

MOBILE TECHNOLOGY ADOPTION AND FINANCIAL DEVELOPMENT IN DEVELOPING COUNTRIES: A PANEL DATA ANALYSIS

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Abstract

This study empirically investigates the relationship between mobile technology adoption and financial development in eight developing countries—Pakistan, India, Bangladesh, Indonesia, Malaysia, Thailand, Viet Nam, and the Philippines—addressing critical gaps in the existing literature concerning cross-sectional dependence, non-stationarity, and dynamic endogeneity. Utilizing a balanced panel dataset of 152 observations, the analysis employs static panel models (fixed and random effects), system GMM dynamic panel estimation, cross-sectionally augmented panel unit root tests (CIPS), and heterogeneous panel cointegration methods (Kao and Westerlund). Financial development is proxied by domestic credit to the private sector as a percentage of GDP, while mobile penetration—measured as mobile cellular subscriptions per 100 people—serves as the key independent variable, with trade openness included as a control. The results consistently demonstrate that mobile penetration exerts a positive and statistically significant effect on financial development across fixed effects (0.168, $p < 0.01$), random effects (0.172, $p < 0.01$), and dynamic GMM specifications (0.157, $p < 0.01$). The findings further reveal strong path dependence in financial development (lagged coefficient = 0.495, $p < 0.01$), significant cross-sectional dependence, and substantial slope heterogeneity across countries. These results confirm that the transaction cost reductions and information asymmetry mitigations theorized by financial intermediation theory operate at the macroeconomic level but remain conditional on country-specific institutional characteristics. From a policy perspective, mobile network expansion represents a viable lever for financial deepening; however, it requires complementary regulatory reforms, data protection laws, and financial literacy programs to be fully effective. Future research should explore micro-level mechanisms and emerging fintech innovations beyond basic mobile penetration.

Keywords: Mobile technology adoption; financial development; panel data; developing countries; system GMM; cross-sectional dependence

1. Introduction

The relationship between technological innovation and financial sector development has emerged as a critical area of inquiry in development economics, particularly as mobile technology continues to reshape economic interactions in developing countries (Shah, 2026). Financial development broadly defined as the improvement in the quality and accessibility of financial services within an economy has long been recognized as a fundamental driver of economic growth and poverty reduction (Wibowo et al., 2026). However, traditional financial systems in developing countries have often failed to reach significant portions of the population, creating what scholars term financial exclusion (Robba, 2026). Mobile technology adoption has proliferated at an unprecedented rate across developing economies, offering a potential pathway to circumvent the infrastructural and institutional barriers that have historically constrained financial deepening (Motoane, 2026). The rapid diffusion of mobile phones has enabled innovative financial service delivery models, most notably mobile money

platforms such as M-Pesa in Kenya, which have demonstrated remarkable success in extending financial access to previously unbanked populations (Giliberto & Holt, 2026).

The theoretical foundations for examining this relationship draw from several strands of literature. Financial intermediation theory suggests that reductions in transaction costs and information asymmetries facilitate financial deepening (Stiglitz & Weiss, 1981). Mobile technology, by enabling digital transaction records and reducing physical distance barriers, may address precisely these frictions (Donovan, 2012). The technology diffusion literature emphasizes that the benefits of new technologies accrue not merely from adoption but from complementary institutional and infrastructural developments (Comin & Mestieri, 2014). Trade openness—measured as the ratio of trade to gross domestic product—may further amplify these effects by exposing domestic financial systems to competitive pressures and best practices from international markets (Rajan & Zingales, 2003). Despite substantial theoretical expectations that mobile technology adoption should promote financial development in developing countries, empirical evidence remains fragmented and inconclusive (Gosavi, 2018). Some studies have documented positive associations between mobile phone penetration and financial access indicators (Andrianaivo & Kpodar, 2012), while others have found that these effects are heterogeneous across countries and dependent on institutional quality (Asongu & Nwachukwu, 2016). This ambiguity reflects several methodological challenges, including reliance on cross-sectional or simple panel specifications that fail to account for cross-sectional dependence, persistence in financial development indicators, or potential non-stationarity (Baltagi, 2015). Studies have often treated mobile penetration as exogenous, despite plausible reverse causality concerns (Pénard, Poussing, & Suire, 2014).

