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Digital Payment Revolution and the Velocity of Money: Does the Classic Inflation Model Still Hold?

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Abstract: The unprecedented proliferation of electronic money (e-money) in Indonesia has fundamentally altered the transactional landscape, raising a critical yet underexplored question: has the digital payment revolution destabilized the classic relationship between money velocity and inflation? This study investigates the long-run and short-run dynamics between e-money transaction volume, inflation, and the velocity of money in Indonesia over the period 2011-2023, employing the Autoregressive Distributed Lag (ARDL) bounds testing approach. Annual data on nominal GDP, M2 money supply, e-money transaction values, and consumer price inflation were sourced from Bank Indonesia and the Indonesian Central Bureau of Statistics (BPS). Augmented Dickey-Fuller (ADF) unit root tests confirm that all variables are integrated of order one, I(1), making the ARDL framework appropriate. The Bounds F-test yields a statistic of 15.343, decisively exceeding the 1% critical upper bound, confirming a stable long-run cointegrating relationship. Results reveal a significant positive short-run effect of e-money on velocity but a negative long-run multiplier, suggesting that the rapid expansion of the digital monetary base ultimately depresses velocity, a phenomenon we term the "digital shadow of money." Inflation exhibits a statistically insignificant role in both the short and long run, challenging the applicability of the classical quantity theory of money in Indonesia's digitizing economy. The CUSUM stability test confirms structural stability. These findings carry substantial implications for monetary policy design, particularly regarding the adequacy of conventional money supply targeting in an era of digital financial transformation.

Keywords: velocity of money; electronic money; digital payments; ARDL bounds test; inflation

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INTRODUCTION

The classical quantity theory of money, encapsulated in Fisher's (1911) exchange equation $MV = PT$, rests on a foundational assumption: that the velocity of money (V) is sufficiently stable to render the money supply a reliable anchor for nominal economic activity and, by extension, the price level. For nearly a century, this assumption served as the intellectual bedrock of monetarist policy frameworks and has guided central banks across the globe. Yet the explosive emergence of digital payment technologies, most notably electronic money (e-money) poses an unprecedented challenge to this paradigm. When every smartphone becomes a payment terminal and every transaction leaves a digital footprint, the classical boundaries of money and its velocity become increasingly blurred.

Indonesia provides a compelling empirical laboratory for this inquiry. E-money transaction values in the country surged from a mere IDR 0.52 trillion in 2009 to IDR 835.84 trillion in 2023, a staggering increase of approximately 160,700 percent in fourteen years. This transformation was catalyzed by the rise of mobile payment platforms such as GoPay, OVO, Dana, and ShopeePay, Bank Indonesia's National Payment Gateway (GPN), and regulatory innovations including the Quick Response Code Indonesian Standard (QRIS). Concurrently, Indonesia's velocity of money measured as the ratio of nominal GDP to the M2 money supply exhibited a counter-intuitive declining trend, falling from approximately 2.72 in 2011 to 2.37 in 2023, with a notable trough of 2.16 in 2021 during the COVID-19 pandemic. This divergence between rapidly increasing digital transaction volumes and declining monetary velocity constitutes what this paper terms the "digital shadow of money" a phenomenon wherein the growth of the digital monetary base casts a shadow over conventional velocity metrics, obscuring the real-sector transmission of monetary impulses.

The monetary economics literature has long recognized that financial innovation can alter the demand for money and its velocity (Baumol, 1952; Tobin, 1956; Durlauf & Blume, 2016). However, the specific impact of e-money as a distinct instrument that reduces transaction costs, increases the frequency of money turnover, yet simultaneously expands the broader measure of the money supply remains theoretically ambiguous and empirically underexplored, particularly in the context of emerging economies. Prior studies such as Hasan et al. (2012) found that retail payment innovations positively contribute to economic growth in European economies, while Schuh and Stavins (2010) demonstrated that electronic payment adoption substitutes for traditional instruments. In the Indonesian context specifically, Stanley et al. (2024) documented that P2P lending platforms, another dimension of the digital financial ecosystem exert a significant positive influence on consumption credit, suggesting that digital financial instruments are actively reshaping the credit and payment landscape in ways that traditional monetary models may fail to capture. More recently, the advent of mobile payment ecosystems and potential Central Bank Digital Currencies (CBDCs) has reinvigorated scholarly interest in the monetary velocity question (Boar & Wehrli, 2021; Agur et al., 2022; Meaning et al., 2021).

