

# **The Role of Stock Markets in Economic Growth: Empirical Evidence from Panel Data Analysis**

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**POVZETEK:** Raziskava opisuje povezavo med razvojem trgovinskih trgovin in ekonomskim rastom, uporabljajoč panelno podatkovno analizo. Izpeljana je, da je povezava pozitivna in značilna v visoko dohodnih državah, vendar slabija in neznatna v nizko in srednje dohodnih državah. Kratek panel VECM kaže, da se prilagodilni proces razlikuje glede na različne ravni finančnega razvoja. Izpeljane so, da finančno manj razvijene države lahko premočno prednostno prejema podpora od oboljelih tržnih institucij, boljše likvidnosti in izboljšane regulativne kakovosti.

**METODA:** Raziskava uporablja panelno cointegracijsko testiranje, fully modified OLS in panelni VECM. Podatki se razdelijo v 36 državah od leta 2003 do 2022.

## **KLJUČNE UGOTOVITVE:**

- Povezava med trgovinsko kapitalizacijo in ekonomskim rastom je pozitivna in značilna, vendar je večja v visoko dohodnih državah.
- Kratek prilagodilni proces je bidirekcijski v visoko dohodnih državah, vendar se lahko prilagodi le od razvoja trgovin do rasti v nizko in srednje dohodnih državah.
- Prilagodilni proces je neenakoten glede na ravni finančnega razvoja, s tem da države z nizko razvojno stopnjo se prilagajajo hitreje in pogostejše, vendar države z višjo razvojno stopnjo se prilagajajo pomembno pomembnejše in pogostejše.

**POMEN ZA TRGOVANJE:** Izpeljana je, da finančno manj razvijene države lahko premočno prednostno prejema podpora od oboljelih tržnih institucij, boljše likvidnosti in izboljšane regulativne kakovosti. To pomeni, da je pomembno, da takšne države prilagajajo svoje tržne institucije, ki jih običajno oblikujejo razvoj finančnega sistema, za boljšo prilagodljivost in podporo ekonomske rasti.

# The Role of Stock Markets in Economic Growth: Empirical Evidence from Panel Data Analysis \*

İshak Demir<sup>†</sup>

## Abstract

Stock market development is widely viewed as an important component of economic performance, influencing how economies mobilise capital, allocate resources, and support long-term growth. This study explores the link between stock market development and economic growth using a quarterly panel of 36 countries from 2003 to 2022. Employing panel cointegration tests, fully modified OLS, and a panel vector error correction framework, we analyse both the long-run and short-run dynamics of this relationship. The long-run association between stock market capitalisation and economic growth is positive and significant, and the magnitude of this effect is substantially larger in high-income economies. Short-run causality is bidirectional in high-income countries but flows only from stock market development to growth in low- and middle-income countries. A threshold panel VECM, which uses financial development level to endogenously identify regimes based on financial maturity shows that the adjustment process is non-linear and depends on countries' level of financial development. The findings suggest that financially less developed economies may benefit from strengthening market institutions, improving liquidity, and enhancing regulatory quality to better harness the growth contributions of stock markets.

*Keywords:* Stock market, economic growth, financial development, cross-country difference, panel cointegration, threshold VECM

*JEL Classification:* C23, O16, G0

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# 1 Introduction

Financial market development refers to the expansion, deepening, and improved functioning of financial institutions and markets that facilitate the mobilisation and allocation of capital (Levine, 1997; IMF, 2021). Economic growth, in turn, reflects the sustained increase in a country's productive capacity and is commonly measured through changes in real GDP. A long-standing body of research suggests a close connection between the two: as financial markets evolve, they reduce frictions in the saving–investment process, enhance risk sharing, improve information transmission, and allocate capital more efficiently, thereby supporting long-run growth (Schumpeter, 1912; King & Levine, 1993; Levine, 1997).

Within this broader literature, the role of the stock market has attracted growing attention. Stock markets facilitate capital mobilisation, improve liquidity, aggregate dispersed information, and support risk-sharing, all of which are central mechanisms through which financial systems may enhance economic performance. Theoretically, stock markets can stimulate growth by improving the allocation of resources toward productive investment (Greenwood & Jovanovic, 1990; Levine, 1991), reducing transaction and liquidity constraints (Bencivenga & Smith, 1991; Levine & Zervos, 1996), and enabling investors to diversify risk more efficiently (Obstfeld, 1994). Stock prices also embed valuable information about firms' future prospects, enhancing corporate monitoring and guiding investment decisions (Grossman & Stiglitz, 1980; Holmström & Tirole, 1993). These functions indicate that stock market development may be an important driver of long-term economic performance, making it essential to understand the conditions under which stock markets most effectively support economic growth.

Despite extensive theoretical and empirical study, the evidence on the stock market–growth relationship remains mixed. Cross-country and panel studies such as King and Levine (1993), Levine, Loayza, and Beck (2000), and Khan and Senhadji (2000) report a positive association between stock market indicators and economic growth. Other studies find weaker or context-dependent effects, particularly in advanced economies where banking sectors are already dominant (Harris, 1997; Arestis, Demetriades, & Luintel, 2001). These differing conclusions suggest that the contribution of stock markets to growth may depend on structural characteristics such as financial development, institutional quality, and the stage of economic development. This motivates a further investigation into how stock market development associated with economic growth under different conditions, allowing for cross-country heterogeneity, potential non-linearity in the relationship, and differences across income groups.

This study focuses specifically on the role of stock market development, measured through market capitalisation relative to GDP as a potential driver of economic growth across a broad sample of 36 developed and developing economies. Market capitalisation captures the size

and depth of equity markets and is widely used in the literature as a measure for stock market development. Understanding how stock markets contribute to economic performance is essential for policymakers aiming to allocate capital more efficiently, promote financial stability, and support sustainable long-run growth.

This study differs from existing studies in three ways. First, using a quarterly panel of 36 countries for 2003Q1–2022Q3, we reassess the long-run relationship between stock market development and economic growth by applying panel cointegration and FMOLS estimators that address potential endogeneity and allow the long-run slope coefficients to vary freely across countries rather than imposing the homogeneity assumed in much of the existing cross-country literature. Second, we analyse the short-run and long-run dynamics jointly through a panel vector error correction model, allowing us to distinguish feedback effects from transient fluctuations. Third, we consider whether the stock market–growth relationship differs systematically across levels of economic development by analysing country groups and by employing a threshold panel VECM based on the IMF’s Financial Development Index. This allows us to test whether the growth effects of stock market development vary with the degree of financial maturity, an aspect that has received limited empirical attention.

Our results show that the relationship between stock market capitalisation and economic growth is both heterogeneous and state-dependent. For the full sample, long-run FMOLS estimates indicate a positive association between market capitalisation and economic growth. This effect is strong and statistically significant in high-income countries but weak and insignificant in low- and middle-income economies. Short-run VECM estimates show bidirectional causality between stock market activity and output in the full sample and in high-income countries, while in lower-income economies short-run causality runs only from stock market development to growth. The threshold panel VECM, which uses the IMF Financial Development Index to endogenously identify regimes based on financial maturity, further demonstrates that the speed of adjustment differs sharply across regimes: countries with low levels of financial development exhibit rapid and pronounced adjustment to long-run equilibrium, whereas those with higher financial development adjust more slowly and gradually. Together, these findings indicate that financial development conditions the strength and dynamics of the stock market–growth nexus.

The rest of the paper proceeds as follows. Section 2 reviews the theoretical and empirical foundations of the finance–growth nexus with emphasis on stock markets. Section 3.1 describes the data and outlines the econometric framework. Section 4 presents and interprets the empirical findings. Section 5 discusses the empirical finding implications and Section 6 concludes.

## 2 A Review on the relationship between stock market development and economic growth

### 2.1 Theoretical foundations

Understanding the link between stock market development and economic growth requires a theoretical framework that explains how financial systems influence real economic activity. Two strands of economic theory provide the conceptual grounding for this relationship: financial intermediation theory and endogenous growth theory.

Financial intermediation theory examines how financial systems mobilise savings, allocate capital, facilitate risk sharing, and reduce information asymmetries. Foundational contributions by Patinkin (1955), Goldsmith (1969), McKinnon (1973), and Shaw (1973) highlight the role of financial intermediaries in promoting productive investment. Subsequent theoretical models extend these insights to encompass stock markets as decentralised intermediaries. In the frameworks developed by Greenwood and Jovanovic (1990) and Bencivenga and Smith (1991), equity markets enhance the efficiency of financial intermediation by enabling risk diversification, providing liquidity, and aggregating information about firms' future prospects. These mechanisms directly affect the allocation of resources to the most productive investment opportunities, reduce financing constraints, and increase the economy's long-run growth potential. In this sense, stock markets act not merely as trading platforms but as integral components of the broader financial architecture that support capital formation and improve productive efficiency.

Endogenous growth theory further reinforces the role of stock markets in sustaining long-term growth. The models by Romer (1986), Lucas (1988), and Romer (1990) emphasise the contributions of knowledge accumulation, innovation, and human capital formation to persistent growth. Building on these ideas, King and Levine (1993) and Levine (1997) demonstrate that financial markets—particularly stock markets—can accelerate technological progress by reducing the cost of capital, reallocating savings toward high-return projects, and facilitating investment in innovative and high-growth sectors. Under this framework, stock markets are viewed as mechanisms that support productivity improvements by rewarding efficient firms, providing financing for innovation, and encouraging resource reallocation from low-productivity to high-productivity sectors.

Together, these theories establish a clear conceptual rationale for examining stock market development as a structural driver of long-run economic performance through channels such as capital allocation, liquidity provision, risk diversification, and productivity enhancement <sup>1</sup>

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<sup>1</sup>For foundational discussions of specific transmission channels from stock markets to economic growth, see:

## 2.2 Empirical literature

Empirical evidence on the stock market–growth nexus is extensive but not uniform, and findings differ systematically across developed, emerging, and developing-country settings. In advanced and cross-country panels, King and Levine (1993), Khan and Senhadji (2000), and Levine et al. (2000) show that financial development, including stock market deepening, contributes to long-run output expansion, while Atje and Jovanovic (1993) report a significant positive correlation between stock market activity and growth across a panel of 40 countries spanning developed and developing economies. For emerging and developing markets specifically, Levine and Zervos (1996) highlight the role of stock market liquidity in fostering long-term growth, Beck, Levine, and Loyaza (2000) and Rousseau and Wachtel (1998) report positive influences of stock markets on subsequent growth across broad emerging-market samples, and Cooray (2010) finds that stock markets are particularly important for long-term growth in developing economies, consistent with the view that financial deepening supports structural transformation in less mature financial systems.