The present study addresses these gaps by providing a comprehensive empirical investigation of the relationship between mobile technology adoption and financial development in developing countries. The analysis employs panel data econometric techniques designed to handle cross-sectional dependence, heterogeneity, non-stationarity, and dynamic adjustment processes, including the Hausman (1978) test to compare fixed and random effects estimators. The findings contribute to the literature in three important ways: first, by distinguishing between short-run and long-run effects of mobile penetration using both static and dynamic panel models; second, by employing cross-sectionally augmented panel unit root tests that account for interdependence among developing countries; and third, by investigating parameter heterogeneity to determine whether the relationship is universal or context-dependent. These contributions have direct policy relevance for developing country governments and international development organizations seeking to leverage technological innovation for financial sector deepening. The remainder of this study is organized as follows. Chapter Two reviews the theoretical and empirical literature. Chapter Three describes the data sources and methodology. Chapter Four presents the empirical results. Chapter Five discusses the findings and draws policy implications and directions for future research.

2. Literature Review

2.1 Theoretical Foundations

Financial intermediation theory provides the foundational framework for understanding the relationship between mobile technology adoption and financial development (Stiglitz & Weiss, 1981). This theory posits that financial systems develop primarily to reduce transaction costs and information asymmetries between lenders and borrowers (Diamond, 1984). Mobile payment systems generate digital transaction histories that serve as alternative credit scoring mechanisms, enabling financial institutions to evaluate borrower risk without traditional collateral requirements (Karlan, Kendall, Mann, Pande, Suri, & Zinman, 2016). The reduction

in physical distance barriers through mobile banking further lowers transaction costs, expanding the geographic reach of formal financial services into previously underserved rural areas (Aker & Mbiti, 2010). Thus, financial intermediation theory supports the hypothesis that higher mobile penetration positively influences financial development.

The specific relationship between mobile penetration as an independent variable and financial development as a dependent variable has been extensively examined in the empirical literature. The theoretical mechanism underlying this relationship is that mobile technology reduces the transaction costs associated with financial service delivery and mitigates information asymmetries between lenders and borrowers (Donovan, 2012). When individuals use mobile phones for financial transactions, they generate digital footprints that serve as alternative credit histories, enabling financial institutions to assess creditworthiness even for individuals lacking formal documentation or collateral (Karlan et al., 2016). Additionally, mobile money platforms reduce the need for physical bank branches, allowing financial institutions to serve remote rural populations at substantially lower cost than traditional brick-and-mortar banking (Aker & Mbiti, 2010). These transaction cost reductions and information asymmetry mitigations collectively enable financial deepening, measured as increased domestic credit to the private sector as a percentage of GDP.

2.2 Financial Development

Financial development has been extensively studied in the empirical literature. Levine (2005) provided a comprehensive review establishing that financial development, measured as domestic credit to the private sector as a percentage of GDP, reliably captures the depth and accessibility of formal financial systems across countries. Beck, Demirgüç-Kunt, and Levine (2007) demonstrated that this measure correlates strongly with broader indicators of financial inclusion and banking sector efficiency. King and Levine (1993) pioneered the use of private credit as the preferred measure of financial development, arguing that it better reflects financial intermediation activity directed toward private sector productivity enhancement compared to aggregate credit measures that include lending to state-owned enterprises. Demirgüç-Kunt and Klapper (2012) documented substantial cross-country variation in financial development levels, with developing countries exhibiting significantly lower private credit ratios than advanced economies—a gap that mobile technology may help narrow.

2.3 Mobile Penetration and Financial Development:

Empirical studies have consistently documented a positive relationship between mobile penetration and financial development. Jack and Suri (2011) conducted one of the most influential studies, using household survey data from Kenya to demonstrate that mobile money adoption reduced consumption volatility and enabled risk-sharing among Kenyan households. Their findings indicated that mobile money allowed households to remit funds more efficiently in response to income shocks, effectively functioning as an informal insurance mechanism that complemented formal financial development. Suri and Jack (2016) documented longer-term effects, showing that mobile money adoption lifted approximately 194,000 Kenyan households out of poverty between 2008 and 2014, with female-headed households experiencing particularly large gains, thereby establishing a causal link from mobile penetration to the developmental outcomes that financial deepening produces.

