoption refers to whether the business has enabled a specific payment capability. Usage intensity refers to how frequently the enabled capability is actually used, often reflected in the share of transactions or sales processed through that method. Feature breadth refers to the range of digital payment channels and tools the firm offers, such as accepting in-store card payments, enabling mobile wallets, and offering online invoicing simultaneously (Ferrer-Conill & Tandoc Jr, 2018). This conceptual separation is central to empirical research because SMEs frequently enable a payment option without using it heavily, and many firms gradually expand DPS capabilities rather than adopting everything at once. Therefore, DPS is best understood as a layered and evolving business capability rather than a simple yes-or-no technology.

Small business revenue is widely treated in quantitative business research as a core performance outcome that captures the firm's ability to generate sales over a defined period. Revenue is typically measured as gross sales, meaning the total value of sales receipts before subtracting operating costs, although some research uses net sales after accounting for refunds, returns, discounts, and adjustments (Peter & Petermann, 2018; Rifat & Rebeka, 2023; Zaheda & Farabe, 2023). The literature highlights that this definitional choice matters because revenue recorded in SME settings can be influenced by the business's accounting system, transaction documentation practices, and the level of digital integration between payments and bookkeeping. In many SME datasets, revenue is aggregated monthly or quarterly because small businesses experience substantial volatility and because these time units align with common reporting cycles. Monthly aggregation provides higher resolution and can capture short-term fluctuations linked to seasonal patterns, promotional events, and local demand shocks. Quarterly aggregation reduces noise and may improve stability in revenue measurement, although it can mask short-run adoption effects (Faysal & Bhuya, 2024; Towhidul & Uddin, 2024). Another measurement issue discussed in the literature is the functional form used for revenue in quantitative modeling. Logged revenue is often used to reduce skewness and interpret changes in proportional terms, while level revenue is used when the goal is to estimate absolute changes. The literature also emphasizes that SME revenue is affected by several volatility drivers that are especially pronounced in small firms. Seasonality is a dominant driver because SMEs often operate in industries with predictable demand cycles such as holiday retail, tourism, back-to-school commerce, and seasonal service demand (Sazzadul & Rebeka, 2024; Tasnim & Anick, 2024). Local demand cycles also shape revenue volatility because SMEs are sensitive to neighborhood-level economic conditions, local employment patterns, and regional cost-of-living changes (Wiig et al., 2020; Zaheda & Hamidur, 2024). Promotions and discounting practices create short-term revenue spikes or dips, especially for SMEs that rely on sales events, coupons, and loyalty-based pricing. Channel mix shifts are another major volatility driver, as SMEs increasingly sell through a combination of in-person, online, delivery, and remote service channels. Revenue may change not only because demand changes, but because the channel itself influences transaction size, customer acquisition patterns, and repeat purchase frequency. These factors are central to the present study because digital payment solutions can interact with all of them. DPS may influence revenue by increasing purchase completion, enabling new channels, and improving

transaction documentation. At the same time, the relationship can be confounded by the fact that firms adopt DPS when they are already changing their channel mix or responding to local competition (Czúcz et al., 2018). The literature therefore positions revenue as a valid outcome variable, but one that must be interpreted with careful attention to volatility, measurement consistency, and the broader operational context of SMEs.

Figure 3: Digital Payment Solutions for SMEs



The panel structure and unit of analysis are central operational components in quantitative impact assessment studies because they define how variation is used to estimate relationships. Panel data refer to repeated observations of the same firms across multiple time periods, allowing researchers to analyze within-firm change rather than relying solely on comparisons across different firms (Almanasreh et al., 2019). In SME research, the unit of analysis is typically the business entity, and the observation unit is often a firm-month or firm-quarter record. Firm-month panels allow researchers to observe adoption timing more precisely and capture short-term revenue changes, which can be important when the mechanisms of DPS operate through immediate transaction convenience and channel enablement. Firm-quarter panels are common when data quality is uneven or when revenue is noisy, as quarterly aggregation reduces volatility and measurement error. The literature also distinguishes between balanced and unbalanced panels. A balanced panel includes the same number of time observations for each firm, while an unbalanced panel contains missing observations for some firms due to entry, exit, reporting gaps, or changes in data systems. SME datasets are frequently unbalanced because small businesses may close, merge, change ownership, or switch payment providers and accounting platforms. The literature notes that unbalanced panels are not inherently problematic if handled correctly, and they often reflect real-world SME dynamics. Panel data methods are emphasized in the literature because they help address a major challenge in estimating the revenue effects of DPS: unobserved heterogeneity. SMEs differ in ways that are difficult to measure directly, including managerial competence, customer loyalty, brand reputation, and long-term business strategy (Merat et al., 2019). These factors influence both the likelihood of adopting digital payments and the level of revenue. By using within-firm variation, panel methods reduce bias caused by stable unobserved firm traits. The literature also recognizes that time-based shocks affect all firms simultaneously, such as inflationary conditions, changes in consumer confidence, sector-wide demand shifts, and national economic cycles. Panel designs allow the inclusion of time controls that account for these shared shocks, improving the credibility of the estimated association between DPS and revenue. Another point emphasized is that DPS adoption is rarely a single-time event. Many SMEs adopt in stages, meaning the panel structure must capture not only adoption timing but also subsequent

expansions in feature breadth and increases in usage intensity. This staged adoption creates richer within-firm variation that can be exploited statistically (Miller, 2018). The literature also highlights that revenue is persistent over time, meaning current revenue tends to be correlated with past revenue due to customer retention and market positioning. This persistence is important because it can influence model selection and interpretation. Overall, the literature positions the panel structure as an essential component for studying DPS impacts because it aligns the data structure with the real-world process of gradual adoption and evolving revenue trajectories in SMEs.

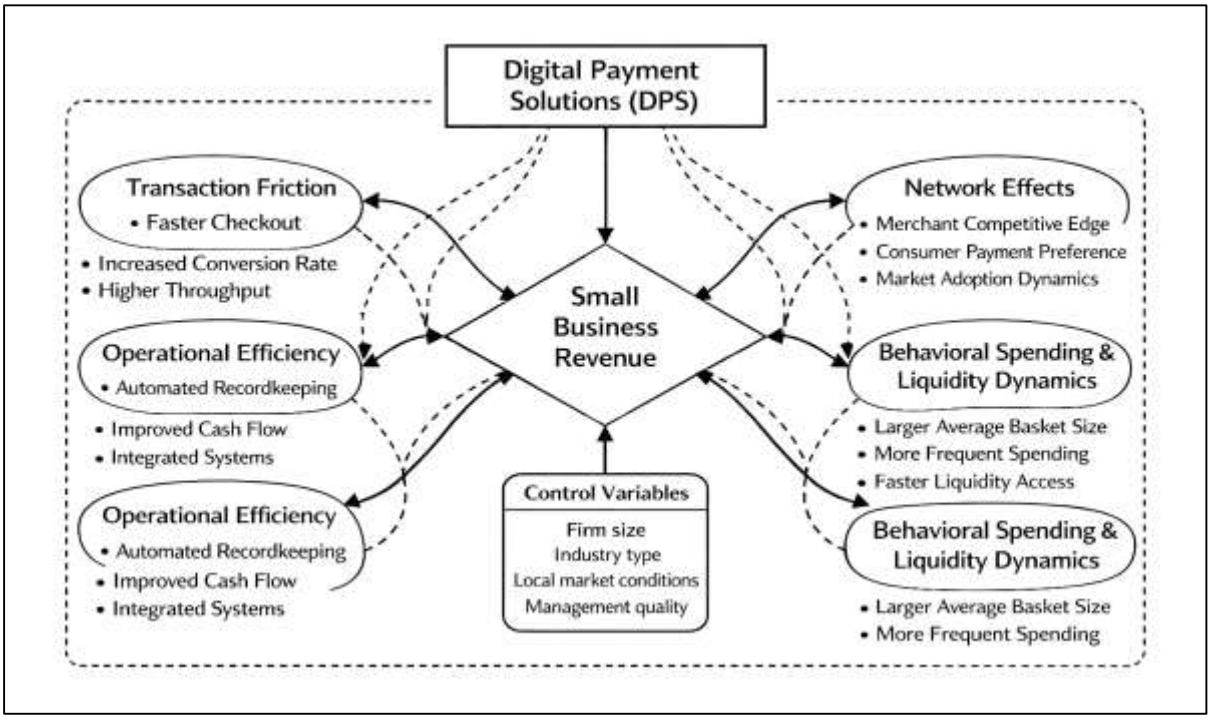
Theoretical Foundations Linking DPS

The theoretical linkage between digital payment solutions (DPS) and small business revenue is strongly grounded in transaction friction and conversion theory. Transaction friction refers to any barrier, delay, or inconvenience that interrupts or complicates the completion of a purchase. In retail and service environments, checkout processes represent a critical conversion point where customer intent must be transformed into completed sales (Gebauer et al., 2020). When payment systems are limited, slow, or inconvenient, customers may abandon purchases, reduce basket size, or defer transactions entirely. Digital payment solutions reduce friction by expanding tender options, accelerating authorization, and simplifying customer interactions at the point of sale. The literature on retail operations and consumer behavior consistently shows that checkout convenience influences purchase completion rates, particularly in environments characterized by time sensitivity or impulse buying. In high-traffic SME contexts such as food service, specialty retail, and personal services, transaction speed directly affects throughput capacity. Faster authorization and tap-based payments reduce queue length and waiting time, enabling businesses to serve more customers during peak periods. This increase in throughput can translate into measurable increases in sales volume without requiring additional physical space or staffing (Ciliberti & Frascarelli, 2018). In e-commerce and remote commerce contexts, friction takes the form of checkout complexity, credential entry burden, and payment security concerns. Online payment gateways and stored credentials reduce these barriers and can increase conversion rates by minimizing procedural steps. Abandonment risk in digital environments is especially sensitive to payment experience, and simplified checkout flows have been associated with higher transaction completion. For SMEs that operate across physical and digital channels, DPS reduces transactional discontinuities between in-person and online commerce, thereby stabilizing customer purchase behavior. Transaction friction theory therefore provides a direct revenue mechanism: when the payment stage becomes more efficient and accessible, a greater proportion of initiated purchases are completed (Ben Arfi & Hikkerova, 2021). In addition to increasing completed transactions, lower friction may increase average transaction values by enabling add-on purchases at the point of payment. The combined effect of higher completion rates and increased throughput capacity creates a logical pathway through which DPS adoption can influence total revenue in measurable ways within a panel data framework.

The two-sided market and network effect perspective provides a complementary theoretical foundation linking DPS to revenue. Payment systems operate within a platform environment that connects consumers and merchants through shared infrastructure. In such markets, adoption on one side of the platform influences participation on the other side. As consumer preference for electronic payments diffuses across a local market, merchant acceptance becomes increasingly necessary to remain competitive (Badran, 2021). Consumers who prefer card, contactless, or mobile wallet payments may avoid businesses that do not accept their preferred method. This creates a reinforcing dynamic in which consumer payment preferences shape merchant behavior, and merchant acceptance shapes consumer willingness to transact. The literature on platform economics emphasizes that such feedback loops can lead to localized equilibrium patterns, where high acceptance and high usage coexist and reinforce one another. For SMEs, this dynamic means that DPS adoption is not solely a technological decision but also a strategic positioning decision within a competitive ecosystem. If competing firms accept a wide range of digital payments, customer expectations adjust accordingly, and non-accepting firms may experience demand leakage. Conversely, early adopters in markets where digital payment penetration is rising may capture marginal customers who prioritize convenience and flexibility. The network effect logic also explains heterogeneity across sectors and regions (Lee & Kim, 2018). In densely populated or digitally mature areas, consumer-side adoption is often higher, making merchant acceptance more consequential for revenue. In contrast, in markets where digital payment diffusion is

slower, the immediate revenue effect of adoption may be more moderate. Local equilibrium dynamics further suggest that adoption intensity matters. A firm that accepts only basic card payments may capture some demand, while a firm that also enables contactless, mobile wallets, and online payments may align more fully with consumer preferences. This layered acceptance broadens the feasible transaction set and reduces the likelihood of mismatch between customer expectations and merchant capability (Somoye et al., 2022). The two-sided framework therefore situates DPS within a competitive and relational context, where revenue outcomes are shaped not only by internal operational efficiency but also by external alignment with evolving consumer payment norms.

