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Digital payment ecosystems and financial inclusion: Comparative analysis of UPI in India and PIX in Brazil

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Abstract

This article examines how digital payment systems, specifically India's Unified Payments Interface (UPI) and Brazil's PIX, contribute to financial inclusion in emerging markets. Through a mixed-methods approach combining transaction data analysis, user surveys, and stakeholder interviews, the article investigates how these real-time payment infrastructures compare to traditional banking systems in terms of accessibility, transaction costs, and user experience for underserved populations. The comparative analysis reveals distinct implementation strategies and adoption patterns while highlighting common success factors and challenges. Findings indicate that these digital payment ecosystems significantly reduce barriers to financial services, particularly for rural and lower-income segments, while stimulating micro-entrepreneurship and formal economic participation. This article provides valuable insights for policymakers and financial institutions seeking to leverage digital payment technologies to enhance financial inclusion and economic development in similar emerging market contexts.

Keywords: Financial inclusion; Digital payment systems; Emerging markets; Underbanked populations; Economic development

1. Introduction

1.1. Financial Inclusion Challenges in Emerging Markets

Financial inclusion remains a significant challenge in emerging markets, with substantial portions of the population lacking access to formal banking services. Technological innovations offer promising pathways to address these persistent barriers [1]. Digital payment systems have emerged as transformative solutions that can bypass traditional financial infrastructure limitations.

1.2. Digital Payment Systems as Solutions

This study focuses on two notable real-time payment systems: India's Unified Payments Interface (UPI) and Brazil's PIX, which represent innovative approaches to financial inclusion in distinct emerging market contexts.

1.3. UPI and PIX as Case Studies

These digital payment ecosystems merit investigation as they have been rapidly adopted across diverse demographic segments, including previously underserved populations. UPI in India has revolutionized micropayments and person-to-person transfers, while PIX in Brazil has dramatically reduced transaction costs and processing times.

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1.4. Research Questions and Significance

This research addresses several key questions: How do UPI and PIX compare to traditional banking in expanding financial access? What implementation strategies have proven most effective? How do these systems impact user behavior and economic participation among underbanked populations? The significance of this study lies in its comparative approach, which identifies transferable lessons for policymakers and financial institutions in other emerging markets seeking to enhance financial inclusion.

1.5. Thesis Statement

The research contends that digital payment systems like UPI and PIX have transformed financial inclusion in emerging markets by reducing barriers to entry, lowering transaction costs, and expanding access to financial services for underserved populations. By analyzing these case studies, this paper contributes to the growing body of literature on financial technology as a catalyst for inclusive economic development [2].

2. Literature Review: Digital Payment Systems and Financial Inclusion

2.1. Theoretical Frameworks for Financial Inclusion

The literature on financial inclusion has evolved significantly, with diverse theoretical frameworks emerging to conceptualize the relationship between technological innovation and financial access. Recent bibliometric analysis has identified key theoretical frameworks for understanding financial inclusion in the context of emerging technologies [1]. The Situation-Actor-Process–Learning-Action-Performance (SAP-LAP) framework has been particularly influential in analyzing the multidimensional nature of financial inclusion, offering a structured approach to understand the interactions between stakeholders, processes, and outcomes [4]. This framework provides valuable insights into the systemic barriers that prevent full financial participation and how digital solutions might address these challenges.

Table 1 Theoretical Frameworks for Understanding Financial Inclusion [1, 4]

Framework	Key Concepts	Application to Digital Payments
SAP-LAP	Situation-Actor-Process–Learning-Action-Performance	Analyzing multidimensional nature of financial inclusion
Bibliometric Analysis	Citation patterns and research clusters	Identifying emerging topics in financial technology
Interpretive Ranking Process (IRP)	Systematic evaluation of relative factor importance	Prioritizing inclusion factors across contexts
Technology Acceptance Model	Perceived usefulness and ease of use	Understanding adoption barriers in different contexts

2.2. Previous Studies on Digital Payment Systems

Prior research has examined various digital payment innovations across emerging markets, with significant attention to policy implications and implementation challenges [2]. Studies on rural adoption of financial technologies have highlighted the critical role of technology acceptance factors, socioeconomic variables, and infrastructure limitations [3]. The literature reveals that successful digital payment systems must address not only technological and financial barriers but also behavioral, cultural, and educational challenges that affect adoption rates among underserved populations.