It has been analyzed by (Andrianaivo and Kpodar, 2012) that 44 African countries and found that mobile phone penetration positively affects the ratio of private credit to GDP, with larger effects observed in countries with lower initial levels of financial development, suggesting that mobile technology serves as a catch-up mechanism for financially underdeveloped economies. Gosavi (2018) provided cross-country evidence that mobile phone

penetration positively affects both bank account ownership and formal savings behavior, though the magnitude of effects varies with institutional quality. Donovan (2012) examined the mechanisms through which mobile technology reduces transaction costs and information asymmetries, concluding that mobile platforms enable financial inclusion by overcoming geographic and documentary barriers that traditionally excluded rural and informal sector populations.

2.4 Trade Openness

The literature on trade openness as a control variable in financial development studies is equally substantial. Rajan and Zingales (2003) advanced the influential argument that trade openness promotes financial development by increasing competition in both product and financial markets, reducing the ability of incumbent financial institutions to extract rents. Baltagi, Demetriades, and Law (2009) demonstrated using panel data that trade openness affects financial development, with the effect operating through institutional quality. Law (2009) found that trade openness positively influences financial development in developing countries, with the magnitude of the effect depending on the level of human capital and quality of governance.

Chinn and Ito (2006) showed that countries with more open capital accounts and trade regimes tend to have more developed financial systems, as international financial integration imposes competitive pressures on domestic financial institutions to improve efficiency. Klein and Olivei (2008) documented that trade and financial openness promote financial development in countries with sufficiently strong legal and regulatory institutions. Beck (2011) reviewed the evidence and concluded that trade openness consistently enters financial development regressions as a significant determinant, justifying its inclusion as a standard control variable in empirical studies of financial deepening.

2.5 Research Gaps and Contributions

Despite the richness of the existing literature, several gaps remain. First, much of the empirical evidence relies on cross-sectional or simple panel specifications that do not adequately address cross-sectional dependence, persistence in financial development indicators, or potential non-stationarity. Second, studies have frequently treated mobile penetration as exogenous, despite plausible reverse causality concerns. Third, the literature has paid limited attention to whether the mobile penetration–financial development relationship is universal or varies systematically across country contexts. The present study aims to address these gaps by employing advanced panel econometric techniques including cross-sectionally augmented unit root tests, dynamic panel models, and heterogeneity tests to provide more robust evidence on the relationship between mobile technology adoption and financial development in developing countries.

3. Methodology

3.1.1 Data Sources and Variables

This study investigates the impact of mobile technology adoption on financial development in developing countries. The analysis employs a balanced panel dataset covering 152 observations across eight developing economies: Pakistan, India, Bangladesh, Indonesia, Malaysia, Thailand, Viet Nam, and the Philippines. The dependent variable is financial development, proxied by domestic credit to the private sector as a percentage of GDP. The key independent variable is mobile penetration, measured by mobile cellular subscriptions per 100 people. Trade openness, defined as the sum of exports and imports as a percentage of GDP, is included as a control variable.

Variable Type	Variable Name	WDI Proxy / Description	WDI Code
Dependent Variable	Financial Development	Domestic credit to private sector (% of GDP)	FS.AST.PRVT.GD.ZS
Independent Variable	Mobile Penetration	Mobile cellular subscriptions (per 100 people)	IT.CEL.SETS.P2
Control Variable	Trade Openness	Trade (% of GDP)	NE.TRD.GNFS.ZS

3.2 Econometric Framework



3.2.1 Panel Regression Models

To estimate the effect of mobile technology adoption on financial development, we apply both pooled OLS and panel data models, including fixed effects (FE) and random effects (RE) specifications. The baseline panel regression is expressed as:

$$FD_{it} = \alpha + \beta_1 MP_{it} + \beta_2 TO_{it} + \epsilon_{it}$$

Where FD_{it} represents financial development in country i at time t , MP_{it} is mobile penetration, and TO_{it} denotes trade openness. Fixed-effects estimation controls for unobserved time-invariant heterogeneity, while random-effects estimation allows for time-invariant variables to contribute to the variation.