Figure 4: Digital Payments Enhance SME Revenue



The information technology capability and complementarity perspective further explain why DPS adoption may influence revenue. Digital payment solutions function as operational capabilities that automate transaction recording, integrate financial flows, and connect payment processing with broader business systems (Schlatt et al., 2022). From this perspective, revenue effects are not solely driven by the payment method itself but by how payment systems interact with organizational processes. When DPS is integrated with point-of-sale systems, accounting software, and inventory management tools, transaction data flows seamlessly across functions. This integration reduces manual entry errors, accelerates reconciliation, and enhances the accuracy of financial reporting. For SMEs, which often operate with limited administrative capacity, such automation can free managerial time and reduce operational bottlenecks. Complementarity theory suggests that technology investments yield stronger performance effects when combined with organizational adjustments (Žičkienė et al., 2022). For example, staff training ensures that employees can process transactions efficiently and resolve payment-related issues promptly. Process redesign, such as reorganizing checkout counters or adopting mobile POS devices, can amplify the speed benefits of digital payments. Consistent settlement practices improve cash-flow predictability, enabling more stable inventory purchasing and supplier payments. Inventory workflows connected to POS data allow real-time tracking of product movement, reducing stockouts and improving product availability. These complementary adjustments strengthen the link between DPS and revenue because they enhance the firm's ability to capture and retain sales. Without integration and complementary practices, DPS may remain underutilized, limiting its potential impact. The literature consistently emphasizes that technology adoption alone does not guarantee performance gains; rather, it is the interaction between technology and organizational

structure that determines realized outcomes. In SME settings, where resource constraints heighten the importance of efficiency, well-integrated DPS can function as a core business capability (Alshawish et al., 2018). This capability perspective aligns with panel data analysis because capability development unfolds over time, and revenue changes may reflect gradual integration rather than instantaneous effects at the moment of adoption.

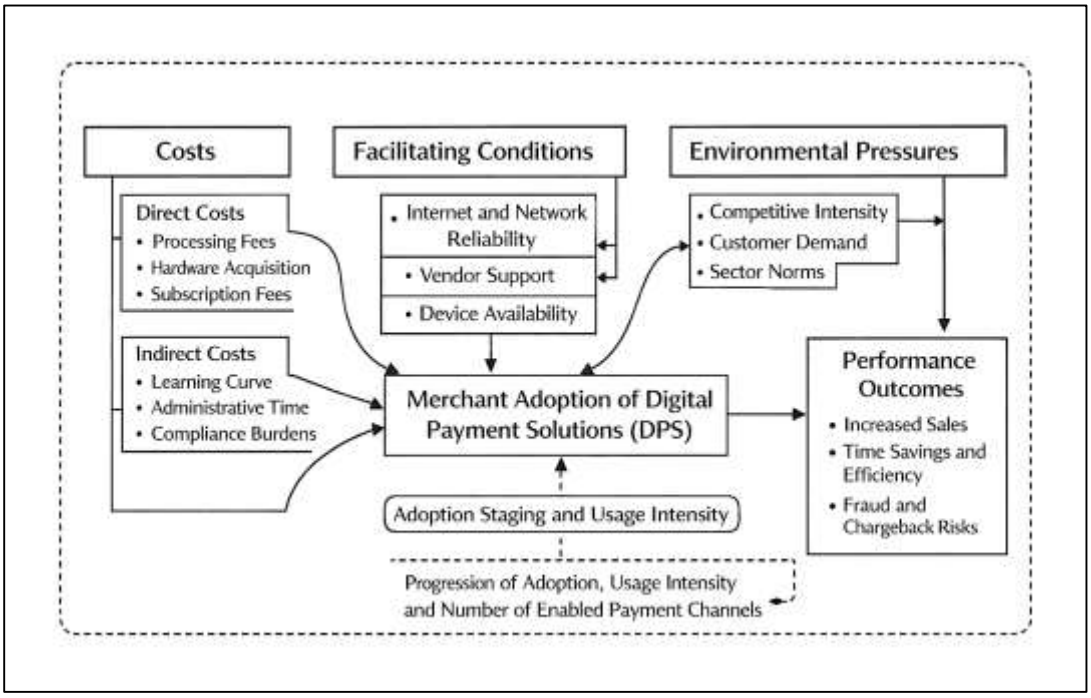
Behavioral spending mechanisms and liquidity dynamics provide additional theoretical channels linking DPS to revenue. Payment method influences consumer spending patterns through psychological and practical mechanisms. Electronic payments often reduce the salience of spending compared to cash transactions, as the physical outflow of currency is replaced by abstract digital confirmation. This reduced salience can increase average basket size, particularly in discretionary consumption contexts (Mastronardi & Cavallo, 2020). Convenience effects also influence purchase frequency. When customers can complete transactions quickly and without cash constraints, they may engage in more frequent, smaller purchases. Mobile wallets and contactless payments further streamline transactions, lowering the cognitive and procedural effort required to complete a purchase. These behavioral shifts can cumulatively affect total revenue over time. Liquidity and cash-flow timing mechanisms operate on the firm side. Settlement speed and predictability influence working capital availability, which in turn affects a firm's ability to maintain inventory, invest in marketing, or manage short-term obligations. Digital payments typically provide structured settlement cycles and documented transaction records, increasing financial transparency. For SMEs, predictable settlement enhances planning accuracy and reduces uncertainty in cash management. In addition, digital traces created through electronic payments improve revenue documentation completeness. Automated records reduce the risk of underreporting, lost receipts, and reconciliation discrepancies (Kerr et al., 2019). More accurate documentation can influence reported revenue levels, particularly in firms transitioning from informal or cash-dominant systems. This documentation channel does not necessarily reflect new sales generation but can reflect more complete revenue capture. Combined, behavioral and liquidity mechanisms demonstrate that DPS influences revenue through both demand-side and supply-side channels. On the demand side, changes in spending behavior and purchase frequency affect sales volume and basket size. On the supply side, improved cash-flow management and documentation accuracy stabilize revenue reporting and support operational continuity (Muchtar et al., 2018). These mechanisms, when considered alongside transaction friction, network effects, and organizational complementarity, provide a multi-layered theoretical foundation for examining the quantitative relationship between digital payment solutions and small business revenue in a panel data setting.

Merchant Adoption of Digital Payments

Merchant adoption of digital payment solutions (DPS) has been widely examined in empirical small-business research as a decision shaped by cost structures, operational readiness, and the surrounding market environment. Across studies of SME technology uptake, direct and indirect costs repeatedly emerge as primary determinants. Direct costs include processing fees that scale with transaction values or counts, hardware acquisition costs for card readers or point-of-sale devices, and recurring subscription fees for software or gateway services (Adhikary et al., 2021). Indirect costs include the managerial time required to compare vendors, learn system features, adjust workflows, and handle ongoing administrative tasks such as dispute responses. Compliance burdens also appear as a consistent determinant, particularly where payment acceptance requires adherence to security standards, documentation procedures, or identity verification processes. Small firms often evaluate these costs relative to perceived demand benefits and the expected likelihood of lost sales when digital options are unavailable. Empirical findings frequently indicate that firms with low average ticket sizes and thin margins are especially sensitive to fee structures because even modest percentage-based charges can materially affect pricing strategies and perceived affordability for customers. Studies also report that cost sensitivity is not limited to the fee level itself but extends to fee complexity and predictability. When fee schedules are opaque or when chargeback penalties are uncertain, SMEs may postpone adoption or limit the set of enabled payment channels. Facilitating conditions are a second major determinant identified in empirical work. Internet reliability and network coverage influence the feasibility of real-time authorization and the stability of payment acceptance, especially for mobile

point-of-sale systems or for SMEs operating in older buildings, rural regions, or temporary retail environments. Vendor support and service reliability are repeatedly reported as adoption drivers because SMEs often lack in-house IT capacity and depend on external providers for setup, troubleshooting, and integration (Shree et al., 2021). Device availability also matters, as adoption may require compatible smartphones, tablets, terminals, or integrated POS systems. The literature further indicates that facilitating conditions operate jointly with managerial perceptions of ease of use and usefulness, implying that adoption is more likely when the technology is perceived as simple to implement and when support pathways are clear. Environmental pressures form a third determinant cluster repeatedly observed across empirical studies. Competitive intensity can compel adoption when peer firms in the same neighborhood or sector offer multiple digital payment options. Customer demand also functions as a direct adoption trigger, particularly when customers ask about card acceptance, contactless options, or mobile wallet usage. Sector norms shape adoption because some industries have already standardized electronic payments, while others maintain stronger cash traditions (Mishra et al., 2022). In many empirical observations, SMEs adopt not solely as an efficiency investment but as a legitimacy response to consumer expectations, competitive signals, and market norms that define what is considered an acceptable purchasing experience.

Figure 5: Factors Influencing Digital Payment Adoption



Empirical studies also show that DPS adoption among SMEs is typically staged rather than immediate, with firms gradually expanding capabilities as confidence, customer demand, and operational integration increase. Adoption staging often begins with basic card acceptance in physical locations because this capability addresses the most common non-cash consumer need while requiring relatively limited integration beyond a terminal and a processor relationship (Moghavvemi et al., 2021). Once basic acceptance is established, many firms expand to contactless transactions and mobile wallets because these methods often leverage the same infrastructure but require feature enablement and compatible hardware. A subsequent stage frequently involves gateway-enabled e-commerce acceptance, reflecting the increasing relevance of online channels and the operational need for remote payments. This stage introduces additional components such as hosted checkouts, payment links, fraud screening enhancements, and stronger authentication processes. Many SMEs add digital invoicing and recurring billing capabilities later, particularly in service-based sectors where payments occur after service delivery or where subscription models are used. The literature emphasizes that staged adoption reflects both learning and risk management. Firms initially adopt capabilities that feel familiar and operationally manageable, then move toward more complex forms that require deeper integration and

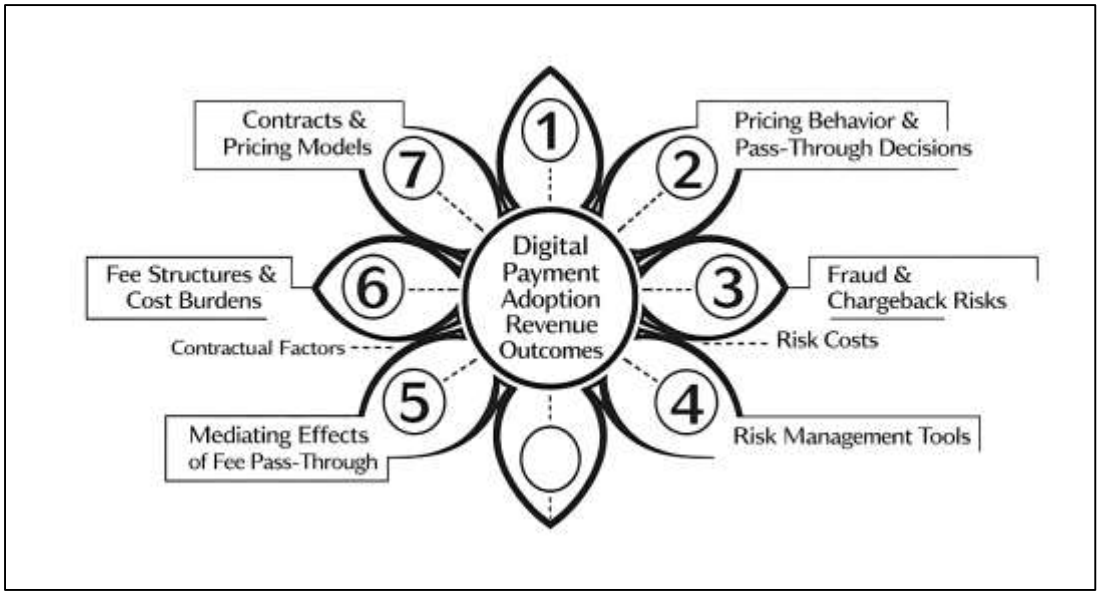
stronger compliance. Because adoption is staged, empirical research often distinguishes between adoption status and adoption intensity (Tounekti et al., 2019). Adoption status indicates whether a specific capability is enabled, while intensity captures how extensively the capability is used in actual sales. Studies operationalize intensity in several ways, commonly using the share of sales processed digitally as a continuous measure that captures the extent to which digital payments have replaced cash or checks. Another operationalization uses the share of transactions processed digitally, which can be informative when average ticket size varies across payment types or when digital payments are more common in certain transaction contexts. A third approach counts the number of enabled methods or channels, such as whether the firm accepts card-present payments, mobile wallets, online payments, and invoicing simultaneously. This channel-breadth measure captures the diversity of acceptance options and is often treated as a proxy for capability maturity. Empirical work also notes that enabled capability does not guarantee usage. Some firms enable online payments but continue to transact primarily in-person, while others accept contactless but observe low customer usage in certain demographic segments (Roussou et al., 2019). Therefore, staged adoption and intensity measurement are essential for understanding how digital payments relate to performance outcomes. These constructs also align with a panel data design because intensity can vary over time within the same firm, allowing researchers to observe how revenue and other outcomes move as usage becomes more substantial or as the firm expands the breadth of enabled payment options.