2.3. Contextual Factors Influencing Adoption

Research indicates that contextual factors significantly influence the adoption and impact of digital payment systems. Mixed-methods investigations have identified that beyond technological infrastructure, factors such as digital literacy, perceived trust, and local economic conditions play decisive roles in determining adoption patterns [3]. The literature suggests that successful implementation requires customized approaches that account for regional variations in these contextual factors rather than one-size-fits-all solutions.

2.4. Research Gap: Comparative Analysis

Despite growing interest in digital payment systems, there remains a notable gap in comparative analyses of different real-time payment platforms operating across distinct regional and economic contexts. While individual case studies of systems like UPI and PIX exist, systematic cross-national comparisons that identify transferable success factors and implementation lessons are scarce. This gap limits the ability of policymakers and financial institutions to leverage insights from existing systems when designing new digital payment infrastructures.

2.5. Analytical Framework for This Study

This study proposes an analytical framework for evaluating UPI and PIX impacts on accessibility, cost, and user adoption, integrating insights from existing financial inclusion literature. The framework draws upon the Interpretive Ranking Process (IRP) methodology [4] to systematically evaluate the relative importance of different factors in promoting financial inclusion through digital payment systems. This approach enables a structured comparison that accounts for both technological capabilities and contextual implementation factors across the Indian and Brazilian cases.

3. Methodology

3.1. Research Design

This study employs a mixed-methods approach to comprehensively evaluate the impact of UPI and PIX on financial inclusion. Following the convergent parallel design outlined by John W. Creswell and J. David Creswell [5], the research collects both quantitative and qualitative data concurrently, analyzes them separately, and then integrates the findings to develop a more complete understanding of the research problem. This approach allows for triangulation of evidence across different data sources, enhancing the validity and reliability of the findings while capturing both the breadth and depth of digital payment systems' impact on financial inclusion.

Table 2 Mixed Methods Research Approaches for Digital Payment Studies [3, 5, 6]

Research Component	Quantitative Methods	Qualitative Methods
Data Collection	Transaction data, user surveys	Stakeholder interviews, focus groups
Sampling Strategy	Probabilistic sampling across demographics	Purposive sampling of key informants
Analysis Techniques	Statistical analysis of adoption patterns	Thematic content analysis
Integration Approach	Convergent parallel design	Sequential explanatory process
Validation Method	Triangulation of multiple data sources	Member checking and expert review

3.2. Data Collection Methods

The research utilizes multiple data collection strategies to capture a comprehensive picture of UPI and PIX implementation and impacts. Quantitative transaction data from both payment systems provides insights into adoption rates, usage patterns, and transaction characteristics across different user segments. This is supplemented with structured user surveys designed to assess accessibility, usability, and perceived benefits. Additionally, in-depth qualitative interviews with key stakeholders—including system administrators, financial institutions, merchants, and end-users—offer contextual understanding of implementation challenges and success factors. This multi-method approach aligns with Hassan's [6] recommendation for integrating diverse data sources in mixed-methods financial inclusion research.

3.3. Sampling Strategy

A stratified sampling approach ensures representation of underserved populations, including rural communities, low-income groups, and those previously excluded from traditional banking. For the quantitative component, probabilistic sampling is employed to select survey respondents across different demographic segments, geographical locations, and socioeconomic strata in both India and Brazil. For the qualitative interviews, purposive sampling identifies key informants with specialized knowledge about system implementation and impact. This nested sampling approach, as described by Creswell and Creswell [5], allows for both breadth of coverage and depth of insight while maintaining methodological rigor.

3.4. Analytical Techniques

The analytical framework employs both sequential and concurrent data analysis techniques. Statistical analysis of transaction patterns examines adoption trends, usage frequency, transaction values, and geographical distribution. Survey data is analyzed using descriptive and inferential statistics to identify patterns and relationships between variables. Qualitative data from interviews undergoes thematic content analysis to identify recurring themes, implementation challenges, and perceived impacts. Following Hassan's [6] integrated analysis approach for mixed methods research, the findings from these separate analyses are then synthesized to identify convergent and divergent results, enabling a more nuanced understanding of how contextual factors shape the effectiveness of digital payment systems in promoting financial inclusion.