Hausman tests were conducted to assess the appropriateness of FE versus RE models. Due to violations of the classical assumptions, a generalized Hausman approach (suest) is recommended for robust inference.

3.2.2 Endogeneity and Cross-Sectional Dependence

The study accounts for potential endogeneity and cross-sectional dependence among countries. Pesaran's CD tests indicate significant cross-sectional dependence in financial development, mobile penetration, and trade openness, justifying the use of robust standard errors and panel-corrected methods.

3.2.3 Stationarity and Cointegration

Panel unit root tests, including Levin-Lin-Chu (LLC) and CIPS (CADF), were employed to assess the stationarity of variables. Financial development, mobile penetration, and trade openness exhibit mixed integration properties, with evidence of $I(0)$ and $I(1)$ processes depending on the test. Cointegration among the variables was examined using Pedroni, Kao, and Westerlund tests. The Kao and Westerlund tests indicate long-run equilibrium relationships, suggesting the appropriateness of error-correction or panel regression techniques for modeling the relationships.

3.4 Robustness Checks

Several robustness checks were undertaken. Variance inflation factors (VIF) were computed to assess multicollinearity, with results indicating minimal collinearity (mean VIF = 1.26). Both linear regression and alternative specifications (including lagged financial development) yield consistent positive effects of mobile penetration on financial development. Panel heterogeneity was formally tested using Pesaran and Yamagata (2008) and Blomquist & Westerlund (2013) delta tests, confirming the presence of heterogeneous slopes across countries.

3.5 Estimation Strategy

The empirical analysis proceeds in several stages. First, pooled OLS regression is employed to establish baseline associations between mobile penetration, trade openness, and financial development. Next, both fixed and random effects panel regressions are conducted to account for unobserved country-specific heterogeneity. The Hausman specification test, using a generalized approach, is then applied to determine the most appropriate model between fixed and random effects. Subsequently, unit root and cointegration analyses are performed to assess the stationarity of the variables and to confirm the existence of long-run equilibrium relationships. Finally, a series of robustness checks, including variance inflation factor (VIF) diagnostics and alternative lagged specifications, are undertaken to ensure the reliability and consistency of the results. All statistical analyses are conducted using Stata 17, and standard significance levels of 1%, 5%, and 10% are applied.

4. Results

4.1 Descriptive Statistics

Table 1 presents the descriptive statistics of the key variables. Financial development (FD) has a mean of 65.63% of GDP, with substantial variation across countries ($SD = 42.47$). Mobile penetration (MP) averages 95.62 subscriptions per 100 people, while trade openness (TO) averages 81.37% of GDP, indicating high heterogeneity in the sample.

Table 1: Descriptive Statistics

Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
FD	152	65.63	42.469	12.02	164.095
MP	152	95.621	42.679	6.219	181.222
TO	152	81.374	50.079	24.702	203.855

4.2 Correlation Analysis

The correlation matrix (Table 2) shows that FD is positively correlated with MP ($r = 0.606$) and TO ($r = 0.843$), suggesting that countries with higher mobile penetration and trade openness tend to have more developed financial systems.

Table 2: Correlation Matrix

Matrix of correlations

Variables	FD	MP	TO
FD	1.000		
MP	0.606	1.000	
TO	0.843	0.454	1.000

4.3. Dynamic Panel Regression (GMM)

To account for endogeneity and the persistence of financial development, a dynamic panel regression using system GMM was employed (Table 3). The lagged dependent variable (L.FD) captures the persistence of financial development, while MP remains the main explanatory variable.

Table 3: Dynamic Panel GMM Regression

Regression results

FD	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
L	.495	.025	20.05	0.000	.447	.544	***
MP	.157	.026	6.03	0.000	.106	.208	***
Mean dependent var		66.528	SD dependent var			42.718	
Number of obs		136	Chi-square			442.100	

*** $p < .01$, ** $p < .05$, * $p < .1$

The results indicate that FD exhibits strong persistence, while mobile penetration continues to have a positive and significant effect even after controlling for dynamic endogeneity.

4.4. Cross-Sectional Dependence

Pesaran CD tests (Table 4) indicate significant cross-sectional dependence for FD, MP, and TO, suggesting that shocks in one country may influence others.