Despite this growing literature, there remains a critical gap: most existing studies are conducted in developed economy contexts, rely on high-frequency data unavailable in emerging markets, or do not explicitly test for a cointegrating long-run relationship between e-money and monetary velocity within an inflation context. Indonesia, as the world's fourth most populous nation and one of Southeast Asia's most dynamic digital economies, represents an ideal yet understudied case. Furthermore, the precise structural question, whether the classic inflation-velocity nexus posited by Fisher's equation remains intact under digital disruption has not been formally tested in the Indonesian context using modern time-series econometric methods.

This study addresses these gaps by asking three interconnected research questions: (1) Is there a stable long-run cointegrating relationship between e-money transaction volume, inflation, and monetary velocity in Indonesia? (2) Does e-money growth have a statistically significant positive effect on monetary velocity in the short and long run? (3) Does the classical positive relationship between inflation and monetary velocity hold in an environment of rapid digital payment growth?

The stability of the long-run relationship between monetary aggregates, inflation, and velocity has increasingly come under scrutiny in the era of digital financial transformation. Recent empirical evidence suggests that the proliferation of electronic money (e-money) is not merely a transactional innovation but a structural shift that redefines monetary dynamics. In the Indonesian context, studies such as Hermawan et al. (2024) demonstrate that monetary velocity is endogenously influenced by digital payment expansion and exhibits a significant interaction with inflation dynamics within a modern macroeconomic framework. Similarly, Anwar et al. (2024), employing an autoregressive distributed lag (ARDL) approach, provide evidence of a long-run equilibrium adjustment mechanism linking e-money transactions, inflation, and velocity, thereby implying the presence of cointegration among these variables. These findings collectively suggest that digital payment instruments have become an integral component of the monetary transmission mechanism, reinforcing the plausibility of a stable long-run relationship despite structural transformation.

H1: There was a stable long-run cointegrating relationship between e-money transaction volume, inflation, and monetary velocity in Indonesia.

The impact of e-money on monetary velocity presents a nuanced and temporally differentiated effect that reflects the dual nature of digital financial innovation. In the short run, the adoption of e-money enhances transaction efficiency, reduces frictions, and accelerates the circulation of money, thereby exerting an upward pressure on velocity. This is consistent with recent findings by Anwar et al. (2024), which indicate that increases in electronic transaction intensity are associated with higher velocity in the immediate term. However, over the long run, the same digital expansion may contribute to a dampening effect on measured velocity, as a growing share of monetary balances becomes stored within digital ecosystems, effectively increasing the denominator of broad money aggregates without a proportional increase in nominal output. Margaretha and Wahyudi (2025) further highlight this dual-channel mechanism, emphasizing that the liquidity and store-of-value functions of e-money can generate opposing effects depending on the time horizon. This temporal asymmetry underscores the importance of distinguishing between short-run dynamics and long-run structural adjustments in monetary analysis.

H2: E-money exerts a positive and significant effect on monetary velocity in the short run, but a negative effect in the long run.

The classical positive relationship between inflation and monetary velocity, long established within the Fisherian framework, is increasingly challenged by the structural changes induced by digital payment systems. Traditionally, higher inflation incentivizes economic agents to reduce real money balances, thereby increasing the speed at which money circulates. However, recent empirical studies suggest that this relationship may no longer hold in its conventional form. Hermawan et al. (2024) find that the interaction between digital currency usage and macroeconomic variables can alter inflation dynamics in ways that deviate from classical predictions, particularly through reduced transaction costs and enhanced payment flexibility. Moreover, the rapid diffusion of e-money and fintech innovations introduces potential structural breaks in the money demand function, weakening the empirical stability of the inflation–velocity nexus. As digital payment systems increasingly decouple transactional activity from traditional monetary aggregates, the sensitivity of velocity to inflationary pressures may diminish or become statistically insignificant.

H3: The classical positive relationship between inflation and monetary velocity is weakened or rendered statistically insignificant due to the structural changes introduced by digital payment proliferation.

The paper contributes to the literature in three ways. First, it provides the first ARDL-based cointegration analysis of the e-money–velocity nexus in Indonesia using a dataset spanning 2011–2023. Second, it introduces and empirically validates the concept of the "digital shadow of money" as a framework for understanding the divergence between digital transaction growth and monetary velocity in emerging markets. Third, it provides policy-relevant evidence for Bank Indonesia and comparable emerging market central banks regarding the adequacy of M2-based monetary targeting frameworks in an era of digital financial transformation.