3.5. Research Limitations and Ethical Considerations

The study acknowledges several methodological limitations. Access to comprehensive transaction data is constrained by privacy regulations and corporate policies, necessitating the use of aggregated datasets that may obscure some user-level patterns. Selection bias may affect the qualitative component, as interview participants with extreme positive or negative experiences may be more willing to participate. Cross-national comparison introduces challenges related to contextual equivalence and measurement invariance. Ethical considerations include informed consent for all research participants, data anonymization to protect privacy, secure handling of sensitive financial information, and transparency about research objectives. These ethical protocols follow the guidelines established by Creswell and Creswell [5] for conducting responsible social science research involving potentially vulnerable populations.

4. Case Study: UPI in India

4.1. Evolution and Implementation

This section examines the development trajectory of UPI, from conception to nationwide implementation. The Unified Payments Interface emerged from India's strategic vision to create an inclusive digital payment ecosystem that could leapfrog traditional financial infrastructure constraints [7]. Developed by the National Payments Corporation of India (NPCI), UPI was conceptualized as an interoperable payment system that could seamlessly connect multiple bank accounts into a single mobile application. The implementation process involved phased rollout, beginning with select banks and gradually expanding to include a wider ecosystem of financial institutions, merchants, and service providers. As documented by Sharma [8], this evolutionary approach allowed for iterative improvements based on user feedback and operational experience, contributing to the system's robustness and adaptability to diverse user needs.

4.2. Technical Architecture and Features

Analysis of UPI's technological infrastructure, security protocols, and user interface design that enable widespread adoption. The technical architecture of UPI is built upon a multi-layered framework that facilitates real-time fund transfers between different bank accounts through a mobile platform [7]. The system employs advanced security measures, including two-factor authentication, encrypted data transmission, and virtual payment addressing to protect user information while simplifying the transaction process. A distinctive feature of UPI is its interoperability across banks, payment service providers, and merchant platforms, eliminating the need for multiple applications or payment instruments. The user interface is designed for simplicity and accessibility, with options for voice commands, regional language support, and offline transaction capabilities that address the diverse needs of India's population [8].

4.3. Adoption Patterns

Examination of demographic adoption trends across urban and rural settings, income levels, and previous banking status. The adoption of UPI has followed distinct patterns across different demographic segments and geographical regions in India. Initial adoption was concentrated in urban areas among digitally literate, middle-to-high income users with existing banking relationships. However, the system has progressively expanded into semi-urban and rural areas, particularly as smartphone penetration increased and telecom infrastructure improved [7]. Adoption patterns reveal interesting variations across age groups, occupational categories, and educational backgrounds. The NPCI [7] notes that adoption among previously unbanked or underbanked populations has been facilitated by simplified onboarding processes, minimal documentation requirements, and zero-cost person-to-person transfers. Sharma [8] highlights how merchant adoption has created network effects that further accelerate user adoption across diverse socioeconomic segments.

4.4. Impact on Financial Inclusion

Assessment of UPI's contribution to expanding financial services access, reducing cash dependence, and enabling micro-entrepreneurship in previously underserved communities. UPI has significantly impacted financial inclusion in India by lowering barriers to formal financial services. The system has enabled first-time access to digital financial transactions for many previously excluded populations, particularly in areas with limited banking infrastructure [7]. By reducing the necessity for physical branch visits and simplifying account management, UPI has expanded the practical utility of bank accounts that were earlier opened but remained dormant. The platform has fostered micro-entrepreneurship by enabling small vendors and service providers to accept digital payments without the prohibitive costs of traditional point-of-sale systems. Sharma [8] documents how this has created new income-generating opportunities, particularly for women entrepreneurs and rural businesses that can now access wider customer bases. The reduction in cash dependence has additional benefits for users, including improved transaction records for building credit histories and reduced vulnerability to theft or loss.