By contrast, evidence from advanced economies with already well-developed banking sectors is more mixed. Harris (1997) argues that stock market development contributes little additional explanatory power to growth once other factors are controlled for, while Arestis et al. (2001), using quarterly data for five developed economies, find that both banking and stock market development contribute to growth but that the effect of banking development is considerably larger, suggesting that the marginal contribution of stock markets may be smaller where alternative channels of intermediation are already mature. Evidence on the temporal dimension of the relationship is also mixed across country types: Demirgüç-Kunt and Levine (1996) document a long-term association between stock market development and growth across a broad country sample, whereas Al-Awad and Harb (2005) find short-run causality running from output to financial development rather than the reverse in a sample of Middle Eastern developing economies.

Taken together, this body of evidence suggests a systematic pattern rather than a simple list of disparate findings: the contribution of stock markets to growth tends to be strong and robust in emerging and developing economies undergoing financial deepening, where stock market expansion represents a genuine widening of the menu of intermediation channels available to firms, while in advanced economies with already-developed banking systems the marginal contribution of stock markets is smaller and more context-dependent. This pattern is consistent with the view that the growth effect of stock market development is conditional on the broader

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capital allocation and productivity enhancement (Greenwood & Jovanovic, 1990; King & Levine, 1993), liquidity provision (Levine & Zervos, 1996; Bencivenga, Smith, & Starr, 1996), risk diversification (Levine, 1991; Pagano, 1993), and information aggregation and monitoring (Greenwood & Jovanovic, 1990; Grossman & Stiglitz, 1980).

financial structure and stage of development of the economy in question, a possibility that motivates the income-group and threshold-based heterogeneity analysis pursued in this paper.

Overall, the empirical literature suggests that the impact of stock markets on growth is heterogeneous and depends on factors such as financial depth, income level, institutional quality, and the degree of financial development. Demirgüç-Kunt and Levine (1996) further show that well-developed financial markets support long-term growth by improving capital allocation and market efficiency, reinforcing the view that the quality and depth of financial institutions matters as much as their size.

The remainder of the paper turns to the data and empirical strategy used to examine this heterogeneity directly, first through panel cointegration and FMOLS estimation across the full sample and income groups, and then through the threshold panel VECM, which lets the data, rather than an income classification, identify where the regime boundary in financial maturity lies.

### **3 Data and Methodology**

#### **3.1 Data and measurement of variables**

The sample for this study comprises quarterly data series from 36 countries, spanning the period from 2003q1 to 2022q3 (see Table 9).<sup>2</sup> The countries were selected primarily because their exchanges, individually or as part of the consolidated regional groupings described above, are members of the World Federation of Exchanges and together account for the substantial majority of global stock market capitalisation and trading activity, ensuring that the sample is representative of the markets through which the bulk of global equity-related capital allocation actually takes place. The sample also spans a wide range of stages of economic and financial development, from advanced economies with long-established exchanges to emerging and developing markets undergoing active financial deepening, which is essential for the cross-country heterogeneity and threshold analysis that forms the core empirical contribution of this paper. A secondary, practical consideration was the availability of continuous quarterly data records throughout this time frame, which was necessary to construct a balanced panel suitable for the cointegration and error-correction techniques employed.

Data for the key variables, including real growth rate, market capitalisation ratio, real fixed capital ratio, inflation, real interest rate, and real exchange rate, were sourced from the World

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<sup>2</sup>See Table 9 in the appendix for data details. We consolidate certain countries into groups to align with stock exchanges. For example, the Nordic and Baltic group includes Denmark, Finland, and Sweden; the Euronext region comprises Belgium, France, Ireland, Netherlands, Norway, and Portugal.

Federation of Exchanges (WFE) and International Monetary Fund (IMF) databases. Below is a detailed description of each variable, its measurement, and the rationale behind its selection.

The dependent variable in this study is the growth rate of real GDP ( $y$ ), which is calculated as the percentage change in the natural logarithm of real GDP. This measure is preferred because it provides a clear picture of the economy's long-term growth trend, accounting for inflation. The use of logarithmic transformation helps mitigate potential issues with data non-normality and smoothens the growth rate, making it more suitable for long-term trend analysis. Real GDP growth is a standard and widely used indicator in economic studies, as it reflects the overall health of an economy (King & Levine, 1993; Levine et al., 2000). In particular, it aligns with the study's objective of examining the relationship between stock market development and economic growth. The use of real GDP ensures that the analysis focuses on genuine growth rather than the distortions that might arise from inflation.

The main explanatory variable in this study is stock market capitalisation ( $m$ ), which is measured by the stock market capitalisation ratio to nominal GDP. This ratio captures the size of the stock market relative to the overall economy. It is a widely used indicator in the literature because it reflects the stock market's ability to mobilise capital for investment, a crucial factor for fostering economic growth. This measure is preferred over alternatives such as stock market liquidity or turnover ratios, as it directly reflects the depth of the stock market, which is hypothesized to influence growth by facilitating investment. Levine (1997) and Beck et al. (2000) have used this measure in similar studies to assess the impact of financial development on growth.

Several control variables are included in the model to account for other factors that influence economic performance. The fixed capital ratio ( $c$ ) is measured as the percentage ratio of fixed capital to GDP. This ratio reflects investment in physical assets, such as machinery, infrastructure, and buildings, which are essential for long-term economic growth. The relationship between fixed capital and growth is well-established in the literature, with studies such as Solow (1956) and King and Levine (1993) showing that capital accumulation enhances productivity and drives economic expansion.

The inflation rate ( $p$ ) is measured as the percentage change in the Consumer Price Index (CPI). Inflation is typically associated with negative effects on growth, as it erodes purchasing power, creates economic uncertainty, and discourages investment. This negative relationship is supported by Fischer (1993) and Akinsola and Odhiambo (2017), who find that high inflation adversely impacts long-term growth by reducing stability and investor confidence.

The real interest rate ( $r$ ) is calculated as the nominal lending rate adjusted for inflation. Real interest rates directly affect borrowing costs, influencing investment and consumption decisions. High interest rates can discourage borrowing and investment, thereby slowing down

economic growth. The negative effect of high interest rates on growth has been documented by Scorcu (1997) and Villanthenkodath (2022), who argue that elevated interest rates generally constrain economic activity by making borrowing more expensive.

Finally, the real exchange rate (*rer*) is measured as the percentage change in the natural logarithm of the real effective exchange rate index, adjusted for inflation. The real exchange rate affects a country's competitiveness in international trade. While its effect on economic growth can vary, depending on factors such as trade openness and the structure of the economy, it remains an important variable to consider. Dufrenot, Fougère, and Nguyen (2005) and Caporale and Škare (2014) highlight the context-dependent nature of exchange rate fluctuations on growth.

Table 1 reports descriptive statistics for the key variables used in the analysis; we discuss the main stylised facts emerging from this table in Section 4, alongside the formal panel diagnostic tests.

## 3.2 The model and econometric methodology

This section discusses the methodology for estimated short run and long run relationship between the stock market and growth.

### 3.2.1 The model

The relationship between economic growth and stock market capitalisation is captured by the following equation:

$$y_{it} = \alpha_i + \beta_1 m_{it} + \gamma' X_{it} + \epsilon_{it} \quad (1)$$

The subscripts  $i$  and  $t$  represent country and time, respectively.  $y_{it}$  stands for the growth rate for real GDP,  $m_{it}$  represents the stock market capitalisation ratio to nominal GDP, and  $X_{it}$  is a vector of control macroeconomic variables that can potentially influence a country's output growth, including the fixed capital ratio to nominal GDP, the inflation rate, the real interest rate, and the real exchange rate.  $\alpha_i$  denotes a country-specific intercept, which absorbs time-invariant country-specific heterogeneity. Consistent with the Grouped Mean and Weighted Pooled FMOLS estimators described in the following subsections, this intercept is allowed to vary freely across countries rather than being pooled.

### 3.2.2 Cross-sectional dependence and panel unit root test

Panel data analysis utilizes observations across entities (e.g., countries, firms) and time periods, offering a powerful tool for empirical investigations. A critical assumption in this framework is

the cross-sectional independence of the error terms. This implies that unobserved factors that influence the outcome of one entity in a given period do not affect the outcome of another entity in the same period. However, in macroeconomic studies, this assumption is typically violated. Common shocks, spillover effects, and regional trends can induce cross-sectional dependence, where the error terms exhibit correlation across entities. Ignoring this dependence can have severe consequences for panel data estimation.

One major implication of neglecting cross-sectional dependence is the loss of estimator efficiency<sup>3</sup>. Standard errors become unreliable, potentially leading to spurious significance levels for estimated coefficients. Consequently, inferences about the relationships between variables in the model become compromised. Additionally, test statistics predicated on the assumption of independent errors become invalid. This undermines the ability to draw accurate conclusions about the model's parameters.

Given the prevalence of cross-sectional dependence in macroeconomic data, it is crucial to assess its presence before panel unit root testing and estimating panel data models. Fortunately, there are several diagnostic tests for this purpose such as Pesaran (2004) CD test<sup>4</sup>. This test utilises the residuals from a panel regression with individual fixed effects and constructs a statistic to evaluate the degree of cross-sectional dependence.

The presence of cross-sectional dependence renders conventional unit root tests invalid. To address this issue and analyze the stationarity properties of our series, we focus on the cross-sectionally augmented Im-Pesaran-Shin (CIPS) panel unit root test developed by M. H. Pesaran (2007). The CIPS test builds upon the Panel Analysis of Non-stationarity in Idiosyncratic and Common components (PANIC) test proposed by Bai and Ng (2004), which decomposes data into common factors and idiosyncratic components. While PANIC assesses the stationarity of each component separately, the CIPS test assumes that cross-sectional dependence arises from common unobserved factors influencing the residuals and calculates the average of individual cross-sectionally augmented Dickey-Fuller (CADF) statistics to determine the presence of unit roots<sup>5</sup>.