METHOD

Data and Variables

This study employs annual time-series data covering the period 2011 to 2023, yielding 13 observations. The sample period is defined by the availability of consistent e-money transaction data from Bank Indonesia. Three primary variables are used. The dependent variable is the velocity of money (*V*), computed as the ratio of nominal Gross Domestic Product (GDP) to the broad money supply (M2), consistent with the quantity theory framework ($V = PY/M$). GDP data are obtained from the Indonesian Central Bureau of Statistics (BPS, 2023) and M2 data from Bank Indonesia (2023). The primary independent variable is the value of electronic money transactions (*UE*), denominated in trillions of Indonesian Rupiah (IDR), sourced from Bank Indonesia's payment system statistics. The control variable is the annual Consumer Price Index (CPI)-based inflation rate (*INF*), sourced from BPS. All monetary variables are transformed to natural logarithms (LN_V and LN_UE) to address scale differences and achieve approximate normality, while inflation is entered in its original decimal form given its bounded nature and the risk of distortion from log transformation near zero.

Table 1 Descriptive Statistics of Research Variables (2011–2023)

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
LN_V	13	0.9038	0.0672	0.7688	1.0018
LN_UE	13	3.4953	2.2186	-0.0202	6.7282
INF	13	0.0406	0.0193	0.0168	0.0838

Econometric Framework

The ARDL bounds testing approach developed by Pesaran et al. (2001) is employed for three methodologically compelling reasons. First, it is applicable regardless of whether the regressors are purely I(0), purely I(1), or mutually cointegrated, avoiding the pre-testing bias inherent in the Engle-Granger and Johansen procedures. Second, it is particularly suited to small samples, a pertinent advantage given the 13-year observation window of this study (Narayan, 2005). Third, it simultaneously provides both short-run and long-run parameter estimates within a unified estimation framework. The unrestricted error correction model (UECM) for the ARDL specification is:

$$\Delta \ln V_t = \alpha_0 + \Sigma_{i=1}{}^{p}\, \beta_i\, \Delta \ln V_{t-i} + \Sigma_{i=0}{}^{g}\, \gamma_i\, \Delta \ln UE_{t-i} + \Sigma_{i=0}{}^{r}\, \delta_i\, \Delta INF_{t-i} + \varphi_1 \ln V_{t-1} + \varphi_2 \ln UE_{t-1} + \varphi_3 INF_{t-1} + \varepsilon_t$$

Where Δ denotes the first difference operator, *V* is monetary velocity, *UE* is e-money transaction value, *INF* is the inflation rate, and ε_t is a white noise error term. Optimal lag lengths for the dependent and independent variables were fixed at two (deplags = 2, reglags = 2), yielding an ARDL(2,2,2) model, selected based on the Akaike Information Criterion (AIC). The long-run cointegration hypothesis tests the null H_0: $\varphi_1 = \varphi_2 = \varphi_3 = 0$ against the alternative of a cointegrating relationship, using the F-statistic bounds test with critical values from Pesaran et al. (2001). The long-run multiplier coefficients are derived from the ratio of the sum of lagged level coefficients to the negative of the error correction coefficient. Model stability is assessed using the Cumulative Sum (CUSUM) test of Brown et al. (1975). Serial correlation and heteroskedasticity are diagnosed using the Breusch-Godfrey LM test and the Breusch-Pagan-Godfrey test, respectively.

Unit Root Testing

Prior to ARDL estimation, all variables are subjected to the Augmented Dickey-Fuller (ADF) unit root test (Dickey & Fuller, 1979) to confirm that none of the series is I(2) a requirement that would invalidate the bounds testing procedure. Lag lengths are selected automatically using the Schwarz Information Criterion (SIC) with a maximum of three lags. For variables exhibiting a deterministic trend in their levels, the ADF specification includes a constant and a linear trend.

RESULTS

Unit Root Test Results

Table 2 presents the ADF unit root test results. All three variables fail to reject the null hypothesis of a unit root at their levels (results not shown for brevity), but all three decisively reject the unit root null at first difference. LN_V is stationary at first difference at the 5% significance level (t-statistic = −4.126, p = 0.0348), with a constant and linear trend included given the visual trending behavior of the series. LN_UE achieves stationarity at the 1% level at first difference (t-statistic = −7.668, p = 0.0008), with a constant and trend specification and three lags. INF becomes stationary at first difference at the 1% level (t-statistic = −4.437, p = 0.0060) with a constant-only specification. These results uniformly confirm that all variables are integrated of order one, I(1), satisfying the prerequisite for ARDL bounds testing.