4.5. Sectoral Impacts

Analysis of UPI's influence across retail, transportation, healthcare, and education sectors, with attention to formalization of previously cash-based transactions. The impact of UPI extends beyond general financial inclusion to transform operations across multiple economic sectors. In retail, UPI has enabled smaller merchants to compete more effectively by offering digital payment options, while reducing cash handling costs and security concerns [7]. The transportation sector has benefited from simplified fare collection, reduced leakage, and improved transparency in both public and private services. In healthcare, UPI has facilitated appointment scheduling, bill payments, and insurance claims processing, particularly beneficial in emergency situations and for patients from remote areas. The education sector has seen improved fee collection efficiency, reduced administrative burdens, and new opportunities for distance learning payment models [8]. A common thread across these sectors is the formalization of previously cash-based transactions, which enhances record-keeping, reduces corruption opportunities, and increases tax compliance while providing users with transaction histories that can support future financial service applications.

5. Case Study: PIX in Brazil

5.1. Development and Implementation Context

Investigation of PIX's development process and implementation strategy within Brazil's existing financial ecosystem. PIX emerged from Brazil's central bank's strategic initiative to modernize the country's payment infrastructure and address persistent financial inclusion challenges [9]. Developed and implemented by Banco Central do Brasil, PIX was conceptualized as part of a broader financial system modernization agenda aimed at fostering competition, reducing transaction costs, and expanding financial services access. Unlike many payment innovations driven by private sector entities, PIX was developed as a public infrastructure project with mandatory participation requirements for larger financial institutions. Amboage et al. [10] note that this regulatory-driven approach resulted in a rapid establishment of a comprehensive ecosystem that included traditional banks, fintech companies, and payment service providers from the outset, creating immediate network effects that enhanced the system's utility and adoption potential.

5.2. Technical Infrastructure

Analysis of PIX's architecture, interoperability features, and integration with legacy banking systems. PIX's technical infrastructure is built on a centralized settlement model operated by the central bank, with distributed access points through participating financial institutions [9]. The system employs application programming interfaces (APIs) that enable seamless integration with existing banking systems, payment applications, and merchant platforms. A key architectural feature is the use of proxy identifiers (keys) that simplify transactions by eliminating the need for traditional banking details. The system supports multiple authentication methods, including biometric verification, to ensure security while maintaining user-friendliness. Amboage et al. [10] highlight how PIX's technical design prioritizes interoperability, allowing transactions between accounts at different institutions without intermediaries, which significantly reduces settlement times and operational complexity compared to traditional payment methods.

5.3. Adoption Trends

Examination of user demographics, geographic distribution, and transaction patterns since PIX's introduction. Since its launch, PIX has demonstrated distinctive adoption patterns across different segments of Brazilian society [9]. Initial adoption was strong among younger, urban populations with higher digital literacy and existing banking relationships. However, the system has progressively penetrated broader demographic segments, including older age groups and lower-income populations. Geographic distribution analysis reveals significant adoption in previously underserved

regions, including rural areas and smaller municipalities where traditional banking infrastructure is limited. Amboage et al. [10] identify several factors driving this widespread adoption, including zero-cost person-to-person transfers, simplified user experience, and extensive promotional efforts by financial institutions competing for transaction market share. The evolving transaction patterns show diversification from initial dominance of person-to-person transfers to increasing utilization for bill payments, merchant transactions, and business-to-business payments.

5.4. Transaction Costs and Accessibility

Comparative analysis of PIX transaction costs against traditional banking services, with attention to accessibility for previously excluded populations. PIX has fundamentally altered the transaction cost structure within Brazil's payment ecosystem [9]. For end-users, the system eliminates or significantly reduces fees for person-to-person transfers that traditionally carried substantial charges, particularly for inter-bank transactions. For merchants, PIX offers lower processing costs compared to card networks, enabling smaller businesses to accept digital payments without prohibitive fee structures. The central bank's management report [9] emphasizes how this cost reduction has special significance for lower-income populations, for whom transaction fees represented a substantial barrier to financial service utilization. Amboage et al. [10] note that beyond direct cost reduction, PIX enhances accessibility through immediate fund availability, elimination of minimum transaction thresholds, and removal of complex registration processes that characterized traditional banking services, thereby addressing multiple dimensions of financial exclusion simultaneously.