By utilising the CIPS test, which is informed by the foundational PANIC approach, we can more effectively address the challenges posed by cross-sectional dependence and accurately assess the stationarity of our macroeconomic data series.

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<sup>3</sup>The implication of cross section dependence can be seen from Gengenbach, Palm, and Urbain (2009)

<sup>4</sup>This test is summarised in the section A2.1. For more details about the CD test see Pesaran (2004)

<sup>5</sup>Further details about these tests are provided in Section A2.2

### 3.2.3 Panel cointegration equation and testing

To assess the presence of long-run equilibrium relationships among the variables, we followed Pedroni (2004) the panel cointegration equation which can be defined as follows:

$$Y_{it} = \alpha_i + \lambda_i t + \sum_{i=1}^l \beta_{it} X_{it} + \varepsilon_{it} \quad (2)$$

$$\varepsilon_{it} = \rho_i \varepsilon_{it-1} + u_{it} \quad (3)$$

where  $Y_{it}$  and  $X_{it}$  represent the observable variables with dimensions of (N\*T),  $l$  denotes the number of cross-sectional units,  $\alpha_i$  denotes individual fixed effects,  $\lambda_i$  refers to individual time trends, capturing country-specific deterministic trend effects. Additionally, the vector of slope coefficients, denoted by  $\beta_{it}$ , is permitted to vary by countries, and  $\varepsilon_{it}$  represents the error term which represented in autoregressive form.

(Pedroni, 2004)'s approach allows for heterogeneity in both the cointegration vectors (the long-term relationships) across the panel units and the panel structure itself (unbalanced panels with missing data). It proposes various statistics, categorised into "Within" and "Between" dimensions. Within-dimension tests (*panel - v*, *panel - rho*, *panel - PP*, and *panel - ADF*) analyse individual unit residuals and then average the results across units. They focus on rejecting the null hypothesis of no cointegration for each unit individually. On the other side, between-dimension tests (group-rho, group-PP, and group-ADF) focus on the average behaviour of the residuals across all units. They test the null hypothesis of no cointegration for the entire panel collectively. Both sets aim to test the null hypothesis of no cointegration,  $H_0 : \rho_i = 1$ ; but differ in how they approach the alternative hypothesis.

For additional robustness checks, we employ (Kao, 1999)'s tests, which are akin to the panel ADF statistic within the framework in (Pedroni, 2004), employing Dickey-Fuller (DF) and Augmented Dickey-Fuller (ADF) frameworks to examine cointegration. However, Kao's test distinguishes itself from (Pedroni, 2004)'s within-dimension ADF test by several characteristics: First, it introduces cross-sectional intercepts in the first-stage regression (Eq. 3), enabling the incorporation of individual intercepts across units. Second, it assumes homogeneous coefficients in the first-stage regression, implying uniform slope coefficients in the cointegration relationship across all units. Third, it excludes any trend coefficients in the first-stage regression, thereby eliminating trends from consideration. Despite these distinctions, Kao's test shares the same null hypothesis (no cointegration) and similar alternative hypotheses as Pedroni's tests<sup>6</sup>.

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<sup>6</sup>For comprehensive insights into these tests and their critical values, it is advisable to refer to the original works by (Pedroni, 2004) and (Kao, 1999).

### 3.2.4 Panel FMOLS estimates

Once cointegration is confirmed, we estimate the long-run relationship between the variables (in Eq.1) using the Fully Modified Ordinary Least Squares (FMOLS) method developed by Pedroni (2000).

While Ordinary Least Squares (OLS) is a popular choice for panel regressions, it suffers from two limitations in our context. First, OLS assumes no serial correlation in the error terms. However, in cointegrated panels, the residuals often exhibit serial dependence, leading to biased and inefficient estimates. Second, in the presence of cointegration, the independent variable ( $X_{it}$ ) may be endogenous, meaning it's potentially correlated with the error term. This can also lead to biased OLS estimates.

To address these limitations, we employ the FMOLS method proposed by (Pedroni, 2000). FMOLS incorporates adjustments to account for serial correlation in the error terms, providing more reliable and efficient estimates. Additionally, the method addresses endogeneity bias by modifying the regression framework, allowing for the estimation of consistent long-run coefficients.

FMOLS modifies the conventional OLS estimator to account for both serial correlation and endogeneity. It achieves this by augmenting the cointegrating regression with lagged differences of the regressors, controlling for the feedback effect between variables. The FMOLS model is represented as follows:

$$Y_{it} = \alpha_i + \beta X_{it} + \sum_k^K \gamma_{ik} \Delta X_{it-k} + \varepsilon_{it} \quad (4)$$

Here, FMOLS incorporates the constant term,  $\alpha_i$ , and the potential correlation between the error term and the differenced regressors ( $\Delta X_{it}$ ). Vector error process  $X_{it} = (\varepsilon_{it}, \Delta X_{it})$  is assumed to be stationary with long-run covariance matrix  $\Omega_i$ . This covariance matrix can be decomposed into  $\Omega_i^0$  and a weighted sum of autocovariances  $\Gamma_i + \Gamma_i'$ .

Non-parametric adjustments are applied to the dependent variable and the estimated long-run coefficients obtained from regressing the adjusted dependent variable on the regressors. The FMOLS estimator can be written as follows:

$$\hat{\beta}_{FMOLS} = N^{-1} + \sum_{i=1}^N \left( \sum_{t=1}^T (X_{it} - \bar{X}_i)^2 \right)^{-1} \left( \sum_{t=1}^T (X_{it} - \bar{X}_i) Y_{it}^* - T \tau_i \right) \quad (5)$$

where  $Y_{it}^* = (Y_{it} - \bar{Y}_i) - \left( \frac{\Omega_{21i}}{\Omega_{22i}} \right) \Delta X_{it}$  and  $\tau_i = \hat{\Gamma}_{21i} + \hat{\Omega}_{21i}^0 - \left( \frac{\hat{\Omega}_{21i}}{\hat{\Omega}_{22i}} \right) (\hat{\Gamma}_{22i} + \hat{\Omega}_{22i}^0)$ . The corresponding t-statistic for the FMOLS estimator converges asymptotically to a standard normal

distribution:

$$\hat{t}_{\hat{\beta}_{FMOLS}} = N^{-1/2} \sum_{t=1}^T (\hat{\beta}_{FMOLS,i}^* - \beta) \left( \hat{L}_{11i}^{-1} \sum_{t=1}^T (X_{it} - \bar{X}_{it})^2 \right)^{1/2} \quad (6)$$

where the traditional FMOLS estimator applied to each panel member is  $\hat{\beta}_{FMOLS,i}^*$ .

In the Panel FMOLS estimation, we account for potential heterogeneity across cross-sectional units due to the diverse countries in our sample. Specifically we employed both the weighted pooled and group mean panel FMOLS estimators. The weighted pooled FMOLS accounts for cross-sectional heterogeneity by allowing each unit to have its own long-run covariance matrix, which is used to re-weight the data prior to computing the pooled estimator. This approach relaxes the assumption of homoskedastic and identically distributed errors across panels. On the other hand, the group mean FMOLS allows for full heterogeneity in the slope coefficients by estimating separate FMOLS regressions for each cross-section and then averaging the resulting coefficients. Unlike the pooled specification, the group mean estimator does not impose homogeneity of the long-run coefficients across cross-sectional units.

This approach provides reliable estimates of the long-run relationships within our heterogeneous panel data, addressing the limitations associated with OLS in the context of cointegrated variables. Given that the Pesaran (2004) CD test reported in Section 4 confirms cross-sectional dependence in our panel, we return to this issue directly in Section 4, where we report a complementary robustness exercise alongside our main FMOLS results.

### 3.2.5 Panel Granger Causality test and VECM

The cointegrating relationship indicates a potential causal relationship, but the direction remains unclear. To explore the direction of short-run and long-run causality among economic growth and market capitalisation, a Panel VECM with a dynamic error correction term is employed. A key advantage of panel VECM is its ability to capture the feedback effects among variables. This allows us to examine the dynamic causal relationships within a temporal framework, as suggested by (Lütkepohl, 2005).

Our approach follows the (Engle & Granger, 1987) two-step procedure. In the first step, we estimate the long-run model (Eq. 3). Next, we employ the residuals obtained from this first-step regression to estimate a Panel VECM which is specified as follows:

$$\Delta y_{it} = c + \sum_{i=1}^n \beta_i \Delta m + \sum_{i=1}^n \Delta x'_{t-1} \gamma_i + \lambda (y_{t-1} - x'_{t-1} \delta - \delta_0 m_{t-1}) + v_t \quad (7)$$

Here, the error correction term,  $ECT_{t-1} = (y_{t-1} - x'_{t-1}\delta - \delta_0 m_{t-1})$ , represents the equilibrium error that is a deviation from the long-run relationship. In Equation (7), the long-run causality is assessed by the statistical significance of the error correction term ( $H_0 : \lambda \neq 0$ ). If this is not the case, the cointegration finding would not be reliable. Conversely, short-run causality is established by the statistical significance of the corresponding independent regressors ( $H_0 : \beta_i = 0 \forall i \in \{1, \dots, n\}$ ). If it can be rejected, there is no evidence of short-run causality.

Although the VECM is valuable for identifying the direction of causal relationships among variables, it has some limitations. Specifically, it is restricted to the selected sample period and does not provide insight into the sign of the impact. To address these shortcomings, we employ generalized impulse response analysis, preferring this approach over a simple Choleski factorisation, which is sensitive to variable ordering in the VECM. This approach offers a more comprehensive examination of the dynamic causal effects and reveals whether the impacts of innovations are positive or negative, as well as their short-run or long-run<sup>7</sup>.

### 3.2.6 Threshold Panel VECM

The standard VECM in Eq. (7) assumes a homogeneous adjustment mechanism across all countries. To allow the long-run dynamics to vary with financial development, we extend the model using a Threshold Panel VECM (TPVECM), following (Hansen, 1999) and (Khan & Senhadji, 2000).