Table 2 Augmented Dickey-Fuller Unit Root Test Results

Variable	Exog.	t-Stat.	Prob.	Lag	Sig.	Order
D(LN_V)	C, T	-4.1261	0.0348	1	5%	I(1)
D(LN_UE)	C, T	-7.6683	0.0008	3	1%	I(1)
D(INF)	C	-4.4373	0.0060	1	1%	I(1)

Note: C = constant; T = linear trend; D() = first difference. Critical values from MacKinnon (1996)

ARDL Model Selection and Bounds Test

The AIC-based model selection procedure identifies the ARDL(2,2,2) specification as optimal among all candidate models (Figure 1). This specification balances parsimony with goodness-of-fit, yielding an R^2 of 0.982 and an adjusted R^2 of 0.945, indicating that the model explains approximately 98.2% of the variation in monetary velocity. The Durbin-Watson statistic of 2.839 is within acceptable bounds at this stage.

Figure 1 AIC Model Selection Criterion - ARDL Candidate Models

[Figure 1: AIC values across candidate ARDL models. The ARDL(2,2,2) model attains the lowest AIC value of −5.258, confirming its selection as the preferred specification.

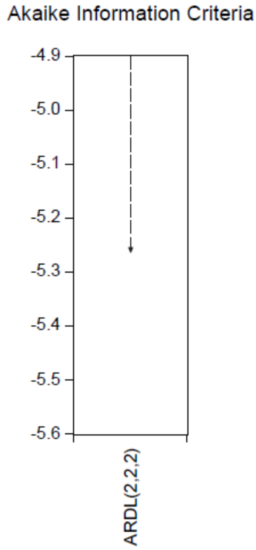


Table 3 presents the ARDL bounds test results. The F-statistic of 15.343 dramatically exceeds the upper bound critical value at the 1% significance level under both the asymptotic (I(1) = 5.580) and sample-specific (I(1) = 6.760, n = 30) critical values tabulated by Pesaran et al. (2001). This result provides strong and unambiguous evidence rejecting the null hypothesis of no long-run levels relationship among LN_V, LN_UE, and INF. A stable, long-run cointegrating relationship therefore exists between monetary velocity, electronic money transactions, and inflation in Indonesia over the sample period.

Table 3 ARDL Bounds Test for Long-Run Cointegration

Statistic	Value	I(0) 10%	I(1) 10%	I(0) 5%	I(1) 5%
F-statistic: 15.343***	15.343	3.020	3.510	3.620	4.160

*Note: *** significant at the 1% level. Critical values (asymptotic) from Pesaran et al. (2001, Table CI, Case II)*

Short-Run and Long-Run ARDL Estimates

Table 4 reports the full ARDL(2,2,2) estimation results. In the short run, the contemporaneous effect of LN_UE on LN_V is positive and marginally significant at the 10% level (coefficient = 0.047, t = 2.744, p = 0.052). This finding is consistent with the transaction-efficiency hypothesis: as e-money facilitates more rapid exchange of goods and services per unit of time, the measured velocity of money increases in the short run. The lagged effects of LN_UE are negative but insignificant, while INF and its lags are uniformly insignificant in the short run, suggesting that inflation has no immediate transmission to monetary velocity within a single year.

Table 4 ARDL(2,2,2) Short-Run Estimation Results (Dependent Variable: LN_V)

Variable	Coefficient	Std. Error	t-Stat.	Prob.
LN_V(−1)	−0.1406	0.2760	−0.510	0.637
LN_V(−2)	−0.5720***	0.1300	−4.400	0.012
LN_UE	0.0473*	0.0172	2.744	0.052
LN_UE(−1)	−0.0240	0.0362	−0.662	0.544
LN_UE(−2)	−0.0698**	0.0344	−2.029	0.112
INF	−0.2196	0.4410	−0.498	0.645
INF(−1)	0.3255	0.3435	0.948	0.397
INF(−2)	−0.3588	0.2937	−1.222	0.289
C	1.6338***	0.3047	5.363	0.006

*Note: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$. $R^2 = 0.982$; Adj. $R^2 = 0.945$; F-stat. = 26.82 (p = 0.003); DW = 2.839*

The long-run multiplier coefficients are derived using the formula: $\beta\_LR = (\Sigma\beta_i) / (1 - \Sigma\varphi_j)$, where $\Sigma\beta_i$ is the sum of all lagged coefficients for each regressor and $\Sigma\varphi_j$ is the sum of lagged dependent variable coefficients. The error correction denominator equals $1 - (-0.1406 + (-0.5720)) = 1.7126$. Table 5 presents the computed long-run coefficients.