Table 4: Cross-Sectional Dependence Tests

Variable	CD Statistic	p-value	Decision
FD	4.933	0.000	Cross-sectional dependence present
MP	20.851	0.000	Cross-sectional dependence present
TO	6.557	0.000	Cross-sectional dependence present

4.5. Fixed vs Random Effects

Fixed-effects regression shows MP is positively and significantly associated with FD (0.168, $p < 0.01$), with similar results in the random-effects model (0.172, $p < 0.01$). The Hausman test indicates that standard assumptions are violated, suggesting a generalized Hausman approach (suest) for reliable model selection.

Table 5 & 6: Fixed and Random Effects Regression

Fixed Effect Regression

FD	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
MP	.168	.022	7.69	0	.125	.211	***
Constant	49.593	2.206	22.48	0	45.232	53.954	***
Mean dependent var		65.630	SD dependent var			42.469	
R-squared		0.292	Number of obs			152	
F-test		59.065	Prob > F			0.000	
Akaike crit. (AIC)		1088.133	Bayesian crit. (BIC)			1094.180	

*** $p < .01$, ** $p < .05$, * $p < .1$

Random Effect Regression

FD	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
MP	.172	.022	7.68	0	.128	.216	***
Constant	49.21	10.136	4.85	0	29.343	69.076	***
Mean dependent var		65.630	SD dependent var			42.469	
Overall r-squared		0.367	Number of obs			152	
Chi-square		58.995	Prob > chi2			0.000	
R-squared within		0.292	R-squared between			0.669	

*** $p < .01$, ** $p < .05$, * $p < .1$

5. Conclusion, Policy Implications, and Future Research

5.1 Conclusion

This study investigated whether mobile technology adoption drives financial development in developing countries using system GMM, cross-sectionally augmented panel unit root tests (CIPS), and heterogeneous panel cointegration methods (Kao and Westerlund), finding that mobile penetration exerts a positive and statistically significant effect on financial development (domestic credit to the private sector as a percentage of GDP) that is robust across fixed effects (0.168, $p < 0.01$), random effects (0.172, $p < 0.01$), and dynamic GMM specifications (0.157, $p < 0.01$), while also documenting strong path dependence in financial development (lagged coefficient = 0.495, $p < 0.01$) and significant cross-sectional dependence and slope heterogeneity across countries, confirming that the transaction cost reductions and information asymmetry mitigations theorized by financial intermediation theory operate at the macroeconomic level but are conditional on country-specific institutional characteristics.

5.2 Policy Implications

The positive and persistent effect of mobile penetration on financial development implies that investments in mobile network expansion constitute a viable policy lever for financial deepening, but the presence of slope heterogeneity indicates that mobile technology alone is insufficient, requiring policymakers to pursue a coordinated strategy that pairs mobile infrastructure investment with three complementary interventions: regulatory reforms enabling interoperability between mobile money platforms and formal banking institutions, data protection laws encouraging digital transaction record-keeping, and financial literacy programs

building trust in digital financial services among previously unbanked populations, particularly women and rural households.

5.3 Future Research Directions

Future research should extend this analysis by incorporating micro-level household or firm panel data to identify whether mobile technology drives financial development through intensive margin effects (increased credit to already-banked individuals) or extensive margin effects (new account openings among the unbanked), by employing active mobile money account penetration or digital transaction volume as alternative independent variables rather than mobile cellular subscriptions alone, and by tracking emerging fintech innovations including agent banking, blockchain-based remittances, and artificial intelligence credit scoring as they diffuse across developing economies to determine whether the relationships documented here for basic mobile penetration generalize to more sophisticated digital financial ecosystems.

CRedit Authorship Contribution Statement

M. Imtiaz handled writing – original draft, visualization, validation, software, methodology, and formal analysis. M. Aqib and M. Wasim handled writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data Availability

The data supporting this study will be made available from the corresponding author upon reasonable request.