Motivated by the finance–growth literature (e.g. (Demirgüç-Kunt & Levine, 2001; Rioja & Valev, 2004)), we use the IMF Financial Development Index ((IMF, 2021)) as the threshold variable  $q_{it}$ . The threshold value  $\gamma$  is estimated endogenously by a grid search that minimises the sum of squared residuals. The TPVECM for economic growth can be written as:

$$\begin{aligned} \Delta y_{it} = & c_i + \sum_{j=1}^n \beta_{ij} \Delta m_{it-1} + \sum_{j=1}^n \Delta x'_{it-j} \gamma_i \\ & + \lambda_1 ECT_{it-1} I(q_{it} \leq \gamma) + \lambda_2 ECT_{it-1} I(q_{it} > \gamma) + v_{it}, \end{aligned} \quad (8)$$

where  $\lambda_1$  denotes the speed at which economies below the financial development threshold adjust toward long-run equilibrium, and  $\lambda_2$  captures the corresponding adjustment for economies above the threshold. The indicator function  $I(\cdot)$  assigns observations to the low or high financial development regime based on the estimated threshold.

The statistical significance of the threshold effect is evaluated using the bootstrap likelihood ratio test proposed by (Hansen, 1999), which confirms the presence of two distinct financial

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<sup>7</sup>Detailed explanations of this technique can be found in the foundational works of Sims (1980) and Bernanke (1986).

development regimes. This approach allows the long-run adjustment mechanism to differ by financial maturity.

## 4 Empirical Results

In this section, we first present the descriptive statistics, cross-section dependence, panel unit root and panel cointegration test results. Second, Panel FMOLS were employed to estimate the long-run relationship, while the VECM estimation technique was applied to estimate the short-run and long-run relationships among the variables. Third, a VECM Granger causality test was conducted to assess causality between the variables. Finally, we analyze the generalized IRF over simple Choleski factorization which is insensitive to the VECM's order.

### 4.1 Descriptive statistics: key stylised facts

Table 1 reports descriptive statistics for the key variables. Three stylised facts stand out as directly relevant to the empirical strategy that follows. First, there is substantial cross-country heterogeneity in stock market development: the market capitalisation ratio ranges from 0.28 to 77.85 with a mean of 4.47, reflecting the coexistence in our sample of countries with shallow, nascent equity markets and others with very large, internationally-integrated exchanges. This heterogeneity is the empirical motivation for the income-group and threshold-based analysis pursued below. Second, real GDP growth averages a modest 0.71% per quarter but with a standard deviation of 1.59 and a range of  $-11.89\%$  to  $11.55\%$ , consistent with the sample period spanning the 2008 global financial crisis, the COVID-19 pandemic, and a range of other country-specific shocks. Third, several macroeconomic control variables, particularly inflation and the real interest rate, exhibit pronounced excess kurtosis and skewness (kurtosis of 84.92 and 47.26, respectively), reflecting episodes of high inflation and sharp monetary policy adjustment in a subset of developing economies in the sample. Together, these patterns indicate a panel with considerable cross-sectional heterogeneity in both the level of financial development and the macroeconomic environment, which we account for explicitly through heterogeneity-robust estimation (Grouped Mean and Weighted Pooled FMOLS) and through the income-group and threshold-based analysis presented later in this section.

Table 1: Descriptive statistics of variables

| Variables                | Mean  | Median | Maximum | Minimum | Std. Dev. | Skewness | Kurtosis |
|--------------------------|-------|--------|---------|---------|-----------|----------|----------|
| Market cap. ratio (m)    | 4.47  | 2.59   | 77.85   | 0.28    | 7.60      | 5.03     | 31.60    |
| Output (y)               | 0.71  | 0.76   | 11.55   | -11.89  | 1.59      | -0.99    | 12.20    |
| Capital share (c)        | 21.72 | 22.33  | 35.18   | 3.26    | 6.19      | -0.91    | 4.41     |
| Inflation (p)            | 0.76  | 0.59   | 24.91   | -3.51   | 1.21      | 5.20     | 84.92    |
| Real interest rate (r)   | 0.81  | 0.66   | 38.83   | -82.98  | 5.13      | -2.30    | 47.26    |
| Real exchange rate (rer) | -0.00 | 0.04   | 19.22   | -21.74  | 2.91      | -0.73    | 11.61    |

## 4.2 Cross-section dependence, panel unit root and panel cointegration test results

### 4.2.1 Cross-section dependence and panel unit root test results

Table 2 reports the results of the Pesaran (2004) CD test for individual series and the overall panel model with fixed effects. The null hypothesis of no cross-sectional dependence is rejected at the 1% significance level for all series and the panel model. This indicates the presence of significant error dependence across the countries, suggesting that the residuals are not independent and identically distributed.

Table 2: Cross-section dependence and panel unit root tests

| <i>Variables</i>         | CD statistics | CIPS statistics |
|--------------------------|---------------|-----------------|
| Output (y)               | 124.83*       | -2.15           |
| Market cap. ratio (m)    | 54.42*        | 2.55            |
| Capital share (c)        | 8.08*         | -2.54           |
| Inflation (p)            | 59.20*        | -2.23           |
| Real interest rate (r)   | 64.21*        | -1.92           |
| Real exchange rate (rer) | 9.99*         | -2.31           |
| Model 1                  | 124.06*       | —               |

Notes: For the Pesaran CD statistics, \*, \*\* and \*\*\* indicate that the test statistics are significant at the 1%, 5% and 10% levels, respectively. In Model 1, growth (dependent variable) is regressed on market cap ratio (independent variable) while controlling for capital share, inflation, real interest rate, and real exchange rate. The CIPS test employs a constant and trend under the null hypothesis of a unit root. The critical values for CIPS statistics from Pesaran (2007) are -2.78 (1%), -2.65 (5%), and -2.57 (10%).

The presence of cross-sectional dependence significantly impacts unit root testing in panel data. Since first-generation panel unit root tests assume independence across entities, they are unsuitable for our data, which shows dependency across countries<sup>8</sup>. Therefore, it is essential to use second-generation panel unit root tests that explicitly account for cross-sectional dependence to obtain reliable results.

<sup>8</sup>Consequently, the outcomes of first-generation panel unit root tests are not reported here.

Table 2 displays the outcomes of the CIPS tests for the panel. The findings indicate that we cannot reject the null hypothesis of a unit root for all series at 5% significance level, in the model with intercept and trend. In essence, all series appear to exhibit non-stationary behaviour within the panel<sup>9</sup>.

#### **4.2.2 Panel cointegration test results**

The results of seven panel cointegration tests suggested by (Pedroni, 2004) and (Kao, 1999) are reported in Table 3. The test results indicate that most statistics are statistically significant, and therefore the null hypothesis of no cointegration can be rejected at 1% significance levels. They support for the presence of cointegration among the economic growth, market capitalisation ratio and other macroeconomic variables.

The finding of cointegration between stock market capitalisation and economic growth suggests a long-term equilibrium relationship between these two variables. This indicates that, although both variables may experience short-term fluctuations, they tend to move together over the long run, adjusting towards a stable relationship. In practical terms, this means that stock market development and economic growth are mutually reinforcing, with changes in one influencing the other over time. This aligns with the finding of Demirgüç-Kunt and Levine (2001), which suggests that well-developed financial markets contribute to long-term economic growth by improving capital allocation and market efficiency.

#### **4.3 Panel FMOLS results**

Given the cointegration identified among our variables, we employ the FMOLS estimation methods, suitable for heterogeneous panels, to estimate the long-run equilibrium relationship. The results are presented in Table 4. Focusing on the core variables of our analysis, economic growth and market capitalisation ratio, the empirical findings reveal a statistically significant and positive association. This suggests that higher market capitalisation is positively associated with economic growth, and vice versa. Quantitatively, a 10% increase in the market capitalisation ratio is associated with a 0.028% increase in long-run economic growth. Conversely, a 1% rise in economic growth leads to a 4% increase in long-run market capitalisation ratio to GDP.

This result confirms a long-run positive relationship between stock market capitalisation and economic growth, aligning with previous studies that emphasize the role of stock markets in enhancing capital formation and economic development (e.g., (Levine, 1991)).

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<sup>9</sup>It's important to note that while the overall panel results indicate non-stationarity, further investigation of the idiosyncratic elements for each country might reveal stationary in some individual cases, with lag selection varying across countries. Additionally, the PANIC test yields similar results, supporting our conclusions.

Table 3: Panel cointegration tests

|                          | <i>Model 1</i> |         |         |         | <i>Model 2</i> |         |         |         |
|--------------------------|----------------|---------|---------|---------|----------------|---------|---------|---------|
|                          | F.E.           |         | F.E.T.  |         | F.E.           |         | F.E.T.  |         |
|                          | Value          | p-Value | Value   | p-Value | Value          | p-Value | Value   | p-Value |
| <i>Between-dimension</i> |                |         |         |         |                |         |         |         |
| Panel v-Statistic        | 3.19*          | 0.001   | 0.22    | 0.412   | 0.59           | 0.276   | 2.87*   | 0.002   |
| Panel rho-Statistic      | -32.55*        | 0.000   | -29.68* | 0.000   | -0.87          | 0.193   | -1.53** | 0.062   |
| Panel PP-Statistic       | -44.98*        | 0.000   | -48.65* | 0.000   | -2.57*         | 0.005   | -3.18*  | 0.001   |
| Panel ADF-Statistic      | -43.79*        | 0.000   | -44.85* | 0.000   | -2.88*         | 0.002   | -3.72*  | 0.000   |
| <i>Within-dimension</i>  |                |         |         |         |                |         |         |         |
| Group rho-Statistic      | -33.41*        | 0.000   | -28.60* | 0.000   | 1.11           | 0.866   | 0.80    | 0.788   |
| Group PP-Statistic       | -54.42*        | 0.000   | -59.83* | 0.000   | -1.92*         | 0.027   | -2.59*  | 0.005   |
| Group ADF-Statistic      | -51.13*        | 0.000   | -49.58* | 0.000   | -0.41          | 0.341   | -2.26*  | 0.012   |
| Kao ADF                  | -7.12*         | 0.000   |         |         | -2.18*         | 0.015   |         |         |

Notes: F.E. indicates t-tests employing fixed effects but no time effects in the regression model, while F.E.T. encompasses both fixed and time effects. In Model 1, the output is the dependent variable, and in Model 2, the market capitalization ratio serves as the dependent variable. The lag length is determined by selecting the model with the minimum Schwarz Information Criterion (SIC), which balances model fit with complexity.