Table 5 Computed Long-Run Multiplier Coefficients

Variable	Sum of Coefficients	LR Multiplier	Interpretation
LN_UE	0.0473 – 0.0240 – 0.0698 = −0.0465	−0.0271	Negative (Velocity ↓)
INF	−0.2196 + 0.3255 – 0.3588 = −0.2529	−0.1477	Negative (Not significant)
EC denominator	1 – (−0.1406 – 0.5720) = 1.7126	—	Speed of adjustment

The long-run multiplier for LN_UE is −0.027, indicating that a 1% increase in e-money transaction volume is associated with a 0.027% decrease in monetary velocity in the long run. For INF, the long-run multiplier is −0.148, suggesting that higher inflation is associated with lower velocity over the long horizon, a result that, while theoretically counter-intuitive under the classical quantity theory, is consistent with the precautionary money demand hypothesis in inflationary environments (Mishkin, 2019).

Diagnostic Tests and Model Stability

Table 6 summarizes the diagnostic test results for the estimated ARDL(2,2,2) model. The Breusch-Godfrey Serial Correlation LM test yields an F-statistic of 0.900 ($p = 0.526$), failing to reject the null hypothesis of no serial correlation at up to two lags. The Breusch-Pagan-Godfrey heteroskedasticity test yields an F-statistic of 2.497 ($p = 0.197$), failing to reject the null of homoskedastic residuals. These results confirm that the model residuals are well-behaved and that inference based on OLS standard errors is valid.

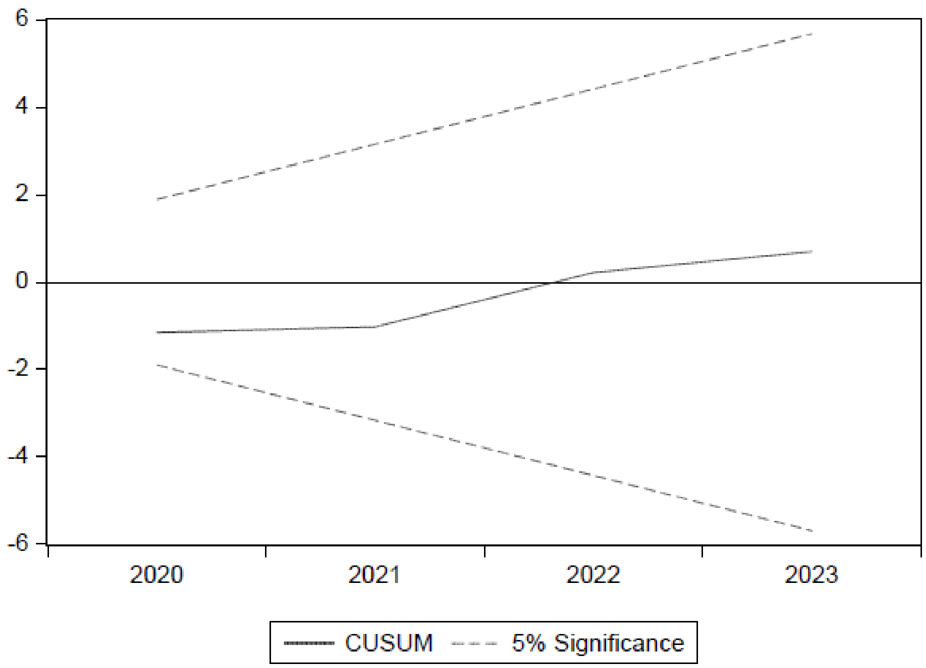
Table 6 Diagnostic Test Summary

Test	F-Stat.	Prob.	Conclusion
Breusch-Godfrey Serial Correlation LM (2 lags)	0.900	0.526	No serial correlation
Breusch-Pagan-Godfrey Heteroskedasticity	2.497	0.197	Homoskedastic
CUSUM Stability Test	—	—	Stable (within 5% bounds)

Figure 2 presents the CUSUM stability test results. The cumulative sum of recursive residuals remains entirely within the 5% significance bands throughout the sample period, confirming that the estimated parameters of the ARDL(2,2,2) model are structurally stable. There is no evidence of parameter instability or structural break, despite the significant acceleration in e-money adoption post-2018 and the macroeconomic disruption of the COVID-19 pandemic in 2020-2021. This stability finding is consistent with the view that the long-run money velocity equation has undergone a gradual, smooth adjustment to digital payment penetration rather than a sudden structural rupture.