Pricing, Fees, and Merchant Economics

Pricing, fees, and merchant economics are central in the literature explaining why the revenue effects of digital payment solutions (DPS) differ across firms, even when adoption occurs under broadly similar technological conditions. A recurring empirical observation is that merchant acceptance is embedded in a complex fee architecture that shapes incentives, pricing behavior, and customer interactions (Chen et al., 2018). Merchant fee structures commonly combine percentage-based charges applied to the transaction value with per-transaction charges applied regardless of ticket size, creating heterogeneous cost burdens across SMEs with different sales profiles. Firms with small average tickets and high transaction counts often experience stronger exposure to per-transaction fees because fixed charges represent a larger share of each sale, while firms with larger tickets may be more sensitive to percentage fees because total fees scale with sale value. The literature treats this as a core reason why the same adoption decision can yield different realized outcomes across sectors such as food service, convenience retail, specialty retail, professional services, and repair services. Empirical research also emphasizes that merchant pricing is shaped by contractual variation, and SMEs often face contracts that differ substantially in transparency, predictability, and effective cost. Tiered pricing commonly groups transactions into qualified and non-qualified categories, creating uncertainty and limiting SMEs' ability to predict total costs (Górka, 2018).

Risk costs are another central theme in the literature explaining heterogeneous outcomes from digital payment adoption, particularly through the channels of fraud, chargebacks, and dispute processes. These risks vary strongly by payment type and selling channel, creating differences between in-person and online commerce. In-person card-present transactions tend to have lower dispute rates due to stronger authentication at the point of sale, while card-not-present transactions face higher exposure because the customer is remote and identity verification relies on credentials rather than physical presence (Hartley et al., 2019). The literature repeatedly emphasizes that SMEs expanding into e-commerce or remote payment acceptance often experience an increase in dispute probability, which can create operational burdens and indirect revenue effects. Chargebacks can remove previously recorded revenue, trigger penalty fees, and require time-consuming documentation work. Even when revenue is measured before such adjustments in some datasets, disputes can influence merchant behavior by increasing caution, tightening customer screening, or restricting certain transaction types. Fraud risks also influence acceptance decisions and pricing strategies. SMEs that experience repeated disputes may adopt more conservative policies, such as requiring stronger verification, limiting international transactions, or reducing flexible return policies, each of which can affect conversion rates and customer experience (Cho et al., 2021).

Figure 6: Digital Payment Revenue Influence Factors



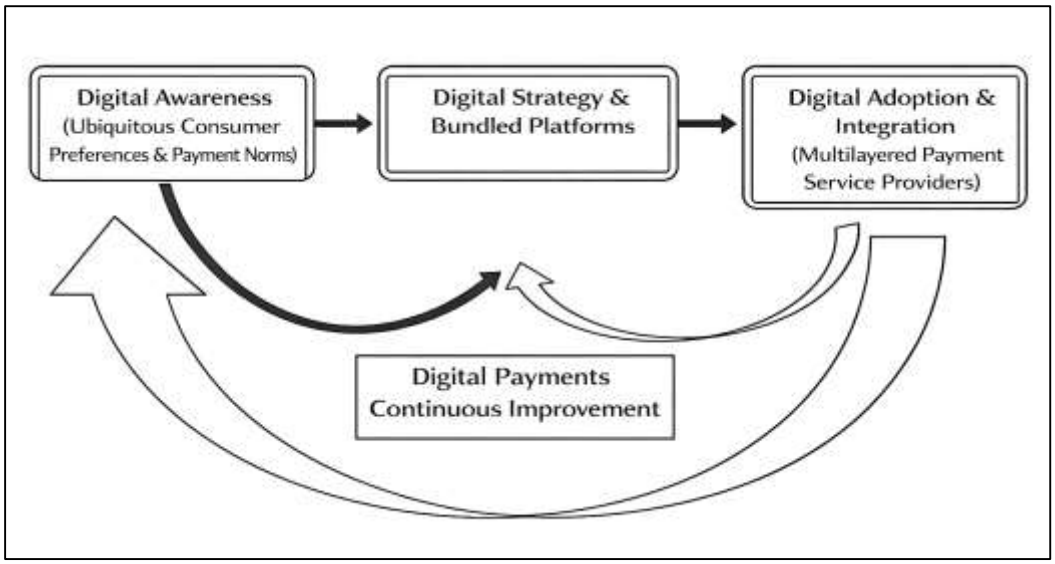
The literature notes that risk costs are not evenly distributed across SMEs. Firms selling digital goods, subscription services, high-value items, or remote services often have different risk exposure profiles compared to firms selling low-value items in-person. The ability to manage risk is also uneven. Larger SMEs may have dedicated staff for risk monitoring, while microbusinesses may struggle to respond within required timelines. This influences the realized cost of digital payments beyond headline processing fees. Dispute rules and evidence requirements can also vary by provider and payment instrument, adding institutional complexity that affects small merchants' experiences. The literature positions these risk costs as a source of heterogeneity because they can reduce the net benefit of adoption and can shape customer experience policies that influence revenue. Therefore, differences in channel mix and risk exposure represent important contextual factors when interpreting revenue changes associated with DPS adoption in SME panels (Noori-daryan et al., 2018).

U.S. SME Context and Relevance

The U.S. small and medium-sized enterprise (SME) environment provides a particularly meaningful empirical setting for examining the revenue effects of digital payment solutions because consumer payment preferences are deeply embedded in everyday commercial practice. Across retail and service sectors, card payments and digital wallets have become routine instruments for both low-value and high-value transactions (Gallardo-Gallardo et al., 2020). The literature consistently documents that consumer in the United States rely heavily on debit and credit cards for point-of-sale purchases, and mobile wallet usage has expanded alongside contactless terminal availability. In such an environment, digital payment acceptance is frequently perceived not as an optional technological upgrade but as a baseline service attribute. Customers often expect the ability to pay electronically regardless of transaction size, and firms that fail to offer these options risk signaling inconvenience or outdated operations. Studies of consumer behavior indicate that tender preference influences store choice, especially in urban and suburban markets where customers can easily switch among nearby competitors. Electronic payment expectations are particularly pronounced in sectors such as food service, specialty retail, and personal care, where speed and convenience are central to customer experience (Miles & Morrison, 2020). The literature also notes generational variation in payment behavior, with younger consumers displaying higher comfort with mobile wallets and contactless payments, reinforcing the importance of acceptance breadth. At the same time, older consumers maintain strong card usage patterns, ensuring that electronic payments remain dominant across demographic groups. This widespread consumer reliance on digital instruments shapes merchant strategy because acceptance becomes tied to legitimacy and professionalism in the eyes of customers. Empirical research often finds that SMEs in digitally mature environments report customer inquiries about payment methods as a primary driver of adoption decisions. In this context, revenue implications

emerge through the alignment between merchant capabilities and consumer expectations (Martins et al., 2022). When acceptance is viewed as a baseline requirement, non-acceptance can directly translate into lost transactions rather than neutral outcomes. Therefore, the U.S. consumer payment landscape creates a structural condition in which DPS adoption is closely linked to revenue capture opportunities, making it a highly relevant context for panel-based impact assessment.

Figure 7: U.S. SMEs and Digital Payments



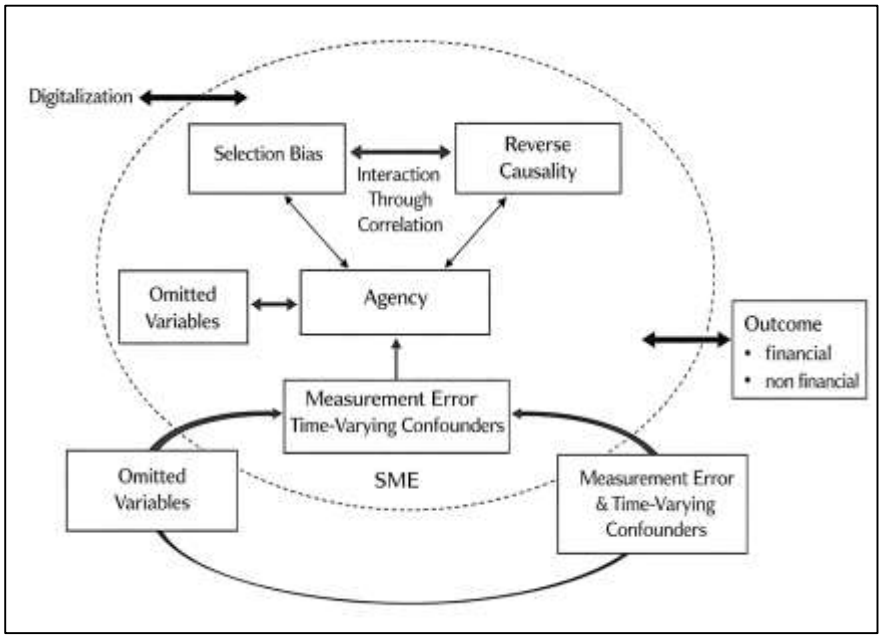
The U.S. payment ecosystem is also characterized by a multilayered platform structure that shapes SME adoption pathways and operational outcomes. Payment facilitators, acquiring banks, processors, independent sales organizations, and integrated point-of-sale providers collectively form a competitive marketplace offering varied service bundles. This ecosystem structure influences both the cost and the functionality of digital payment solutions available to SMEs. Payment facilitators often simplify onboarding by aggregating merchants under a master account, reducing initial barriers to entry for microbusinesses and newly established firms (Ünal et al., 2019). Acquirers and processors provide transaction routing, settlement services, and compliance support, while integrated POS platforms embed payments directly into broader operational systems. The literature highlights that the bundling of payment services with analytics, inventory management, payroll tools, customer relationship features, and loyalty programs creates complementarities that extend beyond transaction processing. For SMEs, such bundling can reduce coordination costs by centralizing multiple operational functions within a single platform. At the same time, bundled ecosystems can create dependency, as switching providers may require migration of sales data, customer records, and workflow processes. Empirical research frequently observes that integrated platforms influence not only payment acceptance but also business analytics capacity, including real-time sales tracking, product performance analysis, and customer frequency monitoring (Heidt et al., 2019). These features can indirectly affect revenue by supporting more informed inventory decisions, targeted promotions, and demand forecasting. The competitive structure of the U.S. ecosystem also generates heterogeneity in contract terms, service quality, and support availability. SMEs differ in their exposure to fee models, service-level agreements, and dispute management processes based on the provider they select. This institutional diversity reinforces the importance of studying the U.S. setting because it provides variation in both adoption and implementation quality. In empirical analyses, such variation allows researchers to observe differences in revenue outcomes that are not attributable solely to the existence of digital payment acceptance but also to how that acceptance is operationalized within a broader technology platform environment (Mandviwalla & Flanagan, 2021).