Furthermore, the sample is stratified based on income level classifications established by the World Bank, dividing countries into high-income and low- and middle-income categories as the impact of stock market on long term economic growth can vary by overall economic development and the level of financial markets development<sup>10</sup>. The empirical results show a statistically significant and positive coefficient of 0.45 for the market capitalisation ratio in high-income countries. This indicates that a 10% increase in the market capitalisation ratio is associated with a 0.045% increase in real economic growth in the long term. This finding suggests a more pronounced positive correlation between stock market development and long-term economic growth within high-income economies compared to the overall sample. Conversely, the coefficient for low- and middle-income countries is negative, albeit statistically insignificant. This implies that the market capitalisation ratio does not show a clear long-term association with economic growth in these countries, and any observed negative association is insufficiently robust to draw definitive conclusions.

These findings suggest that stock market capitalisation generally promotes economic growth across all income groups, though the effect is more pronounced in high-income countries. In low- and middle-income countries, the long-run relationship is weaker, which can be attributed to challenges such as underdeveloped financial systems and structural inefficiencies.

These results align with the established notion that well-developed stock markets offer

<sup>10</sup>Country classification by income data obtained from the World Bank's World Development Indicators [www.databank.worldbank.org/source/world-development-indicators](http://www.databank.worldbank.org/source/world-development-indicators)

Table 4: Panel FMOLS results

|                                                          | Output            | Market cap. ratio |
|----------------------------------------------------------|-------------------|-------------------|
| <i>Output is the dependent variable</i>                  |                   |                   |
| Full panel FMOLS - weighted pooling                      | -                 | 0.357*<br>(0.010) |
| Full panel FMOLS - Grouped estimation                    | -                 | 0.286*<br>(0.092) |
| <i>Market cap. ratio is the dependent variable</i>       |                   |                   |
| Full panel FMOLS - weighted pooling                      | 0.037<br>(0.032)  | -                 |
| Full panel FMOLS - Grouped estimation                    | 0.041<br>(0.032)  | -                 |
| <i>Output is the dependent variable</i>                  |                   |                   |
| High income group panel - Grouped estimation             | -                 | 0.446*<br>(0.093) |
| Low/Middle income group panel FMOLS - Grouped estimation | -                 | -0.271<br>(0.219) |
| <i>Market cap. ratio is the dependent variable</i>       |                   |                   |
| High income group panel FMOLS - Grouped estimation       | 0.055<br>(0.047)  | -                 |
| Low/Middle income group panel FMOLS - Grouped estimation | -0.016<br>(0.019) | -                 |

Notes: \* and \*\* denote statistical significance at the 1% and 5% levels, respectively. Figures in the parentheses are standard errors. In our estimation, we employ a fixed effects term to account for unobserved country-specific characteristics that remain constant over time. To address heterogeneity across the cross-sectional units, we use both the weighted pooled and group mean FMOLS estimators. The weighted pooled FMOLS accounts for cross-sectional heterogeneity by allowing each unit to have its own long-run covariance matrix, which is used to re-weight the data prior to computing the pooled estimator. The group mean FMOLS allows for full heterogeneity in the slope coefficients by estimating separate FMOLS regressions for each cross-section and averaging the resulting coefficients.

greater benefits to high income countries by facilitating increased savings and efficient capital allocation towards more productive investments, ultimately driving economic growth.<sup>11</sup> They are also parallel with the findings of Demircuc-Kunt and Maksimovic (1996), who argue that firms with access to more developed stock markets tend to grow faster.

Taken together, the FMOLS results indicate that the long-run association between stock market capitalisation and economic growth is not uniform across countries but varies with their level of financial development. This heterogeneity, reflected in the contrast between high-income and low-/middle-income economies, motivates the subsequent VECM and threshold analysis, which examine potential non-linearities in greater depth.

These long-run cointegration results warrant a more critical interpretation than a simple positive association. A cointegrating relationship establishes that stock market capitalisation

<sup>11</sup>See (Levine, 1991, 1997; Capasso, 2006).

and economic growth move together in long-run equilibrium; it does not by itself establish that stock market expansion *causes* growth, nor rule out the possibility that the relationship instead reflects growth-driven market development, or a combination of both operating simultaneously. We address the direction of this relationship directly through the VECM and Granger causality analysis presented below, which shows bidirectional short-run causality in high-income countries but causality running predominantly from stock markets to growth in low- and middle-income countries.

These results can be interpreted through the lens of the supply-leading versus demand-following hypotheses from the finance-growth literature (Patrick, 1966; Levine, 1997). Supply-leading finance refers to a causal sequence in which financial development precedes and drives economic growth by mobilising savings and allocating capital to productive investment; demand-following finance refers to the reverse, in which economic expansion generates demand for more sophisticated financial services that then develop in response. Our finding that short-run causality runs only from stock markets to growth in low- and middle-income countries — but is bidirectional in high-income countries — is, on its face, somewhat unexpected relative to a simple prior that would predict demand-following behaviour in less developed economies: it is precisely in less financially developed economies that a supply-leading pattern dominates, while in advanced economies the relationship is mutually reinforcing. We interpret this cautiously through an institutional lens: the strength of the long-run coefficient in high-income countries (Table 4), combined with insignificant long-run effects in low- and middle-income countries, suggests that achieving a statistically robust long-run growth dividend from stock market depth likely requires institutional and regulatory conditions, such as stronger investor protection, more liquid secondary markets, and more developed disclosure and corporate governance regimes, that are more consistently present in high-income economies than in the low- and middle-income group as a whole.

This is consistent with the institutional heterogeneity documented elsewhere in the finance-growth literature (Levine, 1997), and provides further justification for the threshold panel VECM presented below, which models this heterogeneity endogenously using the IMF Financial Development Index rather than an exogenous income classification. We also note that our sample period spans the 2008 global financial crisis and the COVID-19 pandemic; while we do not formally test for structural breaks around these episodes, the FMOLS group mean estimator, by averaging country-specific long-run relationships rather than imposing a single pooled relationship, is less sensitive to any single crisis episode than a pooled specification would be, and the consistency of the sign and broad magnitude of the market capitalisation coefficient across the weighted pooled and group mean estimators (Table 4) provides some reassurance that the long-run relationship is not being driven by a narrow subset of crisis-period observa-

tions.

The rejection of cross-sectional independence by the Pesaran (2004) CD test reported above is unsurprising in an internationally integrated financial system subject to common global shocks. Our empirical strategy already addresses several of the associated econometric issues. Specifically, the CIPS unit root test and the Pedroni and Kao panel cointegration tests are designed to remain valid in the presence of cross-sectional dependence, while the Group Mean FMOLS estimator accommodates heterogeneity by estimating separate long-run cointegrating relationships for each country. In addition, the Newey–West long-run covariance correction accounts for endogeneity and serial correlation, although it does not explicitly model unobserved common factors. As a further robustness check, we re-estimate Eq. 1 as a pooled fixed-effects regression in levels with Driscoll–Kraay standard errors (Driscoll & Kraay, 1998), which are robust to cross-sectional dependence. Under this specification, the coefficient exhibits inflated standard errors, resulting in a decline in its statistical significance, reflecting the more conservative inference obtained once cross-sectional dependence is explicitly accommodated.<sup>12</sup> We do not interpret this result as contradicting the FMOLS findings, because Driscoll–Kraay inference is designed for conventional panel regressions, whereas FMOLS estimates the long-run cointegrating relationship among non-stationary variables. A pooled levels regression of non-stationary variables is itself susceptible to the spurious regression problem that panel cointegration techniques are specifically designed to address; consequently, the two approaches do not estimate the same parameter. We also considered the Common Correlated Effects (CCE) estimator (Pesaran, 2006), whose primary objective is to account for unobserved common factors in heterogeneous panel regressions assumed to be stationary. Its properties under the non-stationary, cointegrated data are not well established, and augmenting each country’s regression with cross-sectional averages in a cointegrated setting risks absorbing part of the common stochastic trend that constitutes the long-run relationship of interest (Kapetanios, Pesaran, & Yamagata, 2011). For this reason we do not adopt CCE as an alternative to FMOLS within the panel cointegration–VECM framework used in this study.

Turning to the macroeconomic control variables reported in Table 5, the empirical results indicate that fixed capital has a positive and statistically significant relationship with economic growth, aligning with the predictions of the neoclassical growth model (Solow, 1956), which emphasises the importance of capital accumulation as a key driver of long-term growth.

Conversely, inflation is found to have a negative impact on growth, which supports the established view that high inflation undermines economic stability, erodes purchasing power, and discourages investment. This finding is consistent with the work of Fischer (1993) and

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<sup>12</sup>The full Driscoll–Kraay results are not reported here for the sake of brevity but are available from the author upon request.

Table 5: Panel FMOLS results with control variables

|                                           | Output           | Market cap. ratio | Fixed capital ratio | Inflation          | Real exchange rate | Real rate          |
|-------------------------------------------|------------------|-------------------|---------------------|--------------------|--------------------|--------------------|
| Dependent variable: output (y)            | -                | 0.357*<br>(0.010) | 0.049*<br>(0.007)   | 0.113<br>(0.021)   | 0.040<br>(0.023)   | -0.045*<br>(0.005) |
| Dependent variable: market cap. ratio (m) | 0.037<br>(0.032) | -                 | 0.031*<br>(0.006)   | -0.093*<br>(0.021) | 0.000<br>(0.023)   | -0.031*<br>(0.005) |

Notes: \* and \*\* denote statistical significance at the 1% and 5% levels, respectively. Figures in the parentheses are standard errors. In our estimation, we employ a fixed effects term to account for unobserved country-specific characteristics that remain constant over time. To address heterogeneity across the cross-sectional units, we use both the weighted pooled estimators. The weighted pooled FMOLS accounts for cross-sectional heterogeneity by allowing each unit to have its own long-run covariance matrix

Akinsola and Odhiambo (2017), who argue that inflation adversely affects growth by creating economic uncertainty.

The real exchange rate is found to be positively associated with economic growth, though this relationship is statistically insignificant. This suggests that exchange rate movements may not have a consistent or significant impact on growth across the countries in our sample. This finding is consistent with Dufrenot et al. (2005) and Caporale and Škare (2014), who argue that the effects of exchange rate fluctuations on economic growth are contingent upon a range of country-specific factors, such as trade balances, external shocks, and the broader economic environment.