Figure 2 CUSUM Structural Stability Test

[Figure 2: CUSUM test plot showing recursive residuals remaining within the two-standard-deviation bounds (dashed lines) at the 5% significance level across 2020–2023.



DISCUSSION

The central finding of this study found that a positive short-run effect of e-money on monetary velocity juxtaposed with a negative long-run multiplier invites a nuanced theoretical interpretation that we frame under the concept of the "digital shadow of money." This framework reconciles apparently contradictory dynamics by distinguishing between two temporally distinct channels through which digital payments affect monetary velocity.

In the short run, the significantly positive coefficient of LN_UE on LN_V ($\beta = 0.047$, $p = 0.052$) is consistent with the transaction-efficiency channel proposed in the original Baumol-Tobin inventory model. Digital payment platforms reduce transaction costs both in time and monetary terms enabling economic agents to hold lower average money balances relative to transaction volume (Baumol, 1952; Tobin, 1956). With lower real money balances required per unit of nominal spending, velocity mechanically increases. This result aligns with Hasan et al.'s (2012) European evidence that retail payment innovations stimulate economic output per unit of money, and with Schuh and Stavins' (2010) finding that electronic payments reduce the demand for physical currency. More recently, Ozili (2022) documented that digital finance expansion in Africa and Asia-Pacific economies improves financial intermediation efficiency, which is consistent with the velocity-enhancing interpretation in the short run.

However, the long-run negative multiplier (−0.027) reveals a fundamentally different dynamic. As Indonesia's digital payment ecosystem matured, exemplified by e-money transaction values growing from IDR 0.98 trillion in 2011 to IDR 835.84 trillion by 2023. The banking system's capacity to create digital money expanded correspondingly. Bank Indonesia's broad money supply (M2) grew from IDR 2,877 trillion in 2011 to IDR 8,824 trillion in 2023, a 207% increase. The denominator of the velocity ratio (M2) thus expanded faster than the numerator (nominal GDP, which grew by approximately 167% over the same period), mechanically depressing measured velocity. This "monetary shadow" effect wherein the aggregate digital money base expands to accommodate and incentivize digital transactions, ultimately overwhelming the velocity-enhancing efficiency gains constitutes the core mechanism behind the digital shadow of money hypothesis.

This finding has important parallels with the observed behavior of money velocity in the United States and other advanced economies following the Global Financial Crisis and subsequent quantitative easing programs, as documented by Castañeda & Cendejas (2024), who showed that the US velocity of M2 declined persistently from approximately 2.0 in 2007 to below 1.5 by the early 2020s. While the US case primarily reflects central bank asset purchases expanding base money, Indonesia's case reflects private-sector digital money creation, a distinction with important policy implications. Agur et al. (2022), in their theoretical analysis of CBDC design, similarly warn that digital currency proliferation can have complex and potentially destabilizing effects on money demand and monetary transmission, depending on whether digital instruments substitute for or complement existing bank deposits.

The statistically insignificant role of inflation in both the short and long run despite the negative sign on the long-run multiplier directly addresses our third hypothesis and the paper's titular question: *does the classic inflation model still hold?"* Our evidence suggests that it does not, at least in its strong form. Fisher's (1911) quantity theory predicts a positive and proportional relationship between the money supply and the price level, conditioned on a stable velocity. The finding that inflation neither significantly drives nor is driven by monetary velocity in Indonesia's digitizing economy suggests that the velocity-inflation nexus has become structurally unstable. This is consistent with Mishkin's (2019) assessment that the predictive power of money supply aggregates for inflation has weakened in economies undergoing significant financial structural change, and with Meaning et al.'s (2021) theoretical argument that CBDC and digital payment penetration alter the channels of monetary transmission in ways that may not be captured by traditional MV = PY frameworks.

From a monetary policy perspective, these findings carry substantial implications for Bank Indonesia. The current BI monetary policy framework, while formally inflation-targeting since 2005, continues to monitor M2 growth as an informational variable. The evidence presented here suggests that the informational content of M2 velocity as a signal of inflationary pressure has diminished considerably as e-money has grown to constitute a non-trivial share of total payment transactions (approximately 2.6% of M2 by 2023). Boar and Wehrli (2021), in their survey of 65 central banks, found that a majority of central banks in emerging economies are actively considering digital currency initiatives partly in response to the erosion of monetary transmission channels by private digital payment systems, a concern directly validated by our empirical results. Bank Indonesia's own digital rupiah initiative, as outlined in its 2023 consultation paper on wholesale CBDC, may represent a strategic response to precisely the type of monetary shadow documented in this study.