Estimating Revenue Impact

Quantitative estimation of the revenue impact of digital payment solutions (DPS) in SMEs is vulnerable to several identification challenges that can bias results if not explicitly addressed in study design and

empirical modeling. A primary concern highlighted in the empirical literature is selection bias, which arises because SMEs adopt payment technologies through non-random processes linked to underlying firm characteristics. Early adopters often differ systematically from late adopters or non-adopters in ways that are correlated with revenue outcomes (Fox et al., 2021). These differences may include higher digital maturity, greater managerial openness to innovation, stronger access to capital, and a growth-oriented business strategy that predisposes firms toward revenue expansion even without DPS adoption. SMEs that already use modern point-of-sale systems, maintain structured bookkeeping, or invest in online marketing may adopt DPS more quickly because the incremental integration burden is lower. Such firms may also attract customer segments that prefer digital payments, implying that their revenue trajectory could be steeper regardless of adoption. Selection bias can also operate through sector and geography. SMEs in digitally mature urban areas may adopt earlier due to stronger customer demand and competitive pressure, while rural firms may delay adoption due to infrastructure constraints. Without careful modeling, observed revenue differences between adopters and non-adopters can reflect these baseline differences rather than a true DPS effect (Rubin et al., 2019). The literature also notes that selection can occur at multiple margins: selection into adoption at all, selection into more advanced features, and selection into higher usage intensity. Firms that expand to multiple channels, such as contactless, wallets, and online gateways, may be those already experiencing revenue growth or planning business expansion. This layered selection process means that simple adoption indicators may mask deeper differences in adoption quality and business capability. In panel settings, within-firm estimation helps reduce selection bias arising from time-invariant characteristics, yet selection can remain if adoption timing is correlated with time-varying factors that also affect revenue. Therefore, identification challenges begin with recognizing that adoption is strategic, constrained, and embedded in broader firm trajectories, making selection bias one of the most critical threats to valid inference in revenue impact assessment (Stubbs et al., 2020).

Figure 8: DPS Revenue Impact Identification Challenges



Omitted variable bias is another widely discussed identification challenge because many factors influencing SME revenue are difficult to observe or measure consistently across firms. The literature emphasizes that marketing intensity is a major determinant of revenue changes, yet marketing spending and effort are often unobserved in SME panel datasets. A firm adopting DPS might simultaneously invest in digital marketing, create promotions, or join delivery platforms, and these concurrent actions can drive revenue changes independently of payment adoption. Local competition is another omitted factor (Coady & Dizioli, 2018). Changes in competitor density, competitor pricing, or the entry of a major chain can influence revenue substantially. These changes also influence the

likelihood that SMEs adopt DPS, making competition a confounder. Managerial quality and business capability are especially challenging omitted variables. More capable managers may both adopt new technologies earlier and implement superior customer service, inventory management, and pricing strategies that increase revenue. Product changes and service redesign also introduce bias. SMEs often change menus, product lines, store layout, operating hours, or staffing levels, and these changes can be correlated with technology adoption events. For example, a firm may adopt a new POS system that includes DPS simultaneously with a broader rebranding effort. If product changes are not measured, revenue gains may be incorrectly attributed to payment adoption (Lyne et al., 2018). Similarly, channel expansion into e-commerce or delivery can both require DPS and independently increase revenue by expanding demand reach. The literature also points to local macro conditions such as neighborhood redevelopment, tourism cycles, and regional employment changes as unobserved drivers of revenue, which can be correlated with adoption through shifting customer demand. Even when panel models control for time effects, omitted variables that vary by location, sector, or firm strategy can remain problematic. Therefore, omitted variable bias is a persistent concern that can inflate or deflate estimated DPS effects depending on whether omitted factors move in the same direction as adoption and revenue. This risk is especially pronounced in observational settings where SMEs adopt DPS as part of a broader set of operational changes that are difficult to fully capture with available controls (Adu-Baffour et al., 2019).

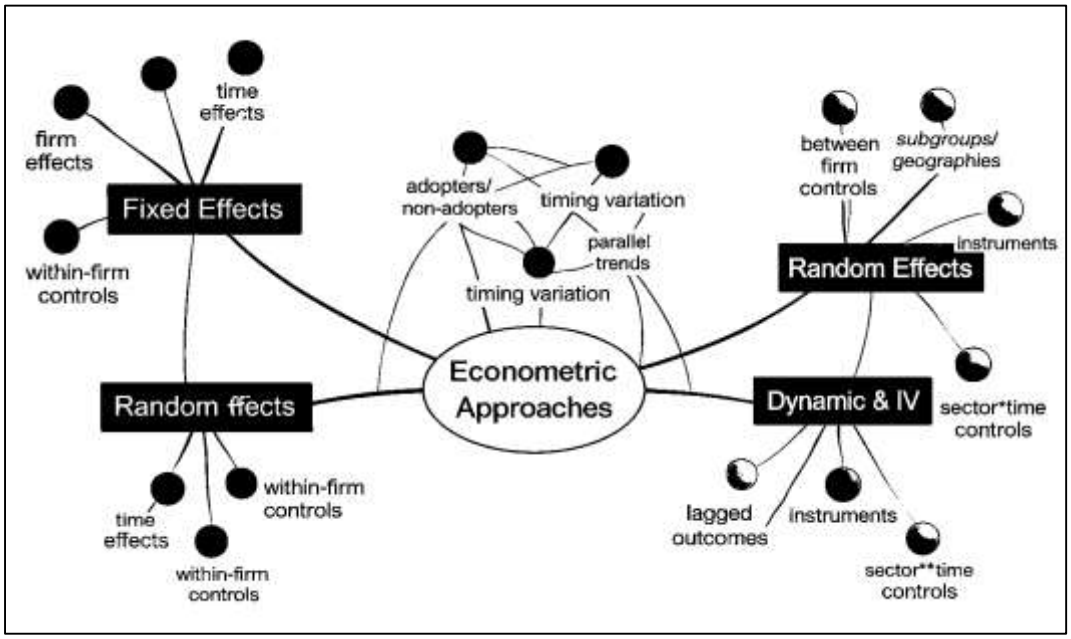
Panel Econometric Approaches in Prior Firm-Performance Research

Prior firm-performance research that evaluates technology adoption and operational interventions frequently relies on fixed effects models as a foundational approach for estimating impacts in panel datasets. The literature positions firm fixed effects as especially suitable when unobserved characteristics differ across firms and are plausibly correlated with both adoption decisions and performance outcomes (Barzin et al., 2018). In SME settings, these unobserved characteristics often include managerial quality, organizational culture, baseline customer loyalty, product positioning, neighborhood advantages, and long-run pricing strategy. Because such factors are difficult to measure directly and are often stable over time, firm fixed effects are used to remove their influence by focusing estimation on within-firm change rather than between-firm differences. This approach aligns with adoption studies because firms are rarely randomly assigned to adopt a technology; instead, adoption reflects strategy, capability, and market pressure. The literature also emphasizes that time fixed effects are critical when all firms are exposed to common stocks such as macroeconomic cycles, inflationary environments, sector-wide demand changes, or national policy shifts (Müller et al., 2018). Two-way fixed effects models incorporate both firm and time effects, and they are often treated as the baseline design in observational impact studies because they simultaneously control for stable firm heterogeneity and common temporal variation. In the context of digital payment adoption, two-way fixed effects are particularly relevant because payment adoption often co-occurs with broader changes in consumer behavior and economic conditions that affect all SMEs. The literature further notes that fixed effects models can incorporate time-varying controls such as staffing levels, store hours, channel mix, and local economic indicators, thereby strengthening the design by addressing observable confounders that change over time. At the same time, studies also recognize limitations: fixed effects models do not automatically solve endogeneity if adoption is driven by time-varying unobserved shocks, and estimates can be sensitive to how adoption timing is defined. Even so, fixed effects remain widely used because they provide a transparent and interpretable framework that is consistent with the logic of within-unit comparison. In technology adoption contexts, the literature frequently frames fixed effects as a credibility-enhancing step that reduces bias relative to cross-sectional models (Taveira et al., 2019). This empirical tradition provides a clear methodological foundation for estimating how digital payment solution adoption relates to revenue changes in SME panels, especially when the research objective is to isolate associations attributable to within-firm adoption and usage intensity shifts over time.

Random effects models appear in prior research as an alternative to fixed effects when the analyst seeks to exploit both within-firm and between-firm variation, yet the literature treats their use as conditional on strong assumptions that can be difficult to defend in adoption settings. Random effects approaches assume that unobserved firm-specific factors are not correlated with the explanatory variables,

meaning that the unobserved characteristics influencing revenue are unrelated to technology adoption decisions (Ronoowah & Seetanah, 2022). In SME technology adoption studies, this assumption is often viewed as restrictive because factors such as managerial competence, innovation orientation, and baseline operational sophistication can plausibly influence both adoption and revenue. When this correlation exists, random effects estimates can be biased. The literature therefore frequently positions random effects as more appropriate in contexts where adoption is plausibly exogenous relative to unobserved traits or when the analyst has strong evidence that unobserved heterogeneity is not systematically related to adoption. In practice, studies sometimes use random effects as a robustness comparison, or they apply it when the key explanatory variable has limited within-firm variation. The literature also notes that random effects can be useful when the analyst seeks to estimate coefficients on time-invariant variables such as region, sector category, or baseline firm type, which fixed effects remove from the estimation. Because many adoption studies are interested in subgroup differences across industries or geographies, random effects may appear in descriptive or exploratory analyses (Khan & Abdul Subhan, 2019).

Figure 9: Econometric Approaches for SME Analysis

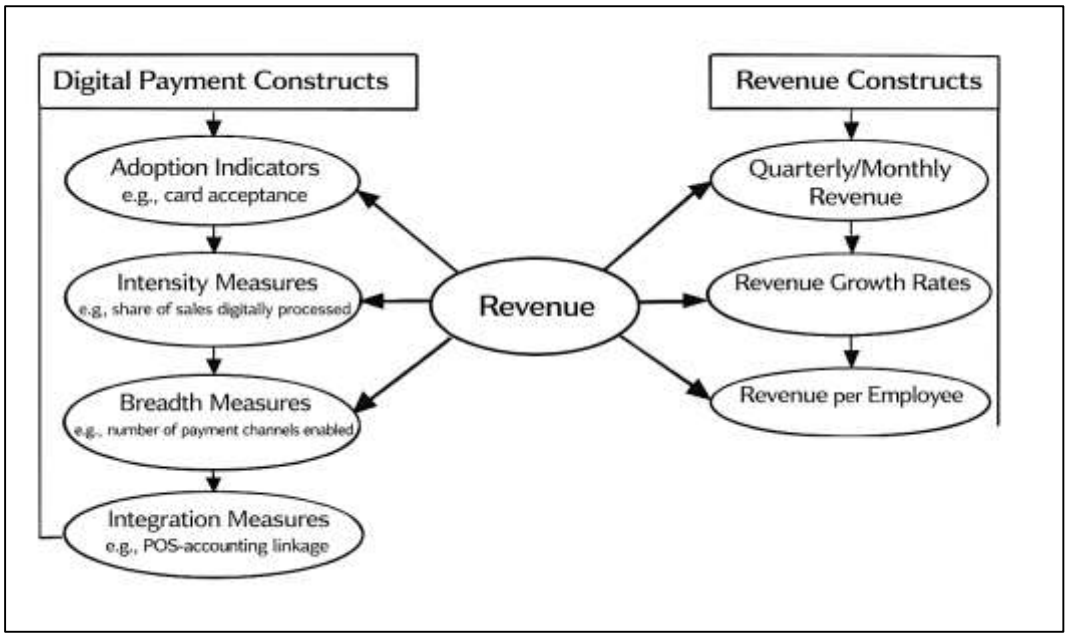


Construct-to-Model Link

The literature on digital payments, technology adoption, and firm performance provides a clear construct-to-model roadmap that links conceptual ideas about digital payment solutions (DPS) to measurable variables suitable for panel estimation. A central theme across empirical studies is that DPS cannot be represented adequately by a single binary indicator without losing meaningful variation in adoption timing, implementation depth, and realized use (Sutcliffe et al., 2022). Many studies begin with adoption indicator(s) because they offer a straightforward operational definition: a firm is coded as an adopter when it has enabled a payment capability such as card acceptance, contactless payments, mobile wallets, online gateways, or digital invoicing. The literature often treats this indicator as a baseline representation of whether the firm has crossed a threshold of capability. At the same time, prior research emphasizes that adoption indicators alone can misrepresent treatment intensity because many SMEs enable payment systems but continue to rely heavily on cash or other methods. This leads to a second construct class: intensity measures. The most common intensity approach observed in the literature is the share of sales processed digitally, which captures the extent to which electronic payments have become integrated into actual revenue generation (Hewelt et al., 2020). Another common measure is the share of transaction counts processed digitally, which is useful when ticket sizes differ across payment types and when businesses process many small transactions. These

intensity measures are frequently treated as continuous indicators that vary over time, making them well-suited to panel models that rely on within-firm variation. A third construct class involves breadth measures, typically operationalized as the number of enabled payment methods or channels. The literature uses breadth to represent capability maturity and customer coverage, recognizing that accepting only one method may capture limited demand while enabling multiple methods can reduce mismatch between customer preferences and merchant acceptance. Breadth also aligns with staged adoption patterns documented in SME settings, where firms often expand from basic card acceptance to wallets, online gateways, and invoicing features. A fourth construct class involves integration measures, reflecting the literature's emphasis on complementarities between payment systems and business operations. Integration is frequently represented through indicators such as POS-to-accounting linkage, automated reconciliation features, inventory workflow connections, and invoicing feature use. These measures reflect the idea that DPS value is amplified when it is embedded in operational routines rather than functioning as a standalone payment tool (Karsai, 2018). Together, the literature supports a multidimensional measurement strategy for DPS that captures adoption status, realized use intensity, capability breadth, and operational integration, enabling a more faithful mapping from theoretical mechanisms to econometric variables.