Finally, the negative relationship between the real interest rate and growth supports the idea that higher interest rates, by raising the cost of borrowing, can restrict investment and consumption, ultimately slowing down economic growth. This result is consistent with the findings of Scorcu (1997) and Villanthenkodath (2022), who demonstrate that higher interest rates typically constrain economic activity by discouraging investment.

#### 4.4 VECM results

The long-run estimates presented from FMOLS do not indicate the direction of causality between the variables. The findings regarding causality are provided by the VECM results and the Panel Granger Causality test, which are reported in Table 6 and Table 7, respectively.

The estimated error correction term (ECT) coefficient, representing the long-run dynamics, exhibits a statistically significant negative sign at the 5% significance level for the model, where output growth is the dependent variable, as expected (see Table 6). This finding suggests the presence of cointegration between the variables, implying a long-run equilibrium relationship. In simpler terms, the model exhibits mean reversion, indicating that any deviations from the long-run equilibrium level are corrected over time. Consequently, any instantaneous shocks to market capitalisation and other macroeconomic variables on economic growth will be fully adjusted in the long run, leading the system back to its equilibrium state. Notably, the low- and

Table 6: Panel VECM results

|                | Full panel    |                 | High income group |                   | Low/middle income group |                   |
|----------------|---------------|-----------------|-------------------|-------------------|-------------------------|-------------------|
|                | Output (y)    | Market Cap (m)  | Output (y)        | Market Cap (m)    | Output (y)              | Market Cap (m)    |
| $y_{t-1}$      | -0.38* (0.04) | 0.08** (0.02)   | -0.532* (0.041)   | 0.093* (0.024)    | 0.011 (0.128)           | -0.021 (0.02)     |
| $y_{t-2}$      | -0.35* (0.04) | 0.06** (0.02)   | -0.421* (0.04)    | 0.084* (0.023)    | -0.108 (0.103)          | -0.007 (0.017)    |
| $y_{t-3}$      | -0.24* (0.03) | 0.04** (0.01)   | -0.24* (0.035)    | 0.05* (0.02)      | -0.145** (0.073)        | -0.007 (0.012)    |
| $y_{t-4}$      | -0.10* (0.02) | 0.01 (0.01)     | -0.1* (0.025)     | 0.012 (0.015)     | -0.043 (0.041)          | 0.003 (0.007)     |
| $m_{t-1}$      | 0.37* (0.05)  | 0.02 (0.02)     | 0.227* (0.045)    | 0.028 (0.027)     | 2.451* (0.267)          | -0.214* (0.043)   |
| $m_{t-2}$      | 0.10** (0.05) | -0.13* (0.02)   | 0.081*** (0.046)  | -0.119* (0.027)   | 0.655** (0.292)         | -0.049 (0.047)    |
| $m_{t-3}$      | 0.15* (0.05)  | 0.04*** (0.02)  | 0.131* (0.045)    | 0.049*** (0.026)  | 0.237 (0.29)            | -0.134* (0.046)   |
| $m_{t-4}$      | 0.02 (0.05)   | 0.12* (0.02)    | -0.011 (0.045)    | 0.127* (0.027)    | 0.721** (0.292)         | -0.062 (0.047)    |
| constant       | -0.06 (0.05)  | 0.02 (0.02)     | -0.069 (0.052)    | 0.025 (0.03)      | -0.096 (0.105)          | 0.034 (0.017)     |
| $ECT_{t-1}$    | -0.73* (0.04) | -0.04*** (0.02) | -0.504* (0.043)   | -0.001*** (0.001) | -1.267* (0.145)         | -0.001*** (0.001) |
| R-squared      | 0.58          | 0.07            | 0.55              | 0.10              | 0.68                    | 0.09              |
| Adj. R-squared | 0.57          | 0.05            | 0.54              | 0.09              | 0.66                    | 0.058             |
| F-statistic    | 117.68        | 5.95            | 74.81             | 7.07              | 47.27                   | 2.43              |

Notes: \*, \*\* and \*\*\* indicate that the test statistics are significant at the 1%, 5% and 10% levels, respectively. Figures in the parentheses are standard errors. The analysis of lagged ECT in the output is negative and statistically significant which indicates that all variables play a role in the adjustment process when the output deviates from its long-run equilibrium. Where it is very close to zero in market capitalisation ratio. Therefore, the results indicate the presence of unidirectional Granger causality from the stock market to output growth in the long-run.

Table 7: Short-run panel causality

|                                                 | Full panel |          | High income group |          | Low/middle income group |          |
|-------------------------------------------------|------------|----------|-------------------|----------|-------------------------|----------|
|                                                 | Coeff.     | p-Values | Coeff.            | p-Values | Coeff.                  | p-Values |
| <i>Dependent variable: output (y)</i>           |            |          |                   |          |                         |          |
| $\Delta m$                                      | 69.52*     | 0.00     | 34.33*            | 0.00     | 87.51*                  | 0.00     |
| $\Delta c$                                      | 7.68*      | 0.10     | 1.70              | 0.79     | 5.71                    | 0.22     |
| $\Delta p$                                      | 26.13*     | 0.00     | 18.57*            | 0.00     | 23.08*                  | 0.00     |
| $\Delta rer$                                    | 94.24*     | 0.00     | 81.27*            | 0.00     | 24.53*                  | 0.00     |
| $\Delta r$                                      | 16.82*     | 0.00     | 14.55**           | 0.01     | 9.15***                 | 0.06     |
| All                                             | 255.90*    | 0.00     | 209.03*           | 0.00     | 185.26*                 | 0.00     |
| <i>Dependent variable: market cap ratio (m)</i> |            |          |                   |          |                         |          |
| $\Delta y$                                      | 14.31*     | 0.00     | 16.65*            | 0.00     | 4.47                    | 0.35     |
| $\Delta c$                                      | 2.75       | 0.60     | 2.04              | 0.73     | 6.32                    | 0.18     |
| $\Delta p$                                      | 7.73       | 0.10     | 22.11*            | 0.00     | 4.20                    | 0.38     |
| $\Delta rer$                                    | 7.72       | 0.102    | 5.29              | 0.26     | 4.45                    | 0.35     |
| $\Delta r$                                      | 7.33       | 0.12     | 22.90*            | 0.00     | 4.40                    | 0.35     |
| All                                             | 66.69      | 0.00     | 112.85*           | 0.00     | 17.19                   | 0.64     |

Notes: \*, \*\* and \*\*\* indicate that the test statistics are significant at the 1%, 5% and 10% levels, respectively.

middle-income group exhibits the most rapid adjustment compared to the high-income group. Conversely, the ECT for the model where market capitalisation is the dependent variable is negative but very close to 0, indicating limited responsiveness to deviations from the long-run equilibrium for all groups.

The VECM results point to significant short-run causality between economic growth and

market capitalisation activity (Table 6) for our full sample. The lagged changes in market capitalisation ratio significantly influence output growth, and vice versa, as evidenced by statistically significant coefficients at the 5% significance level in both models. This implies the presence of bidirectional short-run causality between our two main variables. This bidirectional causality in the short run is further confirmed when coefficients of market capitalisation and output growth for all lags are tested jointly as in Table 7. However, bidirectional short-term causality is absent in low- and middle-income group countries. Instead, short-term causality flows from stock market capitalisation to economic growth. This indicates that in these economies, stock market movements tend to precede changes in economic activity, whereas economic growth itself does not generate comparable feedback into market capitalisation. Such asymmetry is consistent with features often found in less developed financial systems, such as limited market liquidity and narrower investor participation, which may weaken the growth-to-market transmission channel.

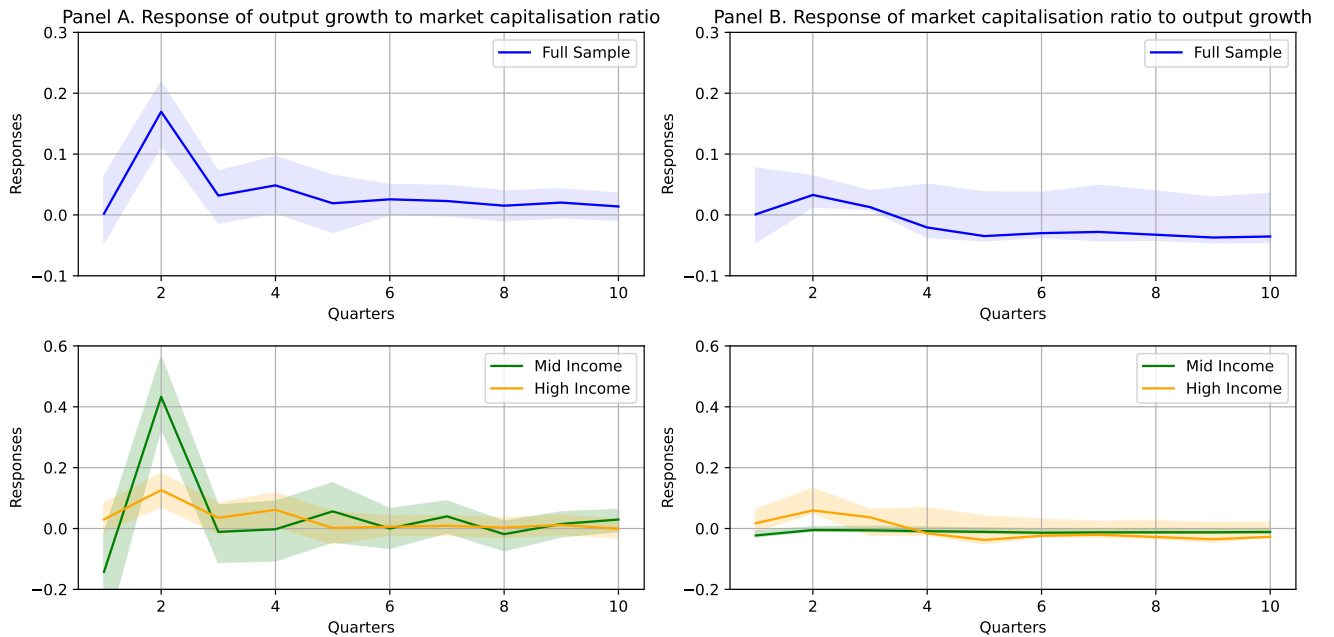


Figure 1: Generalised impulse responses

Note: Response to generalised one unit deviation innovations of core variables output growth,  $y$ , and market capitalisation ratio,  $m$ , with 95% confidence interval using Hall's percentile bootstrap with 999 bootstrap repetitions. The shock is applied in period 1, where a one-unit deviation innovation for  $y$  represents a 1% increase in output growth, and a one-unit deviation innovation for  $m$  reflects a doubling of market capitalisation relative to nominal GDP.