Conclusion, Limitations, and Suggestions

This study investigates the long-run and short-run dynamics between electronic money transactions, inflation, and monetary velocity in Indonesia over 2011-2023 using the ARDL bounds testing framework. Three principal conclusions emerge. First, there exists a stable long-run cointegrating relationship between monetary velocity, e-money transaction volume, and inflation in Indonesia, as evidenced by the Bounds F-statistic of 15.343, far exceeding the 1% critical upper bound. Second, e-money exhibits a positive and marginally significant short-run effect on monetary velocity (transaction-efficiency channel) but a negative long-run multiplier (digital shadow channel), reconciling these apparently contradictory effects through the concept of the "digital shadow of money." Third, inflation is statistically insignificant in both the short and long run, challenging the continued applicability of the classical quantity theory of money and Fisher's exchange equation as a policy guide in Indonesia's increasingly digital economy. The model is structurally stable across the full sample period, as confirmed by the CUSUM test.

These conclusions have direct implications for monetary policy design in Indonesia and comparable emerging economies. The erosion of the velocity-inflation linkage implies that central banks can no longer rely on M2 growth as a reliable leading indicator of inflationary pressure in digital payment-dense environments. Forward-looking frameworks that incorporate digital transaction data including e-money volumes, mobile payment turnover, and ultimately CBDC transaction ledgers may offer superior signal content for near-term inflation forecasting. Bank Indonesia's ongoing development of the digital rupiah infrastructure provides a natural policy laboratory for testing these propositions.

This study acknowledges several limitations that define avenues for future research. The 13-year annual observation window, while sufficient for ARDL-based cointegration, restricts the degrees of freedom available for more complex multi-variable models. Future research should exploit higher-frequency (quarterly or monthly) data as these become available from Bank Indonesia's enhanced payment system statistics. Second, the study focuses on aggregate monetary velocity (M2-based) and does not decompose the differential impacts of specific digital payment instruments (credit transfers, debit cards, prepaid cards, mobile wallets). A disaggregated panel analysis at the provincial level, exploiting spatial variation in digital payment penetration across Indonesia's 38 provinces, could yield richer insights into regional monetary transmission heterogeneity. Third, future work should incorporate structural break tests such as the Zivot-Andrews (1992) or Lee-Strazicich (2003) procedures to formally test whether the COVID-19 pandemic of 2020–2021 induced a structural shift in the velocity-e-money relationship, supplementing the CUSUM evidence.

REFERENCES

Agur, I., Ari, A., & Dell'Ariccia, G. (2022). Designing Central Bank Digital Currencies. *Journal of Monetary Economics, 125*, 62–79. https://doi.org/10.1016/j.jmoneco.2021.05.002

Anwar, C. J., Ayunda, V. T., Suhendra, I., Ginanjar, R. A. F., & Kholishoh, L. N. (2024). Estimating the Effects of Electronic Money on the Income Velocity of Money in Indonesia. *International Journal of Innovative Research and Scientific Studies, 7*(2), 390–397. https://doi.org/10.53894/ijirss.v7i2.2632

Bank Indonesia. (2023). Statistik Sistem Pembayaran dan Infrastruktur Pasar Keuangan. Bank Indonesia. Retrieved 15 April, 2026, from: https://www.bi.go.id

Baumol, W. J. (1952). The Transactions Demand for Cash: An Inventory Theoretic Approach. *Quarterly Journal of Economics, 66*(4), 545–556. https://doi.org/10.2307/1882104

Boar, C., & Wehrli, A. (2021). Ready, Steady, Go? – Results of the Third BIS Survey on Central Bank Digital Currency. BIS Papers No. 114. Bank for International Settlements. Retrieved 15 April, 2026, from: https://www.bis.org/publ/bppdf/bispap114.pdf

BPS (Badan Pusat Statistik). (2023). Statistik Indonesia 2023. BPS. Retrieved 7 April, 2026, from: https://www.bps.go.id

Brown, R. L., Durbin, J., & Evans, J. M. (1975). Techniques for Testing the Constancy of Regression Relationships Over Time. *Journal of the Royal Statistical Society: Series B (Methodological), 37*(2), 149–163. https://doi.org/10.1111/j.2517-6161.1975.tb01532.x