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Appendix

Table 7: Pooled OLS Regression

Regression results

FD	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
MP	.2	.023	8.76	0.000	.155	.245	***
TO	.213	.055	3.90	0.000	.106	.32	***
Constant	29.125	9.696	3.00	0.003	10.122	48.128	***
Mean dependent var		65.630	SD dependent var			42.469	
Overall r-squared		0.744	Number of obs			152	
Chi-square		78.460	Prob > chi2			0.000	
R-squared within		0.322	R-squared between			0.815	

*** $p < .01$, ** $p < .05$, * $p < .1$

Table 8: Linear Regression

FD	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
MP	.279	.044	6.41	0.000	.193	.365	***
TO	.607	.037	16.33	0.000	.533	.68	***
Constant	-10.448	4.219	-2.48	0.014	-18.786	-2.11	**
Mean dependent var		65.630	SD dependent var			42.469	
R-squared		0.773	Number of obs			152	
F-test		253.646	Prob > F			0.000	
Akaike crit. (AIC)		1350.614	Bayesian crit. (BIC)			1359.686	

*** $p < .01$, ** $p < .05$, * $p < .1$

Table 9: Panel Cointegration Test Results

Test Method	Test Statistic	Statistic Value	p-value	Significance	Cointegration Decision
Pedroni Test	Modified Phillips–Perron t	0.3015	0.3815	—	No cointegration
	Phillips–Perron t	-1.2377	0.1079	*	Weak evidence
	Augmented Dickey–Fuller t	-0.7826	0.2169	—	No cointegration
Kao Test	Modified Dickey–Fuller t	-2.1734	0.0149	**	Cointegration exists
	Dickey–Fuller t	-2.0430	0.0205	**	Cointegration exists
	Augmented Dickey–Fuller t	-2.1505	0.0158	**	Cointegration exists
	Unadjusted Modified DF t	-2.1450	0.0160	**	Cointegration exists
	Unadjusted DF t	-2.0316	0.0211	**	Cointegration exists



Test Method	Test Statistic	Statistic Value	p-value	Significance	Cointegration Decision
Westerlund Test	Variance Ratio	-1.5903	0.0559	*	Cointegration (weak)

Table 10. Panel Unit Root and Integration

Variable	Test Method	Model Form	Test Statistic	p-value	Significance	Order of Integration
FD	LLC	Level	-1.8495	0.0322	**	I(0)
	CIPS (CADF)	Level	-2.226	0.087	*	I(0) (weak)
	LLC	First Difference	-3.8430	0.0001	***	I(1)
	CIPS (CADF)	First Difference	-3.075	0.000	***	I(1)
MP	LLC	Level	-5.9323	0.0000	***	I(0)
	CIPS (CADF)	Level	-1.846	0.375	—	Non-stationary
	LLC	First Difference	-2.9343	0.0017	***	I(1)
	CIPS (CADF)	First Difference	-3.256	0.000	***	I(1)
TO	LLC	Level	-3.1539	0.0008	***	I(0)
	CIPS (CADF)	Level	-1.639	0.599	—	Non-stationary
	LLC	First Difference	-6.8577	0.0000	***	I(1)
	CIPS (CADF)	First Difference	-3.204	0.000	***	I(1)

Table 11. Heterogeneity

Test Method	Statistic	Value	p-value	Significance	Decision
Pesaran & Yamagata (2008)	Delta (Δ)	9.269	0.000	***	Reject H_0 (Heterogeneity present)
	Adjusted Delta (Δ_{adj})	10.101	0.000	***	Reject H_0 (Heterogeneity present)
Blomquist & Westerlund (2013)	Delta (Δ)	9.720	0.000	***	Reject H_0 (Heterogeneity present)
	Adjusted Delta (Δ_{adj})	10.592	0.000	***	Reject H_0 (Heterogeneity present)



Table 12. Hausman Specification Test (Fixed Effects vs Random Effects)

Variable	FE Coefficient (b)	RE Coefficient (B)	Difference (b – B)	Std. Error
MP	0.1677	0.1717	-0.0040	—

Hausman Test Statistics

Statistic	Value
Null Hypothesis (H ₀)	Difference in coefficients not systematic (RE preferred)
χ^2 (1)	-0.68
Prob > χ^2	Not reported (invalid test)
Decision	Test assumptions violated
Recommended Action	Use generalized Hausman test (suest)