Figure 1 plots the responses of our core variable to the shocks, unexpected changes, in each other, with 95% bootstrap confidence interval. We use the generalised impulses specification to construct an orthogonal set of innovations that do not depend on the VEC ordering (M. H. Pesaran & Shin, 1998).

We find a weak and statistically insignificant response of market capitalisation to an output growth shock (Figure 1, Panel B). In contrast, the response of output growth to a market capitalisation ratio shock is positive and significant (Figure 1, panel A). A doubling market capitalisation ratio leads to about 0.17% with this effect fading over time. Output growth returns to its normal level within roughly six quarters.

Further analysis grouped countries by income level. We found that low- and middle-income group experience a stronger response in output growth to changes in market capitalisation activity compared to high-income countries (Figure 1, Panel A). This finding suggests that policy interventions aimed at stimulating market capitalisation activity may have a more pronounced short-term impact on economic growth in low- and middle-income. However, the effectiveness of such interventions will depend on the specific economic and financial context of each country, and the long-term sustainability of economic growth in these countries may require a more comprehensive approach that addresses underlying structural issues and promotes sustainable development.

Building on these findings, we next examine whether the stock market–growth relationship changes systematically with financial development using a threshold panel VECM.

#### **4.5 Threshold Panel VECM: Accounting for non-linearity and financial development**

We estimated the long-term relationship between stock market development and economic growth using the exogenous grouping VECM. However, this approach assumes a homogenous relationship across countries within the same group. Although this approach is still relevant for understanding economic development stages, it forces countries with slightly different financial structures within the same group to share linear and homogeneous long-run dynamics. It may not fully reflect the reality of economic systems that differ significantly across countries, especially those at varying stages of financial development.

To address these limitations, we adopt a more flexible approach by employing a Threshold Panel VECM (TPVECM). This approach statistically accounts for both non-linear relationships and country-specific heterogeneity by allowing the long-run and short-run coefficients to switch across distinct regimes. It allows us to directly test the hypothesis that the relationship between the stock market and economic growth is conditional on the level of financial development, which varies across countries.

This approach is rooted in the finance-growth literature, particularly the work of Demirgüç-Kunt and Levine (2001), who emphasise the role of financial structure, and Rioja and Valev (2004), who argue that the relationship is contingent on a country's stage of financial devel-

opment. Rather than relying on a binary distinction group countries based on income, the threshold model provides a more data-driven approach to determining at what level financial development influences economic growth.

Following the seminal work of Hansen (1999) on panel threshold models and Khan and Senhadji (2000) on threshold cointegration, we estimate the TPVECM. We hypothesize that the structural break is driven by financial maturity, and therefore select the IMF's Financial Development Index as the threshold variable (IMF, 2021). The optimal, data-driven threshold value ( $\gamma$ ) is then estimated endogenously by performing a grid search over all candidate values of the index, identifying the value that minimizes the sum of squared residuals across the two resulting regimes.

The financial development index is a comprehensive measure of a country's financial system's depth, efficiency, and accessibility, making it a reliable indicator of financial maturity widely used in the literature to distinguish between advanced and emerging markets. By setting this index as the threshold, we can examine how the dynamics between stock market capitalisation and growth differ for countries below and above this threshold of financial development.

We find strong statistical evidence supporting the existence of a threshold effect, confirming the non-linearity in the relationship between stock market capitalisation and economic growth. This threshold value ( $\hat{\gamma}$ ) optimally splits the panel into a *lower financial development regime* and a *higher financial development regime*.

The results from the Threshold Panel VECM reveal significant differences in the speed of adjustment between regimes (Table 8). These differences provide strong evidence of the non-linear relationship between stock market development and economic growth.

In the lower financial development regime, the ECT coefficient of -0.81 (negative and large magnitude) suggests a rapid and strong speed of adjustment back towards the long-run equilibrium following a deviation. This suggests that countries with less mature financial systems correct deviations quickly, likely because shallow markets and limited institutional capacity leave little room for shocks to be absorbed gradually. In such settings, disruptions tend to trigger sharp corrections rather than smooth rebalancing.

In the higher financial development regime, the ECT of -0.014 (closer to zero) indicates a much slower and more gradual adjustment process. Mature financial systems appear capable of absorbing short-term disturbances more effectively, with deeper markets, stronger institutions, and broader participation enabling adjustments to unfold over a longer horizon. This results in more stable, less abrupt movements after shocks.

Taken together, these contrasting adjustment speeds underscore the non-linear and state-dependent nature of the stock market–growth relationship. Countries' capacity to absorb shocks

Table 8: Threshold Panel VECM results

|                    | Output (y)        | Market Cap (m)   |
|--------------------|-------------------|------------------|
| $y_{t-1}$          | -0.309* (0.085)   | -0.005 (0.011)   |
| $y_{t-2}$          | -0.284* (0.071)   | -0.003 (0.009)   |
| $y_{t-3}$          | -0.208* (0.055)   | -0.002 (0.007)   |
| $y_{t-4}$          | -0.060** (0.036)  | 0.001 (0.005)    |
| $m_{t-1}$          | 1.659* (0.280)    | -0.079** (0.037) |
| $m_{t-2}$          | 0.166 (0.285)     | 0.030 (0.037)    |
| $m_{t-3}$          | 0.184 (0.270)     | 0.000 (0.035)    |
| $m_{t-4}$          | -0.099 (0.267)    | -0.123* (0.035)  |
| constant           | -0.016 (0.095)    | 0.020*** (0.012) |
| $ECT_{Low_{t-1}}$  | -0.819* (0.094)   | -0.000 (0.000)   |
| $ECT_{High_{t-1}}$ | -0.014*** (0.012) | 0.000 (0.000)    |
| R-squared          | 0.60              | 0.06             |
| Adj. R-squared     | 0.58              | 0.03             |
| F-statistic        | 45.04             | 1.95             |

Notes: \*, \*\* and \*\*\* indicate that the test statistics are significant at the 1%, 5% and 10% levels, respectively. Figures in the parentheses are standard errors.  $ECT_{Low_{t-1}}$  denotes the ECT for the the lower financial development regime and  $ECT_{High_{t-1}}$  for the higher financial development regime.

and return to equilibrium depends strongly on their level of financial development, reinforcing the importance of modelling heterogeneity rather than assuming a single linear process across all economies.

The directional finding that less financially developed economies adjust faster than more developed ones is, on its own, broadly consistent with priors in the finance-growth literature. The additional contribution of the threshold panel VECM lies less in this direction than in three further aspects that the exogenous income-group classification used elsewhere in the paper cannot deliver. First, the threshold value  $\hat{\gamma}$  is estimated endogenously from the data rather than imposed by an external classification, so the boundary between regimes is determined by where the adjustment process itself changes, rather than by a researcher-imposed income cut-off that may not coincide with the point at which financial structure actually shifts. Second, the magnitude of the contrast in adjustment speed that this data-driven threshold reveals, an ECT of  $-0.81$  below the threshold versus  $-0.014$  above it, is considerably starker than the gap implied by the income-group VECM estimates in Table 6 ( $-1.267$  for low/middle income versus  $-0.504$  for high income), indicating that financial maturity, as captured by the IMF Financial Development Index, is a sharper and more discriminating classifier of adjustment dynamics than income level alone. This suggests that the relevant state variable governing how quickly economies absorb deviations from the long-run stock market-growth equilibrium is financial market depth and institutional capacity specifically, rather than income or overall economic development more broadly, a distinction with direct relevance for policy sequencing in coun-

tries that may be middle-income but financially underdeveloped, or vice versa. Third, because the threshold is estimated rather than assumed, the approach provides a formal statistical test, via the Hansen (1999) bootstrap likelihood ratio test, of whether a regime-switching adjustment process exists at all, rather than asserting non-linearity based on an income split chosen *a priori*. In this sense, the threshold panel VECM should be read as a methodological refinement of the heterogeneity already suggested by the income-group results: it confirms that the heterogeneity is real, sharpens its magnitude, and identifies financial development rather than income as the variable that organises it.

While the findings are compelling, it is also important to consider several factors that might influence the results. The dataset, while comprehensive, may have potential biases due to data availability issues, particularly in less developed markets. For countries with large shadow economies, official economic growth data may be misleading, potentially obscuring the true impact of stock market activity on growth. Additionally, micro-level factors, such as the structure of financial markets, sectoral differences across stock markets, corporate governance and investor behaviour, which also play a role in influencing economic growth. Furthermore, the study does not fully account for external structural economic shocks or policy changes during the study period, which could impact the observed relationships.

Moreover, while our analysis specifically focuses on stock markets, understanding the broader relationship between financial markets and economic growth would require a more comprehensive study encompassing other financial sectors, such as banking, microfinance, and peer-to-peer lending. This expanded approach could provide deeper insights into the ways financial markets as a whole contribute to economic development.

In summary, the combined FMOLS, VECM and TPVECM results indicate that the stock market–growth relationship is heterogeneous across countries and varies with their level of financial development. These empirical patterns provide the foundation for the broader interpretation developed in the next section

## 5 Discussion

The empirical results presented in this study provide a coherent picture of how stock market capitalisation relates with economic growth across countries at different stages of financial maturity. Three central insights emerge.

First, the long-run estimates obtained from the FMOLS models show a positive and statistically significant association between stock market capitalisation and economic growth for the full panel, with stronger effects observed in high-income economies. This confirms the view that stock markets support long-term growth by improving capital allocation, reducing financ-

ing frictions and enhancing investment efficiency. The absence of a significant long-run effect in low- and middle-income countries suggests that the productivity-enhancing role of stock markets strengthens only when institutional, regulatory, and financial infrastructures reach a certain level of sophistication.

Second, the VECM results highlight an important asymmetry in short-run dynamics. In high-income countries, stock market capitalisation and economic growth mutually reinforce one another in the short term. This bidirectional causality indicates that well-developed markets not only contribute to growth but also respond predictably to changes in economic conditions. By contrast, in low- and middle-income economies, short-run causality flows only from stock market development to economic growth. This suggests that while stock markets in these economies contribute to growth, economic expansion is less likely to feed back into market capitalisation. Structural factors such as limited market liquidity, narrow investor participation, and lower institutional depth may disrupt the growth–market feedback mechanism.