Castañeda, J. E., & Cendejas, J. L. (2024). Money Growth, Money Velocity and Inflation in the US, 1948–2021. *Open Economies Review, 35*(5), 999–1014. https://doi.org/10.1007/s11079-023-09739-0

Dickey, D. A., & Fuller, W. A. (1979). Distribution of the Estimators for Autoregressive Time Series with a Unit Root. *Journal of the American Statistical Association, 74*(366), 427–431. https://doi.org/10.2307/2286348

Fisher, I. (1911). The Purchasing Power of Money: Its Determination and Relation to Credit, Interest and Crises. New York, NY: Macmillan. https://doi.org/10.2307/2965060

Durlauf, S., & Blume, L. E. (2016). The New Palgrave Dictionary of Economics. New York, NY: Springer.

Hasan, I., De Renzis, T., & Schmiedel, H. (2012). Retail Payments and Economic Growth. *Bank of Finland Research Discussion Papers No. 19.* https://doi.org/10.2139/ssrn.2100651

Hermawan, D., Lie, D., Sasongko, A., & Yusan, R. I. (2024). Money Velocity, Digital Currency and Inflation Dynamics in Indonesia. *Bulletin of Indonesian Economic Studies, 60*(3), 305–345. https://doi.org/10.1080/00074918.2024.2398347

MacKinnon, J. G. (1996). Numerical Distribution Functions for Unit Root and Cointegration Tests. *Journal of Applied Econometrics, 11*(6), 601–618. http://www.jstor.org/stable/2285154

Margaretha, V., & Wahyudi, S. T. (2025). Revealing the Impact of Electronic Money and Economic Factors on the Velocity of Money in Indonesia. *Jurnal Ekonomi Pembangunan, 23*(1), 123–134. https://doi.org/10.29259/jep.v23i1.23217

Meaning, J., Dyson, B., Barker, J., & Clayton, E. (2021). Broadening Narrow Money: Monetary Policy with a Central Bank Digital Currency. *International Journal of Central Banking, 17*(2), 1–42. https://dx.doi.org/10.2139/ssrn.3180720

Mishkin, F. S. (2019). The Economics of Money, Banking and Financial Markets (12th ed.). New York, NY: Pearson.

Narayan, P. K. (2005). The Saving and Investment Nexus for China: Evidence from Cointegration Tests. *Applied Economics, 37*(17), 1979–1990. https://doi.org/10.1080/00036840500278103

Ozili, P. K. (2022). Digital Financial Inclusion, New Trends in Banking and Finance. New York: Springer.

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds Testing Approaches to the Analysis of Level Relationships. *Journal of Applied Econometrics, 16*(3), 289–326. https://doi.org/10.1002/jae.616

Schuh, S., & Stavins, J. (2010). Why are (Some) Consumers (Finally) Writing Fewer Checks? The Role of Payment Characteristics. *Journal of Banking & Finance, 34*(8), 1745–1758. https://doi.org/10.1016/j.jbankfin.2009.09.018

Stanley, N., Kohardinata, C., Widianingsih, L. P., Junianto, Y., Ismawati, A. F., & Sari, E. T. (2024). Is P2P Lending Emerging as a New Threat to Bank Credits?. *Journal of Accounting, Entrepreneurship and Financial Technology (JAEF), 6*(1), 1–16. https://doi.org/10.37715/jaef.v6i1.4630

Strazicich, M. C., & Lee, J. (2003). Minimum Lagrange Multiplier Unit Root Test with Two Structural Breaks. *The Review of Economics and Statistics, 85*(4), 1082–1089. https://doi.org/10.1162/003465303772815961

Tobin, J. (1956). The Interest Elasticity of the Transactions Demand for Cash. *Review of Economics and Statistics, 38*(3), 241–247. https://doi.org/10.2307/1925776

World Bank. (2022). The Global Findex Database 2021: Financial Inclusion, Digital Payments, and Resilience in the Age of COVID-19. *World Bank Group*. Retrieved 15 April, 2026, from: http://documents.worldbank.org/curated/en/099818107072234182

Zivot, E., & Donald W. K. Andrews. (1992). Further Evidence on the Great Crash, the Oil-Price Shock, and the Unit-Root Hypothesis. *Journal of Business & Economic Statistics, 10*(3), 251–270. https://doi.org/10.2307/1391541