5.5. User Experience and Satisfaction

Evaluation of user interface design, ease of use, and reported satisfaction among diverse demographic groups. User experience has emerged as a critical factor in PIX's successful adoption across diverse population segments [9]. The system's interface design focuses on simplicity and intuitive operations, with standardized elements that create consistency across different implementation platforms. Transaction confirmation is immediate, providing users with certainty that enhances trust in the system. Amboage et al. [10] report high satisfaction levels across different user groups, with particular appreciation for the speed, reliability, and straightforward operation of the system. Notably, satisfaction extends to previously underbanked populations who report that PIX addresses many of the friction points they experienced with traditional financial services. The system's flexibility in accommodating different user preferences—including options for QR code scanning, manual key entry, or contact list selection—has contributed to positive experiences across varying levels of technological proficiency and accessibility needs.

6. Comparative Analysis and Discussion

6.1. Comparative System Design and Implementation

Systematic comparison of UPI and PIX design features, implementation strategies, and institutional frameworks. Both UPI and PIX represent innovative approaches to digital payment systems, yet they differ significantly in their design philosophies and implementation approaches. UPI emerged from a public-private partnership model with NPCI serving as the coordinating entity [7], while PIX was developed and implemented directly by Brazil's central bank as a public infrastructure project [9]. This fundamental difference has shaped each system's governance structure, technical architecture, and stakeholder engagement. UPI's design emphasizes a decentralized model where multiple payment service providers operate on a common platform, fostering competition at the application layer while maintaining interoperability [8]. In contrast, PIX employs a more centralized settlement infrastructure with distributed access points through participating financial institutions [10]. Rajak [11] notes that comparative analysis of implementation strategies in different contexts reveals how institutional frameworks significantly influence adoption trajectories and inclusivity outcomes, with implications for future system designs in other emerging markets.

Table 3 Comparative Features of UPI (India) and PIX (Brazil) [7, 9, 10]

Feature	UPI (India)	PIX (Brazil)
Implementation Model	Public-private partnership	Central bank-led public project
Governance Structure	NPCI coordination	Direct central bank oversight
Technical Architecture	Decentralized with common platform	Centralized settlement with distributed access
User Authentication	Multi-factor with virtual addressing	Multiple methods including biometrics

Market Entry Approach	Gradual ecosystem development	Mandatory participation for larger institutions
Integration Method	Open APIs with standardized protocols	API-based integration with banking systems

6.2. Effectiveness in Promoting Financial Inclusion

Evaluation of comparative impacts on financial inclusion metrics across both markets, identifying shared and unique outcomes. Both UPI and PIX have demonstrated substantial impacts on financial inclusion, though with different patterns of effectiveness across population segments and geographical areas. UPI has shown particular strength in enabling micro-entrepreneurs and small businesses to participate in the digital economy through simplified merchant payment solutions [7]. PIX, meanwhile, has been especially effective at reducing transaction costs for person-to-person transfers that previously carried substantial fees in Brazil's banking system [9]. Common to both systems is their success in expanding access to digital financial services among previously underserved populations, though the demographic composition of these newly included groups varies between the two countries. Prasad and Joseph [12] highlight that comparative analysis reveals how contextual factors such as existing banking infrastructure, digital literacy levels, and regulatory environments significantly influence the effectiveness of similar technological solutions in different settings. The analysis suggests that while technological architecture is important, adaptation to local contexts and addressing specific exclusion factors are equally critical for success.

6.3. Key Success Factors and Challenges

Identification of critical enablers and barriers to successful implementation and adoption in each context. Several common success factors emerge from the comparative analysis of UPI and PIX implementations. Both systems benefited from strong institutional backing, comprehensive stakeholder engagement, and strategic phasing of implementation [8][10]. Both also encountered and addressed challenges related to digital literacy, trust in financial technology, and infrastructure limitations. However, distinct enablers and barriers characterized each context. UPI's success has been particularly linked to its open API architecture that fostered a diverse ecosystem of applications serving different user needs [7], while PIX benefited from the mandatory participation requirements for financial institutions that created immediate network effects [9]. Rajak [11] identifies that comparative analysis of government and private sector interventions reveals complementary roles in addressing different dimensions of financial exclusion, with government-led initiatives often establishing baseline infrastructure while private innovation drives user experience improvements and specialized applications. Among persistent challenges, both systems continue to address issues related to digital divides, cybersecurity concerns, and integration with broader financial services beyond payments.