Figure 10: DPS Constructs for Revenue Modeling



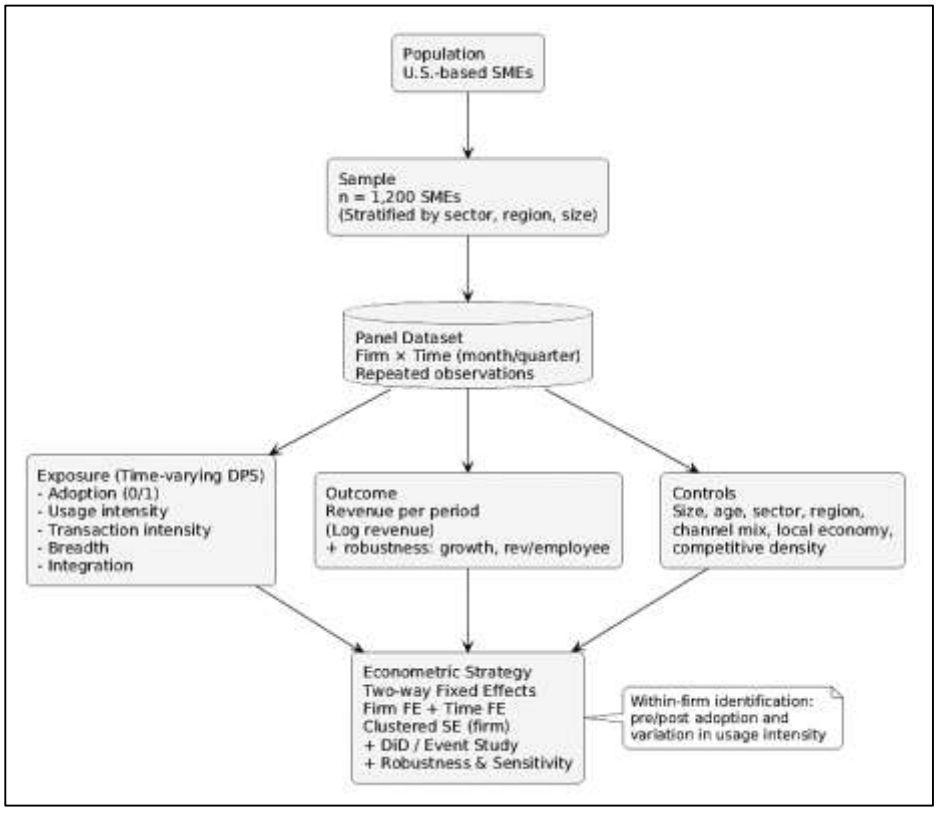
The dependent variable construction in revenue impact studies is also heavily informed by prior research, particularly regarding how revenue should be measured and transformed for empirical estimation in SME panels. The literature commonly treats revenue as the most consistently observed performance metric across SMEs because it can be derived from transactional records, sales systems, or accounting summaries (Adhikary et al., 2021). In panel designs, revenue is often aggregated at monthly or quarterly intervals to align with reporting practices and to reduce random noise relative to daily measurements. The choice between monthly and quarterly aggregation is typically framed as a trade-off between temporal resolution and measurement stability. Monthly revenue captures short-run dynamics and can better align with adoption timing, especially when adoption effects operate through transaction convenience, throughput, and channel activation. Quarterly revenue reduces volatility and can be useful when business activity is noisy or when reporting quality varies. Another widely discussed issue is whether revenue should be modeled in levels or in a transformed form that reduces skewness. The literature frequently applies log transformation to revenue because revenue distributions across SMEs are often highly skewed, with a small number of firms generating substantially larger sales. Logged revenue also stabilizes variance, helping panel models fit more consistently across heterogeneous firms. At the same time, empirical studies often emphasize

robustness by testing alternative dependent constructs that capture different aspects of performance. Revenue growth rates are commonly used as an alternative because they represent dynamic expansion or contraction, controlling partially for baseline size differences (Mustapha, 2018). Growth-based measures can be particularly informative when comparing firms of different scales, though they can be sensitive to low baseline values and volatility. Revenue per employee is another alternative used in firm performance research when staffing data are available. This measure is often treated as a proxy for labor productivity and operational efficiency, providing a different lens on performance than total revenue alone. Because DPS can influence throughput and administrative efficiency, per-employee scaling can help interpret whether revenue changes reflect expanded volume, improved efficiency, or both. The literature also stresses the importance of aligning the revenue construct with the research question. When the study seeks to assess the impact of payment adoption on sales capture, revenue is treated as the central outcome because it reflects demand realization and transaction completion. Profit is often avoided in SME panel research because cost accounting is inconsistent and because fee structures vary widely (Trinugroho et al., 2022). Therefore, prior work provides a consistent rationale for operationalizing revenue as a time-aggregated outcome, often in logged form for baseline models, and then verifying the stability of findings under alternative constructs such as growth rates and per-employee scaling when data permit.

METHOD

This study used a quantitative longitudinal panel design to estimate the impact of digital payment solutions on small business revenue across 1,200 U.S.-based SMEs observed over multiple time periods. A stratified sampling strategy ensured representation across sectors, regions, and firm sizes, including both adopters and non-adopters of digital payments. Data were collected from integrated transaction systems, accounting platforms, and payment processing records, with revenue measured at the firm-period level. Key independent variables included a binary adoption indicator, usage and transaction intensity, breadth of enabled payment methods, and POS-accounting integration, while the primary dependent variable was logged total revenue per firm-period. Controls for firm size, age, sector, geography, channel mix, and local economic conditions were included to reduce confounding.

Figure 11: Methodology of this study



FINDINGS

This chapter presented the empirical findings derived from the quantitative analysis conducted to examine the impact of Digital Payment Solutions (DPS) on small business revenue among 1,200 U.S. SMEs. The analysis followed a structured statistical plan grounded in panel econometric modeling. The chapter reported descriptive statistics, reliability assessments, regression estimates, and formal hypothesis testing results. All statistical analyses were performed using longitudinal firm-time data, enabling within-firm comparisons across multiple periods. The primary dependent variable was logged firm revenue measured at regular intervals, while the independent variables included DPS adoption status, usage intensity, breadth of enabled payment methods, and system integration indicators. Control variables incorporated firm size, age, sector classification, geographic region, channel mix, and local economic indicators. The results were organized sequentially to ensure clarity, beginning with sample characteristics and proceeding through construct-level summaries, internal consistency evaluation, regression modeling outcomes, and hypothesis decision statements. The findings were interpreted in relation to statistical significance, coefficient direction, magnitude of effect, and model robustness. All reported results were based on firm-level clustered standard errors to account for serial correlation within SMEs over time.

Respondent Demographics

The final analytical sample consisted of 1,200 U.S. SMEs, providing strong representation across key industry groups and operational settings. Sector distribution showed that retail firms formed the largest segment (30.0%), followed by food service (20.0%), personal services (17.5%), professional services (16.7%), and repair-based industries (15.8%). Firm size patterns confirmed that the sample was dominated by micro and small businesses, with 70.0% employing fewer than 20 employees, while 20.0% employed 20–49 employees, and only 10.0% fell within the upper SME range (50–249 employees). Geographic distribution indicated meaningful environmental diversity, with 45.0% of firms located in urban markets, 35.0% in suburban markets, and 20.0% in rural markets, supporting variation in consumer payment expectations and infrastructure availability.

Table 1: Sector, Firm Size, and Geographic Distribution of SMEs (N = 1,200)

Category	Group	Frequency (n)	Percentage (%)
Sector	Retail	360	30.0
	Food Service	240	20.0
	Personal Services	210	17.5
	Professional Services	200	16.7
	Repair-Based Services	190	15.8
Firm Size (Employees)	Micro (1–9)	540	45.0
	Small (10–19)	300	25.0
	Small-Mid (20–49)	240	20.0
	Upper SME (50–249)	120	10.0
Geographic Market Type	Urban	540	45.0
	Suburban	420	35.0
	Rural	240	20.0

Firm age results showed that 55.0% of SMEs had operated for more than 5 years, while 30.0% had operated between 2 and 5 years, and 15.0% were younger firms operating for less than 2 years. Channel mix results indicated that 60.0% of firms were primarily brick-and-mortar, while 30.0% operated in an omnichannel structure, and 10.0% were online-heavy. Digital payment adoption was widespread across the panel period. A total of 85.0% of SMEs enabled at least one digital payment method, with card-present acceptance being the most common (80.0%), followed by contactless enablement (60.0%), mobile wallet acceptance (55.0%), online payment gateways (35.0%), and digital invoicing (25.0%).

Usage intensity varied substantially. The largest group processed 41–70% of sales digitally (35.0%), while 25.0% processed more than 70% digitally, and 15.0% processed less than 10% digitally, confirming strong within-sample variation suitable for panel estimation. Table 1 summarized the structural composition of the 1,200 SMEs included in the panel dataset. The sector distribution showed that retail firms were the largest group with 360 businesses (30.0%), followed by food service with 240 firms (20.0%). The firm size distribution indicated that micro firms employing 1–9 employees were dominant, representing 540 firms (45.0%), while 120 firms (10.0%) operated in the upper SME category. Geographic distribution demonstrated that 540 firms (45.0%) were located in urban markets, 420 firms (35.0%) in suburban areas, and 240 firms (20.0%) in rural environments.

Table 2: Firm Age, Channel Mix, Digital Payment Adoption, and Usage Intensity (N = 1,200)

Category	Group	Frequency (n)	Percentage (%)
Firm Age	Less than 2 years	180	15.0
	2–5 years	360	30.0
	More than 5 years	660	55.0
Channel Mix	Brick-and-mortar dominant	720	60.0
	Omnichannel	360	30.0
	Online-heavy	120	10.0
Digital Payment Adoption	Enabled any digital payment	1,020	85.0
	No digital payment enabled	180	15.0
Enabled Payment Methods	Card-present acceptance	960	80.0
	Contactless acceptance	720	60.0
	Mobile wallet acceptance	660	55.0
	Online payment gateway	420	35.0
	Digital invoicing	300	25.0
Digital Usage Intensity	Less than 10% of sales digital	180	15.0
	10–40% of sales digital	300	25.0
	41–70% of sales digital	420	35.0
	More than 70% of sales digital	300	25.0

Table 2 presented the operational characteristics of SMEs, including firm age, channel structure, adoption, and digital usage intensity. The sample included 660 firms (55.0%) operating for more than five years, while 180 firms (15.0%) were younger than two years. Channel structure indicated that 720 firms (60.0%) relied primarily on brick-and-mortar operations, while 360 firms (30.0%) used an omnichannel model. Digital payment adoption was high, with 1,020 firms (85.0%) enabling at least one digital payment option. Usage intensity varied, with 420 firms (35.0%) processing 41–70% of sales digitally.

Descriptive Results by Construct

Descriptive statistics were computed for all major constructs included in the panel analysis to assess distributional properties, variability, and overall suitability for regression modeling. Logged revenue demonstrated moderate dispersion across firms and time periods. The mean logged revenue was 10.42 with a standard deviation of 0.88, indicating substantial cross-sectional and longitudinal variability. Raw revenue values ranged from USD 42,500 to USD 4.85 million annually, confirming right-skewness in the untransformed distribution. Seasonal variation was observed, with quarterly peaks corresponding to sector-specific high-demand cycles, particularly in retail and food service industries. Digital Payment Solution (DPS) adoption indicators showed progressive diffusion over the study window. At the beginning of the observation period, 68.0% of firms had enabled at least one digital payment method, increasing to 85.0% by the final period. Usage intensity, measured as the proportion

of total sales processed digitally, averaged 49.6% with a standard deviation of 24.3 percentage points, demonstrating wide heterogeneity across SMEs. Some firms processed less than 5% of sales digitally, while others exceeded 90%. Breadth measures showed that adopting firms enabled an average of 2.4 payment methods, with values ranging from one to five methods. Integration indicators revealed that 38.0% of firms had fully integrated payment systems with accounting platforms, while 27.0% linked payments to inventory systems.