Third, the threshold analysis provides strong statistical evidence of non-linearity in the stock market–growth relationship. The TPVECM results show that the speed of adjustment toward long-run equilibrium differs sharply across regimes defined by financial development. Countries below the financial development threshold exhibit rapid and strong corrections following shocks, reflecting the more fragile nature of underdeveloped financial systems. In contrast, countries above the threshold adjust slowly and gradually, consistent with deeper, more resilient financial structures. This finding reinforces the idea that the influence of stock market development on growth is conditional on financial maturity and cannot be assumed to be uniform across countries.

Taken together, these results suggest that the contribution of stock markets to economic growth is both heterogeneous and state-dependent. While stock markets can play a supportive role in fostering economic growth, the strength of this relationship appears to vary with countries' levels of financial development. For policymakers, the implications are that countries in earlier stages of financial development may benefit from strengthening market infrastructure, widening investor participation and improving regulatory frameworks so that stock markets can function more effectively as part of the overall financial system. In more financially advanced economies, preserving market stability and ensuring efficient capital allocation remain central to maintaining the growth-supporting role of stock markets.

Overall, the results highlight the importance of examining financial development through a non-linear and heterogeneous lens. By integrating long-run cointegration techniques, short-run error correction dynamics, and threshold modelling, this study shows that the stock market–growth nexus is more complex than a single linear relationship. Future work may explore how institutional quality, governance, or sectoral composition of markets further shape the

transmission mechanisms between stock markets and growth.

## 6 Conclusion

This study examined the relationship between stock market development, measured through market capitalisation ratio, and economic growth for 36 countries between 2003Q1 and 2022Q3 using panel cointegration, FMOLS, VECM, and threshold VECM approaches. The results reveal a heterogeneous and non-linear finance–growth nexus shaped by countries’ stages of financial development.

The FMOLS estimates show a positive long-run association between stock market capitalisation and economic growth, with a markedly stronger effect in high-income economies. The VECM results indicate bidirectional short-run causality in high-income economies but only a one-way effect from stock market development to growth in low- and middle-income countries. The threshold panel VECM further demonstrates that this relationship is non-linear: countries below the financial development threshold adjust rapidly to deviations from long-run equilibrium, whereas highly developed financial systems exhibit a slower and more gradual adjustment path.

These findings carry some policy implications. The contribution of stock markets to economic growth appears to strengthen with financial maturity. For high-income economies, preserving market stability, transparency and efficient capital allocation is important for sustaining these growth benefits. For low- and middle-income countries, the results point to the value of foundational reforms that improve market liquidity, strengthen regulatory capacity and widen investor participation, creating conditions under which stock markets can more effectively support long-term growth.

Future research could further examine micro-level transmission mechanisms, structural features of stock markets, and the interaction between financial development and institutional quality, offering a richer understanding of how stock markets contribute to economic performance across different development stages.

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# A1 Appendix: Data, Tables and Figures

Table 9: Country classification

| Country       | Economy Level      | Income Group        |
|---------------|--------------------|---------------------|
| Australia     | Advanced economy   | High income         |
| Austria       | Advanced economy   | High income         |
| Belgium       | Advanced economy   | High income         |
| Brazil        | Developing economy | Upper middle income |
| Canada        | Advanced economy   | High income         |
| Chile         | Developing economy | High income         |
| China         | Developing economy | Upper middle income |
| Denmark       | Advanced economy   | High income         |
| Finland       | Advanced economy   | High income         |
| France        | Advanced economy   | High income         |
| Germany       | Advanced economy   | High income         |
| Greece        | Advanced economy   | High income         |
| Hong Kong     | Advanced economy   | High income         |
| Hungary       | Developing economy | High income         |
| India         | Developing economy | Lower middle income |
| Indonesia     | Developing economy | Upper middle income |
| Ireland       | Advanced economy   | High income         |
| Israel        | Advanced economy   | High income         |
| Japan         | Advanced economy   | High income         |
| Luxembourg    | Advanced economy   | High income         |
| Malta         | Advanced economy   | High income         |
| Mexico        | Developing economy | Upper middle income |
| Netherlands   | Advanced economy   | High income         |
| Norway        | Advanced economy   | High income         |
| Philippine    | Developing economy | Lower middle income |
| Poland        | Developing economy | High income         |
| Portugal      | Advanced economy   | High income         |
| Singapore     | Advanced economy   | High income         |
| Slovenia      | Advanced economy   | High income         |
| South Africa  | Developing economy | Upper middle income |
| South Korea   | Advanced economy   | High income         |
| Spain         | Advanced economy   | High income         |
| Sweden        | Advanced economy   | High income         |
| Switzerland   | Advanced economy   | High income         |
| Thailand      | Developing economy | Upper middle income |
| Turkey        | Developing economy | Upper middle income |
| United States | Advanced economy   | High income         |

Notes: Country income classifications are based on data from the World Bank's World Development Indicators, while economy level classi-

cations are sourced from the International Monetary Fund.

## A2 Appendix: Tests

### A2.1 Cross-section dependence Test

Following Pesaran (2004), suppose that we have a panel data model:

$$y_{it} = \beta_{it}' x_{it} + u_{it} \quad (9)$$

for  $i = 1, 2, \dots, N$  and  $t = 1, 2, \dots, T$  where  $x_{it}$  is a  $k$ -dimensional column vector of regressors,  $\beta_i$  are the corresponding cross-section specific vectors of parameters to be estimated. Pesaran points out that while this specification has cross-section specific coefficients, the tests described below are also applicable to the more restrictive fixed and random effects models. The general null hypothesis of no cross-section dependence may be stated in terms of the correlations between the disturbances in different cross-section units:

$$H_0 : \rho_{ij} = \text{Corr}(u_{it}, u_{jt}) = 0 \text{ for } i \neq j \quad (10)$$

For balanced samples,  $\rho_{ij}$  is the product-moment correlation coefficients of the residuals.

$$\hat{\rho}_{ij} = \frac{\sum_{t=1}^T \hat{u}_{it} \hat{u}_{jt}}{(\sum_{t=1}^T \hat{u}_{it}^2)^{1/2} (\sum_{t=1}^T \hat{u}_{jt}^2)^{1/2}} \quad (11)$$

To address the size distortion, Pesaran (2004) proposes an alternative statistic based on the average of the pairwise correlation coefficient,  $\rho_{ij}$ :

$$CD_p = \frac{2}{N(N-1)} \sum_{i=1}^N \sum_{j=i+1}^N T_{ij} \hat{\rho}_{ij}^2 \rightarrow N(0, 1) \quad (12)$$

which is asymptotically standard normal for  $T_{ij} \rightarrow \infty$  and  $N \rightarrow \infty$  in any order. Further Pesaran (2004) points out that for a wide array of panel data models, the mean of CD is exactly equal to zero for all  $T_{ij} > k + 1$  and all  $N$ , so that the CD test is likely to have good properties for both  $T_{ij}$  and  $N$  small which is supported by evidence of Monte Carlo simulations.

### A2.2 Panel Unit Root Tests

We consider the integrated panel data model:

$$Y_{it} = D_{it} + u_{it} \quad (13)$$

where  $Y_{it}$  represents the observed data at cross-section  $i$  and time  $t$ ,  $D_{it}$  represents the model's deterministic dynamics (e.g., intercept, trend), and  $u_{it}$  is the innovation term capturing all deviations from the deterministic component.

To address cross-sectional dependence, we model  $u_{it}$  using a factor model structure:

$$u_{it} = \lambda_i F_t + \epsilon_{it} \quad (14)$$

$$(1 - L)F_t = C(L) + \eta_t \quad (15)$$

$$\epsilon_{it} = \rho \epsilon_{it-1} + v_{it} \quad (16)$$

where  $F_t$  is a vector of  $r$  common factors capturing the variation affecting multiple cross-sections, generated by a multivariate white noise process  $\eta_t$ .  $\lambda_i$  denotes a vector of cross-section-specific factor loadings, and  $\epsilon_{it}$  is a multivariate idiosyncratic component assumed to be independent across cross-sections  $i$ .  $v_{it}$  is a mean-zero, stationary, and invertible MA process.

To test the presence of a unit root in the idiosyncratic component, an Augmented Dickey-Fuller (ADF) regression with lags is conducted for each cross-section. Failure to reject the null hypothesis for a specific cross-section indicates the presence of a unit root in that dataset.

Earlier panel unit root tests utilized pooled tests to address the issue of low statistical power associated with univariate tests, particularly when faced with limited time series observations ( $T$ ). Likewise, a pooled test statistic can be calculated based on the methodologies proposed by Maddala and Wu (1999) and Choi (2001):

$$P_N^e = \frac{2 \sum_{i=1}^N (\log(p_i^e) - 2N)}{\sqrt{4N}} \rightarrow N(0, 1) \quad (17)$$

where  $p_i^e$  is the p-value associated with the idiosyncratic component ADF test for the  $i$ -th cross-section.

M. H. Pesaran (2007)'s Cross-Sectionally Augmented IPS (CIPS) test, a popular adopted modification of the PANIC test, addresses cross-sectional dependence by assuming it arises from a single stationary common factor.

When the deterministic terms in the model include both a trend and an intercept, we can express Eq. (13) in Augmented Dickey-Fuller (ADF) form as:

$$\Delta Y_{it} = \mu_i + \gamma_i t + \rho_i Y_{it-1} + \sum_{k=1}^p \phi_{ik} \Delta Y_{it-k} + \lambda_i F_t + \epsilon_{it} \quad (18)$$

The  $p$  lagged differences are added to account for correlation in the  $\epsilon_{it}$ , and  $\lambda_i F_t$  represents factor augmentation. Non-stationarity arises when the  $\rho_i$  autoregressive coefficient is equal to 0.

Let  $\tau_i^{CADF}$  denote the t-statistic associated with the traditional ADF null hypothesis  $H_0 : \rho_i = 0$  for cross-section  $i$ . The panel unit root test of interest is a pooled version of individual CADF statistics, or the cross-sectionally augmented (CIPS) statistic:

$$\tau^{CIPS} = \frac{1}{N} \sum_{i=1}^N \tau_i^{CADF} \quad (19)$$