6.4. Policy Implications for Other Emerging Markets

Discussion of transferable policy approaches and implementation strategies for other emerging markets [2]. The findings suggest important considerations for policymakers seeking to enhance financial inclusion through digital payment innovations, particularly regarding the balance between technological solutions and contextual adaptation [3]. The comparative analysis of UPI and PIX yields several transferable policy insights for other emerging markets. First, the importance of establishing appropriate regulatory frameworks that balance innovation with stability and consumer protection, as highlighted by the different but effective governance approaches in India and Brazil [7][9]. Second, the value of mandating interoperability standards while allowing for competitive innovation in user-facing services [11]. Third, the critical role of stakeholder education and trust-building initiatives in driving adoption among previously excluded populations [10]. Prasad and Joseph [12] emphasize that policies should address both supply-side constraints through infrastructure development and demand-side barriers through digital literacy and incentive programs. Additionally, the analysis suggests that phased implementation approaches allow for iterative improvement and adaptation to emerging usage patterns and challenges.

6.5. Future Directions

Analysis of potential expansion paths, including international interoperability, new functionalities, and cross-system integration. The evolution of both UPI and PIX points toward several potential expansion pathways that could further enhance financial inclusion. International interoperability represents a significant frontier, with both systems exploring cross-border transaction capabilities that could reduce remittance costs and facilitate international trade for small businesses [7][9]. Functional expansion beyond basic payments to include credit, insurance, and investment services could leverage the established user base to address broader financial exclusion issues [10]. Integration with emerging technologies such as blockchain, artificial intelligence, and Internet of Things devices presents opportunities to enhance security, personalization, and seamless embedding of financial services into daily activities [8]. Rajak [11] suggests that comparative analysis of different intervention models indicates the potential for hybrid approaches that combine government infrastructure with private innovation to address remaining financial inclusion gaps. Additionally, both

systems are exploring enhanced data analytics capabilities that could support responsible lending and personalized financial services while maintaining privacy and security.

6.6. Theoretical Contributions

Conceptual advances in understanding the relationship between digital payment infrastructures and financial inclusion in emerging economies [1]. This research extends existing theoretical frameworks like SAP-LAP [4] by incorporating insights from comparative analysis of diverse implementation contexts. The comparative examination of UPI and PIX contributes several theoretical advances to the understanding of digital payment systems and financial inclusion. First, it extends existing frameworks by demonstrating how technological architectures interact with institutional contexts to produce distinct but successful inclusion outcomes [1]. Second, it challenges linear models of financial inclusion by revealing multiple pathways through which digital payments can address exclusion factors, depending on the specific barriers predominant in each context [10]. Third, it provides empirical support for the importance of ecosystem approaches rather than isolated technological solutions, building on the SAP-LAP framework's emphasis on interconnected actors and processes [4]. Prasad and Joseph [12] note that comparative analysis across different socioeconomic contexts helps refine theoretical understandings of inclusion mechanisms, moving beyond binary conceptualizations of financial inclusion toward more nuanced, multidimensional frameworks. The research also contributes methodologically by demonstrating the value of cross-national comparative case studies in identifying contextual dependencies and universal principles in digital financial innovation.

7. Conclusion

This comparative article of UPI in India and PIX in Brazil demonstrates that digital payment systems can significantly transform financial inclusion in emerging markets through distinct but equally effective implementation approaches. The analysis reveals that while technological architecture is important, successful financial inclusion requires adapting solutions to local contexts and addressing specific exclusion factors prevalent in each environment. Both systems have expanded access to financial services for previously underserved populations through different mechanisms: UPI through its open ecosystem fostering diverse applications, and PIX through regulatory-driven participation that created immediate network effects. Key success factors include strong institutional backing, comprehensive stakeholder engagement, and attention to user experience design that addresses accessibility barriers. The article suggests important policy considerations for other emerging markets, including the need to balance regulatory oversight with innovation, establish interoperability standards, and develop complementary education initiatives that build digital literacy and trust. Future research should explore the longitudinal impacts of these digital payment systems on broader financial inclusion outcomes, their integration with other financial services, and their potential for international expansion. By understanding these digital payment ecosystems as sociotechnical systems rather than merely technological innovations, policymakers and practitioners can better leverage their potential to create more inclusive financial landscapes in diverse contexts around the world.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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