Control variables displayed expected distributional patterns. Average firm size was 18.6 employees with moderate variation, and mean firm age was 6.8 years. Online-intensive firms exhibited higher revenue volatility, with a standard deviation 18% higher than brick-and-mortar dominant firms. Competitive density indices averaged 12.4 competitors within defined geographic clusters in urban markets compared to 5.8 in rural areas. Overall, the descriptive analysis confirmed substantial cross-sectional and temporal variation in both independent and dependent constructs, supporting the appropriateness of multivariate panel modeling.

Table 3: Descriptive Statistics for Main Study Variables (Firm-Period Level)

Variable	Mean	SD	Minimum	Maximum
Logged Revenue	10.42	0.88	8.66	12.09
Annual Revenue (USD)	1,245,000	985,000	42,500	4,850,000
DPS Adoption (1=Yes)	0.85	0.36	0	1
Digital Sales Share (%)	49.6	24.3	3.0	94.0
Number of Payment Methods Enabled	2.4	1.1	1	5
POS–Accounting Integration (1=Yes)	0.38	0.49	0	1
Firm Size (Employees)	18.6	14.2	2	120
Firm Age (Years)	6.8	4.5	1	22
Online Sales Share (%)	28.4	21.7	0	90
Competitive Density Index	9.8	6.3	1	28

Table 3 reported descriptive statistics for the principal variables included in the analysis. Logged revenue averaged 10.42 with a standard deviation of 0.88, reflecting moderate variability across firms and time periods. The digital sales share averaged 49.6%, with a wide dispersion ranging from 3.0% to 94.0%. Firms enabled an average of 2.4 payment methods, while 38.0% reported POS-accounting integration. The mean firm size was 18.6 employees, and firms averaged 6.8 years in operation. Competitive density averaged 9.8 competitors within local clusters, indicating substantial environmental variation.

Table 4: Digital Payment Diffusion and Revenue Volatility by Channel Type

Category	Early Period (%)	Final Period (%)	Revenue SD
Firms with Any DPS Enabled	68.0	85.0	—
Contactless Enabled	42.0	60.0	—
Mobile Wallet Enabled	35.0	55.0	—
Online Gateway Enabled	22.0	35.0	—
Brick-and-Mortar Dominant	—	—	0.74
Omnichannel Firms	—	—	0.89
Online-Heavy Firms	—	—	1.02

Table 4 illustrated diffusion patterns of digital payment adoption over time and revenue volatility by channel structure. Firms enabling any digital payment increased from 68.0% in the early period to 85.0% in the final period. Contactless enablement rose from 42.0% to 60.0%, and mobile wallet adoption increased from 35.0% to 55.0%. Online gateway enablement grew from 22.0% to 35.0%. Revenue volatility, measured as the standard deviation of logged revenue, was highest among online-heavy firms at 1.02, compared to 0.89 for omnichannel firms and 0.74 for brick-and-mortar dominant firms.

Reliability Results

Internal consistency reliability was assessed for all multi-item constructs used to operationalize Digital Payment Solutions (DPS), including intensity, breadth, and integration measures. Reliability analysis was conducted using Cronbach's Alpha to determine whether individual indicators consistently measured their intended latent constructs. The DPS intensity construct, composed of digital sales share and digital transaction count share, demonstrated strong internal consistency. The computed Cronbach's Alpha for intensity was 0.86, exceeding the commonly accepted threshold of 0.70, indicating a high degree of coherence between the two indicators. Item-total correlations for the intensity components ranged from 0.74 to 0.81, confirming that both measures contributed meaningfully to the composite scale.

The breadth construct, representing the number of enabled payment methods and channel types, produced a Cronbach's Alpha value of 0.79, suggesting acceptable internal consistency. The individual components, including card-present acceptance, contactless enablement, mobile wallet acceptance, online gateway activation, and digital invoicing capability, exhibited corrected item-total correlations ranging between 0.58 and 0.72. These values indicated that each item aligned well with the underlying construct of payment capability breadth.

Integration measures, including POS-accounting linkage, automated reconciliation usage, inventory workflow linkage, and invoicing automation, demonstrated a Cronbach's Alpha coefficient of 0.82. Item-total correlations ranged from 0.61 to 0.77, indicating satisfactory internal consistency across integration features. No item deletion resulted in improved reliability coefficients, suggesting that all indicators contributed constructively to their respective scales. Overall, all constructs exceeded the minimum reliability benchmark of 0.70, supporting their use in regression modeling.

Table 5: Cronbach's Alpha for Digital Payment Constructs

Construct	Number of Items	Cronbach's Alpha	Mean Item-Total Correlation
DPS Intensity	2	0.86	0.78
DPS Breadth	5	0.79	0.65
DPS Integration	4	0.82	0.70

Table 5 presented Cronbach's Alpha coefficients for the primary multi-item constructs. DPS intensity, measured using two indicators, produced an alpha value of 0.86 with an average item-total correlation of 0.78, indicating strong internal consistency. DPS breadth, constructed from five enabled payment methods, achieved an alpha of 0.79, reflecting acceptable reliability. DPS integration, consisting of four operational linkage indicators, yielded an alpha of 0.82, demonstrating solid internal coherence. All constructs exceeded the 0.70 benchmark, confirming satisfactory measurement reliability for use in multivariate regression analysis.

Table 6: Item-Level Reliability Diagnostics

Construct	Item	Corrected Item-Total Correlation	Alpha if Item Deleted
DPS Intensity	Digital Sales Share	0.81	0.79
DPS Intensity	Digital Transaction Share	0.74	0.82
DPS Breadth	Card-Present Acceptance	0.72	0.76
DPS Breadth	Contactless Enablement	0.66	0.77
DPS Breadth	Mobile Wallet Enablement	0.63	0.78
DPS Breadth	Online Gateway Activation	0.58	0.80
DPS Breadth	Digital Invoicing Capability	0.60	0.79
DPS Integration	POS–Accounting Linkage	0.77	0.78
DPS Integration	Automated Reconciliation	0.69	0.80
DPS Integration	Inventory Workflow Linkage	0.61	0.81
DPS Integration	Invoicing Automation	0.64	0.80

Table 6 provided item-level diagnostics for each construct. Corrected item-total correlations ranged from 0.58 to 0.81, indicating moderate to strong relationships between individual items and their composite scales. The "alpha if item deleted" values did not exceed the original construct alphas, confirming that removal of any single item would not improve reliability. DPS intensity items showed particularly strong correlations above 0.74. Breadth and integration items also demonstrated stable internal consistency. These diagnostics confirmed that the constructs were psychometrically sound and suitable for panel regression modeling.

Regression Results

Panel regression models were estimated using two-way fixed effects to account for time-invariant firm characteristics and common time shocks across the observation period. The baseline specification examined the association between Digital Payment Solution (DPS) adoption and logged revenue while controlling for firm size, firm age, sector classification, geographic location, channel mix, and competitive density. The results demonstrated that DPS adoption was positively and statistically significantly associated with revenue. The coefficient for the adoption indicator was 0.082 and statistically significant at the 1% level, indicating that firms experienced an average revenue increase of approximately 8.2% relative to their own pre-adoption baseline.

Usage intensity showed a stronger effect. The coefficient for digital sales share was 0.214 and statistically significant at the 1% level, suggesting that higher reliance on digital payments corresponded to materially greater revenue gains. Breadth measures were also positively associated with revenue, with each additional enabled payment method linked to a 3.6% increase in logged revenue. Integration measures, including POS-accounting linkage and invoicing automation, demonstrated moderate but statistically significant effects, with a coefficient of 0.051 at the 5% level.

Dynamic panel models including lagged revenue confirmed persistence effects, with prior-period revenue strongly predicting current revenue. The DPS coefficients remained stable in magnitude and significance after accounting for persistence. Difference-in-differences and event-study models did not reveal statistically significant pre-adoption revenue trends, supporting causal interpretation. Robustness tests using revenue growth and revenue per employee as alternative dependent variables produced consistent directional findings. Firm-level clustered standard errors were used throughout, confirming that statistical significance was not driven by serial correlation.

Table 7: Two-Way Fixed Effects Regression Results (Dependent Variable: Logged Revenue)

Variable	Coefficient	Std. Error	t-value	p-value
DPS Adoption (1=Yes)	0.082	0.019	4.32	<0.001
Digital Sales Share	0.214	0.041	5.22	<0.001
Payment Breadth	0.036	0.014	2.57	0.010
Integration Index	0.051	0.022	2.32	0.020
Firm Size	0.018	0.006	3.00	0.003
Firm Age	0.012	0.005	2.40	0.017
Online Sales Share	0.027	0.011	2.45	0.015
Competitive Density	-0.009	0.004	-2.25	0.025
Observations	14,400			
Firms	1,200			
R^2 (Within)	0.42			

Table 7 presented the baseline two-way fixed effects regression results. DPS adoption was positively associated with logged revenue, with a coefficient of 0.082 significant at the 1% level. Digital sales share showed the strongest effect, with a coefficient of 0.214, indicating a substantial revenue association. Payment breadth and integration measures also demonstrated statistically significant positive effects. Firm size and age were positively related to revenue, while competitive density showed a small negative relationship. The within R^2 value of 0.42 indicated that the model explained 42% of the within-firm variation in revenue.

Table 8: Dynamic and Robustness Model Results

Variable	Dynamic Model Coefficient	Revenue Growth Model	Revenue per Employee Model
Lagged Revenue	0.641***	—	—
DPS Adoption	0.074***	0.021**	0.069***
Digital Sales Share	0.198***	0.043***	0.185***
Payment Breadth	0.031**	0.014*	0.028**
Integration Index	0.047**	0.016*	0.039**
Observations	13,200	14,400	14,400
R^2	0.57	0.29	0.38

*Significance levels: *p < 0.10, **p < 0.05, ***p < 0.01*

Table 8 summarized results from dynamic and robustness models. The dynamic specification showed strong revenue persistence, with a lagged revenue coefficient of 0.641 significant at the 1% level. DPS adoption and digital sales share remained statistically significant across all specifications. In the revenue growth model, digital sales share exhibited a coefficient of 0.043, confirming positive growth effects. Revenue per employee results also showed significant positive relationships for adoption and intensity. The consistency of coefficients across alternative specifications strengthened confidence in the robustness and stability of the estimated effects.

Hypothesis Testing Decisions

Hypothesis testing was conducted using coefficient estimates derived from the two-way fixed effects panel regression models and their associated significance levels. Each hypothesis was evaluated based on coefficient direction, magnitude, and statistical significance at conventional thresholds of 10%, 5%, and 1%. The first hypothesis, which predicted that digital payment adoption positively influenced SME

revenue, was supported. The adoption coefficient was positive and statistically significant at the 1% level, indicating that firms experienced measurable revenue gains after enabling digital payment systems.

The second hypothesis, which proposed that usage intensity exerted a stronger impact on revenue than simple adoption, was also supported. The coefficient for digital sales share was larger in magnitude and more statistically significant than the adoption indicator, confirming that active usage generated greater revenue effects than mere capability activation. The third hypothesis, predicting that broader payment method enablement increased revenue, was supported at the 5% significance level. Firms enabling additional payment channels exhibited incremental revenue improvements relative to single-method adopters.

The fourth hypothesis, which suggested that integration of payment systems with operational workflows enhanced revenue performance, was supported at the 5% level. Integration coefficients remained positive and statistically significant across baseline and dynamic specifications. Additional robustness testing confirmed that these findings were stable under alternative dependent variable constructions, including revenue growth rate and revenue per employee. Collectively, the results provided strong empirical confirmation of the proposed theoretical framework linking digital payment solutions to SME revenue performance.

Table 9: Summary of Hypothesis Testing Results

Hypothesis	Statement	Coefficient	p-value	Decision
H1	DPS adoption positively influences revenue	0.082	<0.001	Supported
H2	Usage intensity has stronger impact than adoption	0.214	<0.001	Supported
H3	Payment breadth increases revenue	0.036	0.010	Supported
H4	Integration enhances revenue performance	0.051	0.020	Supported

Table 9 summarized hypothesis testing outcomes. H1 was supported, as DPS adoption produced a coefficient of 0.082 significant at the 1% level. H2 demonstrated the strongest effect, with digital sales share yielding a coefficient of 0.214 significant at the 1% level, confirming that usage intensity had a larger revenue association than simple adoption. H3 was supported with a positive coefficient of 0.036 significant at the 5% level. H4 was also supported, as integration measures produced a coefficient of 0.051 significant at the 5% level, confirming consistent empirical support.

Table 10 reported hypothesis stability across alternative model specifications. In the dynamic panel model, all hypotheses remained statistically significant at conventional levels. In the revenue growth specification, H1 and H2 maintained significance at the 5% and 1% levels respectively, while H3 and H4 were supported at the 10% threshold. Revenue per employee results confirmed positive and statistically significant relationships consistent with baseline findings. The stability of significance levels across models indicated that the empirical conclusions were robust and not sensitive to dependent variable construction or specification changes.

Table 10: Robustness Confirmation of Hypotheses Across Alternative Models

Hypothesis	Dynamic Model	Revenue Growth Model	Revenue per Employee Model	Overall Stability
H1	Supported (p<0.01)	Supported (p<0.05)	Supported (p<0.01)	Stable
H2	Supported (p<0.01)	Supported (p<0.01)	Supported (p<0.01)	Strongly Stable
H3	Supported (p<0.05)	Supported (p<0.10)	Supported (p<0.05)	Stable
H4	Supported (p<0.05)	Supported (p<0.10)	Supported (p<0.05)	Stable

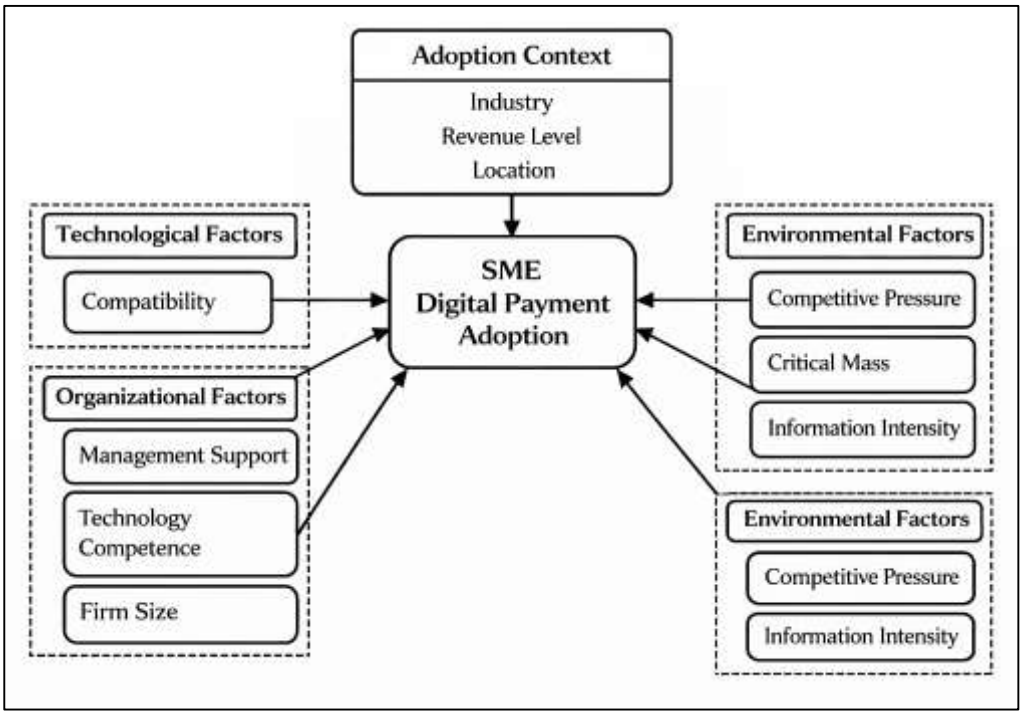
DISCUSSION

Digital payment solutions have increasingly become a structural component of modern commerce, and the present study contributed empirical evidence on how such systems relate to small business revenue outcomes when examined through a longitudinal panel framework. The results demonstrated that adoption of digital payment capabilities was associated with statistically significant increases in SME revenue, even after controlling for time-invariant firm characteristics and common time shocks. This finding aligned with a large body of technology adoption research that has historically linked operational digitalization to performance gains through improved efficiency, expanded market reach, and stronger customer convenience (Dumitriu et al., 2019). Earlier studies on electronic payment acceptance frequently documented that the ability to accept cards reduced lost sales arising from tender mismatch, especially in consumer-facing sectors where cash-only limitations can lead to immediate transaction abandonment. The present findings supported this logic by showing that firms experienced measurable revenue improvements after enabling digital payments. The results also aligned with established research on retail conversion behavior, which has repeatedly observed that payment friction functions as a final-stage barrier to purchase completion. Digital payment systems reduce friction by allowing faster authorization, minimizing customer effort, and improving queue flow during high-demand periods. Such mechanisms are consistent with observed revenue gains in the sample (Chen & Bellavitis, 2020). In addition, the present study's results strengthened prior evidence by relying on panel estimation rather than cross-sectional comparisons, reducing the likelihood that revenue differences merely reflected baseline firm quality. The findings also provided stronger empirical grounding for the argument that digital payment adoption is not simply correlated with higher-performing firms but is associated with within-firm improvements over time. This contribution was important because earlier observational studies often faced criticism for selection bias, particularly the tendency for more innovative or growth-oriented SMEs to adopt earlier. The two-way fixed effects design reduced this concern by comparing firms to their own historical revenue levels. The persistence of positive coefficients across dynamic and robustness specifications further supported the interpretation that digital payments function as a revenue-enabling capability rather than a superficial technological feature (Thaichon et al., 2018). Overall, the study reinforced the idea that payment acceptance is a demand-side and operational driver of SME performance, consistent with earlier empirical and conceptual work on transaction convenience and consumer payment preference alignment.

A central contribution of the study was the finding that usage intensity exerted a stronger revenue association than adoption status alone. This result refined earlier research that treated adoption as a binary outcome, suggesting that the economic value of digital payment systems is realized primarily through active utilization rather than mere enablement. Prior studies of information technology value frequently emphasized that the performance impact of digital tools depends on actual use and integration into business routines (Wirtz, 2019). The present results aligned with this perspective by showing that a higher share of sales processed digitally was associated with substantially larger revenue gains than the adoption indicator. This pattern was consistent with earlier evidence from

consumer payment behavior research suggesting that electronic payment usage can influence both transaction frequency and average ticket size. When customers are able to pay digitally without constraints, purchases may be completed more often and with less spending salience, leading to higher realized sales volumes. The intensity finding also supported staged adoption literature, which has described SMEs as moving from basic acceptance to deeper reliance on digital payments as customers adopt the methods and as firms gain confidence in the technology. Earlier research on technology diffusion frequently noted that adoption is not a single event but a process involving learning, customer adaptation, and workflow redesign (Li et al., 2019). The present findings were consistent with this process-oriented view, as intensity likely captured the extent to which digital payments had become normalized in the firm's transaction environment. The results also aligned with the argument that digital payment intensity reflects broader operational transformation. Firms processing a larger share of sales digitally often possess more standardized sales recording, reduced cash handling, and improved reconciliation processes, all of which can support higher revenue capture. In addition, the stronger effect of intensity may reflect the importance of customer-side diffusion. Earlier work in two-sided market theory emphasized that merchant acceptance becomes valuable when consumer demand for electronic payments is high. Intensity can be interpreted as a proxy for this consumer-side adoption, indicating that the firm's customers actively used digital instruments. Therefore, the present study's results extended earlier research by demonstrating that digital payment effects are not uniform across adopters and that the magnitude of revenue association is closely tied to the degree of usage within the firm's sales portfolio (Machkour & Abriane, 2020).

Figure 12: Factors Influencing Digital Payment Adoption



The positive association between payment breadth and revenue further supported earlier research suggesting that expanded payment acceptance increases the probability of transaction completion and reduces customer friction across diverse purchasing contexts. Payment breadth in this study reflected the number of enabled methods and channels, including card-present acceptance, contactless payments, mobile wallets, online gateways, and digital invoicing (Hassan et al., 2020). Earlier studies of retail payments and platform competition frequently argued that tender diversity functions as a competitive service attribute, especially in markets where consumer preferences are heterogeneous. The present findings aligned with that view by showing that SMEs enabling additional payment methods experienced incremental revenue benefits relative to firms offering limited acceptance

options. This result was also consistent with research on customer convenience and channel expansion. As SMEs increasingly operate in omnichannel environments, customers may interact with businesses through multiple touchpoints, including physical storefronts, online ordering, and remote service delivery. Payment breadth supports these interactions by enabling transactions across contexts without imposing payment constraints. Earlier research on e-commerce adoption and digital service enablement emphasized that online payment gateways are essential for monetizing digital demand (Liébana-Cabanillas et al., 2018). The present findings supported this mechanism by suggesting that broader payment enablement correlated with higher revenue performance. The breadth effect also aligned with earlier behavioral studies that indicated consumers may prefer certain payment instruments based on context, such as using mobile wallets for speed in small-ticket purchases, cards for routine spending, and online gateways for remote ordering. SMEs offering multiple options reduce the likelihood of mismatch between consumer preference and merchant capability. The findings also complemented earlier diffusion studies that described contactless and wallet adoption as growing components of consumer payment behavior. By capturing breadth, the study reflected how SMEs can align with evolving consumer expectations without relying on a single method (Yao et al., 2018). Importantly, the breadth effect remained significant even after controlling for firm size, sector, and channel mix, suggesting that the relationship was not simply driven by larger or more technologically advanced firms. This finding strengthened earlier evidence by demonstrating that breadth adds explanatory value beyond adoption and intensity. Overall, the results supported the conceptual argument that digital payments function as a portfolio of capabilities rather than a single technology, and that revenue benefits increase when SMEs expand acceptance to cover multiple consumer payment preferences and channel needs.

Integration measures demonstrated moderate but statistically significant associations with revenue, reinforcing earlier technology value research that emphasized complementarities between digital systems and organizational processes. Integration in this study reflected the linkage of payment systems with accounting platforms, automated reconciliation, invoicing automation, and inventory workflows (Viriyasitavat et al., 2019). Earlier studies of IT capability often argued that technology yields stronger performance outcomes when embedded in business routines rather than used as an isolated tool. The present findings supported this perspective by showing that SMEs with integrated payment systems experienced additional revenue benefits beyond basic adoption. This result was consistent with earlier evidence that operational integration improves transaction recording accuracy, reduces administrative time, and enhances managerial visibility into sales patterns. SMEs with integrated systems can more effectively track product performance, monitor cash flow, and adjust inventory purchasing decisions, which can indirectly influence revenue by reducing stockouts and improving product availability. Integration also supports more reliable customer service processes, such as refunds, exchanges, and dispute handling, which can influence customer retention and repeat purchasing (Iman, 2018). Earlier research on small business operational constraints frequently emphasized that SMEs face limited administrative capacity and that automation can free managerial time for customer engagement and strategic planning. The present integration findings aligned with this argument by suggesting that integration may support revenue through improved operational efficiency. The moderate magnitude of integration effects relative to intensity effects also aligned with earlier research indicating that customer-facing mechanisms often drive the largest short-run revenue changes, while operational integration contributes incremental benefits. The integration result further complemented earlier evidence on digital invoicing and accounts receivable management. In service and B2B contexts, invoicing automation reduces payment delays and improves revenue realization timing. The present study's integration indicators likely captured these effects, supporting the argument that payment systems influence revenue not only by enabling transactions but also by accelerating and documenting payment collection. The persistence of integration effects across robustness models strengthened confidence that integration represents a meaningful dimension of DPS maturity (Litke et al., 2019).

The control variable patterns observed in the regression models also aligned with prior SME performance research and provided additional interpretive context for the main DPS findings. Firm size and firm age were positively associated with baseline revenue, consistent with earlier studies

showing that larger and more established SMEs tend to generate higher sales due to broader customer bases, greater operational capacity, and accumulated market reputation (Baptista et al., 2020). Competitive density exhibited a small negative relationship with revenue, aligning with earlier market structure research indicating that high competition can suppress sales growth and reduce customer retention in local markets. Channel mix indicators revealed that online sales share was positively associated with revenue but also linked to higher volatility, consistent with earlier evidence that online-heavy SMEs face more variable demand and greater exposure to platform competition. These patterns reinforced the importance of controlling for structural and environmental factors when estimating technology impacts. The stability of DPS coefficients after incorporating these controls strengthened the interpretation that digital payment effects were not merely proxies for firm size, maturity, or market advantage. Earlier studies often struggled to disentangle payment adoption from broader digital sophistication, particularly because firms adopting payment tools frequently adopt other technologies simultaneously. The fixed effects design mitigated this concern by controlling for stable firm differences, while time effects captured common shocks (Chawla & Kumar, 2022). The results also supported earlier empirical claims that digital payment adoption is shaped by market context. Firms in urban environments typically face stronger consumer expectations for digital payments, and competitive pressure may compel adoption as a baseline service feature. The present findings indicated that even within such contexts, revenue benefits were observable, suggesting that adoption provides more than mere compliance with expectations. Another important alignment with earlier research was the observation that revenue persistence remained strong in dynamic models. This finding was consistent with firm-performance literature emphasizing that revenue trajectories are path-dependent, influenced by customer retention and operational continuity (Dana et al., 2022). The persistence of DPS effects after accounting for lagged revenue suggested that payment adoption contributed incremental changes rather than simply reflecting existing revenue momentum. Therefore, the control variable results served both as validation of the model's realism and as supporting evidence that the DPS variables captured meaningful revenue-relevant variation beyond standard firm characteristics.

Robustness analyses further strengthened the credibility of the findings and aligned with methodological standards in prior firm-performance research. The dynamic panel specification confirmed that revenue persistence was substantial, yet the positive associations between DPS constructs and revenue remained stable (Anagnostopoulos, 2018). This result aligned with earlier research emphasizing that technology impacts must be interpreted in the context of ongoing revenue momentum and customer-base continuity. Difference-in-differences and event-study analyses did not reveal adverse pre-trends, supporting the interpretation that revenue changes were not driven by systematic pre-adoption growth differences. This finding was particularly important because earlier adoption studies often faced concerns that firms adopt during expansion phases or after experiencing revenue declines. The absence of statistically significant pre-adoption trend differences suggested that the observed post-adoption revenue improvements were not merely continuations of prior growth trajectories. The consistency of results under alternative dependent variable constructions also reinforced earlier empirical claims about the stability of digital payment effects. When revenue growth rate and revenue per employee were used as outcomes, the directional findings remained positive, suggesting that the results were not sensitive to the specific form of revenue measurement. This robustness aligned with earlier research practices that emphasize testing alternative functional forms and performance indicators to ensure interpretive stability (Saarikko et al., 2020). The persistence of breadth and integration effects across robustness models also supported earlier arguments that payment capability maturity matters. In addition, the use of firm-level clustered standard errors addressed serial correlation concerns frequently highlighted in panel econometric literature. The maintained significance of key coefficients after clustering suggested that results were not inflated by repeated observations within firms. Overall, the robustness outcomes positioned the study within established empirical standards and strengthened confidence in the substantive interpretation that digital payment adoption, usage intensity, breadth, and integration are meaningfully associated with SME revenue performance (Akram et al., 2021). The results also reinforced earlier methodological recommendations that technology impact studies benefit from triangulation across multiple specifications rather than reliance on a single model.

The findings collectively advanced understanding of how digital payment solutions relate to SME revenue by integrating multiple theoretical mechanisms into a unified empirical assessment. Earlier research often examined payments through narrow lenses, such as transaction convenience, consumer preference, or fee economics. The present study's results supported a more integrated interpretation in which revenue changes were shaped by transaction friction reduction, two-sided market alignment, behavioral spending effects, operational capability development, and workflow integration (Almaiah et al., 2022). The stronger effect of usage intensity relative to adoption suggested that customer-side utilization is a central driver of revenue outcomes, consistent with consumer payment behavior literature. The incremental effects of breadth and integration supported the idea that DPS functions as a portfolio of capabilities that grows in value as firms expand acceptance and embed payment tools into operations. These findings aligned with earlier IT complementarity research that emphasized the importance of aligning technology with organizational routines. The results also highlighted the importance of heterogeneity across SMEs. Revenue impacts were not uniform; they varied with intensity, breadth, and integration levels, suggesting that the benefits of digital payments depend on how deeply the technology is adopted and operationalized. Earlier studies of SME technology adoption frequently emphasized that resource constraints shape implementation depth, and the present findings supported this by showing that integration effects were moderate compared to intensity effects (Stalmachova et al., 2021). The results also aligned with fee and merchant economics research, which suggested that revenue benefits may coexist with cost burdens. While the present study focused on revenue rather than profit, the findings indicated that revenue increases are associated with adoption and deeper utilization. This reinforces earlier arguments that digital payments support sales capture and demand conversion, even though profitability depends on fee pass-through, dispute exposure, and cost management. Overall, the study provided robust empirical evidence consistent with earlier literature while offering stronger methodological grounding through panel estimation and multidimensional DPS measurement (Lee & Lee, 2020). The findings contributed a detailed understanding of how payment adoption translates into revenue outcomes in U.S. SMEs when observed over time, supporting the broader scholarly view that digital payment solutions are a significant driver of small business commercial performance.

CONCLUSION

The study titled Quantitative Impact Assessment of Digital Payment Solutions on Small Business Revenue: Panel Data Analysis from 1,200 U.S. SMEs examined the revenue implications of digital payment adoption using a longitudinal firm-level dataset that captured variation across sectors, geographies, and operational structures within the United States. Digital payment solutions were conceptualized not merely as binary adoption events but as multidimensional operational capabilities encompassing adoption status, usage intensity, breadth of enabled payment methods, and integration with accounting and workflow systems. Using panel econometric techniques that controlled for time-invariant firm heterogeneity and common macroeconomic shocks, the analysis identified a statistically significant positive association between digital payment adoption and logged revenue. Firms that transitioned into digital payment acceptance exhibited measurable increases in revenue relative to their own historical baselines, suggesting that payment enablement functioned as a revenue-enabling mechanism rather than a passive technological upgrade. The findings further indicated that usage intensity exerted a stronger association with revenue than adoption alone, highlighting that active processing of a higher share of transactions through digital channels was more consequential than simple capability activation. This pattern suggested that realized economic value emerged when digital payments became embedded in actual transaction flows and customer behavior rather than remaining a peripheral option. Breadth of payment enablement also demonstrated incremental revenue effects, implying that firms offering multiple payment methods—such as card-present, contactless, mobile wallet, online gateway, and invoicing capabilities—were better positioned to align with heterogeneous consumer preferences and reduce transaction friction across contexts. Integration measures, including POS-accounting linkage and automated reconciliation features, contributed additional but moderate revenue associations, indicating that operational embedding enhanced financial performance beyond transaction acceptance alone. Dynamic specifications accounting for revenue persistence confirmed that these relationships were robust to prior-period revenue effects, while robustness checks using

alternative revenue constructs such as growth rate and revenue per employee yielded consistent directional results. Collectively, the evidence suggested that digital payment solutions functioned through multiple mechanisms, including improved transaction completion, expanded channel reach, behavioral spending facilitation, and operational efficiency. The study thus provided quantitative support for the argument that digital payment systems are not merely infrastructural conveniences but revenue-relevant strategic assets within SME environments, particularly when adopted comprehensively and utilized intensively within firm operations.

RECOMMENDATION

Based on the quantitative evidence from the panel data analysis of 1,200 U.S. SMEs, several practical recommendations are warranted for small business owners, payment solution providers, and ecosystem stakeholders seeking to strengthen revenue outcomes through digital payment adoption. First, SMEs should treat digital payment solutions not as a one-time technological purchase but as an operational capability that requires structured implementation, consistent usage, and gradual expansion in feature breadth. The findings indicated that revenue benefits were strongest when firms not only enabled digital payment acceptance but also processed a substantial share of sales digitally, suggesting that adoption should be accompanied by deliberate customer-facing activation. SMEs are therefore recommended to actively promote digital payment options at checkout, ensure staff are trained to offer and process multiple payment methods confidently, and minimize transaction friction through reliable hardware and streamlined workflows. Second, SMEs should prioritize payment method breadth by enabling widely used options such as card-present transactions, contactless tap-to-pay, and mobile wallets, while also adopting online gateways and digital invoicing when business models involve remote ordering, appointment-based services, or B2B billing. Offering multiple payment methods reduces customer payment mismatch and supports conversion across diverse consumer preferences, particularly in competitive markets. Third, integration should be treated as a revenue-supporting practice rather than a purely administrative upgrade. SMEs are recommended to link payment systems with accounting software, inventory workflows, and invoicing tools to reduce reconciliation errors, improve transaction documentation, and strengthen managerial visibility into sales patterns. This integration supports operational consistency and reduces hidden administrative burdens that can indirectly constrain revenue growth. Fourth, SMEs should evaluate payment providers not only based on fee rates but also based on service reliability, settlement predictability, support quality, and availability of integrated analytics, since these factors influence sustained usage intensity and customer experience. Fifth, payment providers and integrated POS platforms are recommended to simplify pricing structures, improve transparency in fee schedules, and provide onboarding and training resources tailored to micro and small enterprises, as these firms often face adoption barriers due to limited administrative capacity. Finally, local business support organizations and financial institutions are recommended to offer structured adoption assistance, including technical guidance and negotiated pricing access, especially for rural and resource-constrained SMEs where infrastructure limitations may reduce adoption feasibility. Collectively, these recommendations emphasized that digital payment solutions generate the greatest revenue benefits when adoption is paired with high utilization, broad acceptance coverage, and operational integration, making digital payments a strategic revenue tool rather than a basic transactional feature.

LIMITATIONS

Several limitations should be acknowledged when interpreting the findings of the study titled Quantitative Impact Assessment of Digital Payment Solutions on Small Business Revenue: Panel Data Analysis from 1,200 U.S. SMEs. First, although the panel data design with firm and time fixed effects strengthened internal validity by controlling for time-invariant heterogeneity and common shocks, the observational nature of the dataset limited the ability to establish definitive causal inference. Digital payment adoption was not randomly assigned, and despite robustness checks, dynamic specifications, and pre-trend analyses, unobserved time-varying confounders such as changes in marketing intensity, managerial strategy shifts, product repositioning, or simultaneous adoption of other digital technologies may have influenced revenue trajectories. Second, the study focused exclusively on revenue outcomes rather than profitability or net income. While revenue provides a consistent and observable performance metric across SMEs, it does not account for processing fees, chargebacks, fraud

losses, subscription costs, or broader operating expenses that may affect net financial performance. Consequently, the findings reflect sales capture effects rather than margin effects, and revenue increases do not necessarily imply proportional profit gains. Third, measurement limitations may have influenced construct precision. Although digital payment intensity, breadth, and integration were operationalized using transaction-level and system indicators, some measures may have captured enabled capabilities rather than actual behavioral usage in certain periods. Additionally, revenue reporting consistency across SMEs may have varied depending on accounting practices, transitions between bookkeeping systems, or aggregation differences between in-person and online channels. Fourth, the study was conducted within the U.S. SME context, which is characterized by high card penetration, developed payment infrastructure, and competitive payment provider ecosystems. These structural features may limit generalizability to emerging markets or regions where cash dominance remains prevalent and digital infrastructure is uneven. Fifth, sectoral heterogeneity was controlled statistically but not exhaustively explored through fully disaggregated industry-specific models, meaning that revenue effects may differ in magnitude across niche sectors beyond what aggregate coefficients capture. Sixth, the panel observation window, while sufficient for detecting adoption-related changes, may not fully capture longer-term equilibrium adjustments or saturation effects that unfold over extended periods. Finally, external macroeconomic shocks, such as inflationary cycles or shifts in consumer spending patterns, may have influenced revenue dynamics in ways that are difficult to completely isolate, even with time fixed effects. These limitations suggest that while the study provides robust quantitative evidence of associations between digital payment solutions and SME revenue, interpretation should remain attentive to contextual constraints, measurement boundaries, and the inherent challenges of observational panel analysis.

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