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Threshold Effects of Fixed Capital Formation on Economic Growth in Asian Countries

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ABSTRACT
This study investigates the threshold effects of fixed capital formation (FCF) on economic growth in selected Asian countries over the period 1991–2020. Drawing on a balanced panel of eleven Asian economies and employing a panel Autoregressive Distributed Lag (ARDL) framework, the study examines both short-run and long-run dynamics between FCF and economic growth while controlling for key macroeconomic factors. Panel unit root tests, panel cointegration techniques, and error-correction–based estimators are applied to ensure robustness. The results provide strong evidence that fixed capital formation exerts a positive and statistically significant impact on economic growth in the long run, whereas short-run effects are weaker and heterogeneous across countries due to adjustment costs and investment gestation lags. Causality analysis further indicates bidirectional causality between FCF and economic growth, supporting the presence of a virtuous investment–growth cycle. The findings underscore the importance of prioritizing productive capital investment, improving investment efficiency, and maintaining macroeconomic stability to sustain long-term growth in Asian economies.

Keywords: *Fixed Capital Formation; Economic Growth; Panel ARDL; Investment; Asian Economies.*

1. Introduction

Economic growth remains a central objective of macroeconomic policy in developing and emerging economies. Among the various determinants of growth, fixed capital formation occupies a pivotal role as it represents sustained investment in productive assets such as infrastructure, machinery, equipment, and industrial facilities. In economies undergoing structural transformation, capital accumulation is particularly important for enhancing productive capacity, improving labor productivity, and facilitating technological diffusion.

Asian economies provide an instructive context for analyzing the growth effects of fixed capital formation. Over the past three decades, many Asian countries have experienced rapid industrialization, urbanization, and integration into the global economy. These developments have been accompanied by large-scale investments in physical capital, financed through domestic savings, foreign direct investment, and public sector borrowing. While such investments have contributed to impressive growth performance in some countries, others have struggled with inefficiencies, macroeconomic instability, and debt-related constraints.

This paper is derived from the author's PhD thesis and focuses specifically on the role of fixed capital formation in driving economic growth. Although the original dissertation primarily examined the relationship between public debt and economic growth, fixed capital formation

emerged as a consistently important explanatory variable. The present study isolates and strengthens this dimension to provide a focused and policy-relevant contribution to the literature.
The study addresses three key research questions. First, does fixed capital formation have a statistically significant impact on economic growth in selected Asian countries? Second, how do the short-run and long-run effects of FCF differ? Third, what is the direction of causality between fixed capital formation and economic growth? By answering these questions, the paper contributes to the empirical literature on growth and investment in developing Asia.

2. Literature Review

2.1 Theoretical Perspectives

The relationship between fixed capital formation and economic growth is well established in economic theory. In the classical and neoclassical growth frameworks, capital accumulation is a key determinant of output growth. The Solow growth model emphasizes that increases in the capital stock raise output levels in the short to medium run, while long-run growth depends on technological progress. Nevertheless, in capital-scarce economies, sustained investment in physical capital can significantly enhance growth performance.
Endogenous growth theories extend this framework by emphasizing the role of investment in generating positive externalities, learning-by-doing effects, and technological spillovers. According to these models, capital formation—particularly when combined with human capital and innovation—can lead to sustained long-run growth rather than merely transitional dynamics.
Chowdhury (2001) and Cunningham (1993) demonstrate, an increase in public debt is associated with reduced capital formation, as well as capital flight, resulting in less economic growth For African countries, however, debt is not significantly tied to economic growth, unlike for Latin American countries, Lin and Sosin (2001). For developing nations like those in Asia, the relationship is beneficial but not very significant. This implies that effective debt management is essential for economic expansion. While debt may be a useful tool for supporting economic growth, excess burdens may hinder long-term growth if it is not managed carefully. In order to optimize the positive effects of debt on economic growth while mitigating the risks associated with over indebtedness, policymakers should implement prudent debt management strategies, including controlling borrowing levels, ensuring debt sustainability, and investing borrowed funds in productive ways.
Chowdhury and Levy (1993) point out, a rise in public debt is associated with a decline in capital formation and capital flight, which results in a slowdown in economic growth. It indicates that as we increased the ratio of public debt which automatically reduced the capital formation as well as capital flight will reduced economic growth. The findings underscore the importance of prudent debt management and policies that prioritize capital formation and investment. The policymakers of selected Asian countries can foster robust economic growth and sustainable development by controlling public debt levels, promoting favorable investment climates, and mobilizing domestic resources.
As the government's debt service obligation increases, Agénor and Montiel (1996) showed that distorted measures will be used to finance its debt service (the inflation tax). Their findings have contributed to the literature by highlighting the implications of an increasing stock of public sector debt. The inflation tax, they argue, is a distorted measure governments may rely on as their debt burden grows.

2.2 Empirical Evidence

Empirical studies generally find a positive association between fixed capital formation and economic growth, particularly in developing and emerging economies. Investment in

infrastructure reduces transaction costs, facilitates market integration, and crowds in private investment. Conversely, low levels of capital formation are often associated with supply-side constraints and sluggish growth.

Evidence from Asian economies suggests that countries with high and sustained investment rates—such as China, India, and several Southeast Asian economies—have achieved rapid growth over extended periods. However, the literature also highlights that the growth impact of investment depends critically on its efficiency and composition. Poorly allocated or debt-financed unproductive investment may fail to generate growth and can exacerbate macroeconomic vulnerabilities.

2.3 Gaps in the Literature

Despite the extensive literature on investment and growth, relatively few studies focus explicitly on the short-run versus long-run dynamics of fixed capital formation in Asian economies using modern panel techniques. Moreover, many studies treat capital formation as a control variable rather than the central variable of interest. This paper addresses these gaps by providing a focused panel ARDL analysis of FCF and economic growth.

3. Data and Methodology

3.1 Data and Variables

The study uses annual panel data for eleven Asian countries—Pakistan, China, Bhutan, Bangladesh, India, Indonesia, Turkey, Nepal, Thailand, Sri Lanka, and Vietnam—covering the period 1991–2020. Data are primarily obtained from the World Development Indicators (WDI).

The dependent variable is real GDP per capita growth (GDP_gr). The key explanatory variable is gross fixed capital formation (FCF), measured as a percentage of GDP. Control variables include GDP per capita, GDP per capita squared, foreign direct investment (FDI), inflation (INF), population growth (POP), and dummy variables for the Asian Financial Crisis (1997–1998) and the Global Financial Crisis (2008–2009).

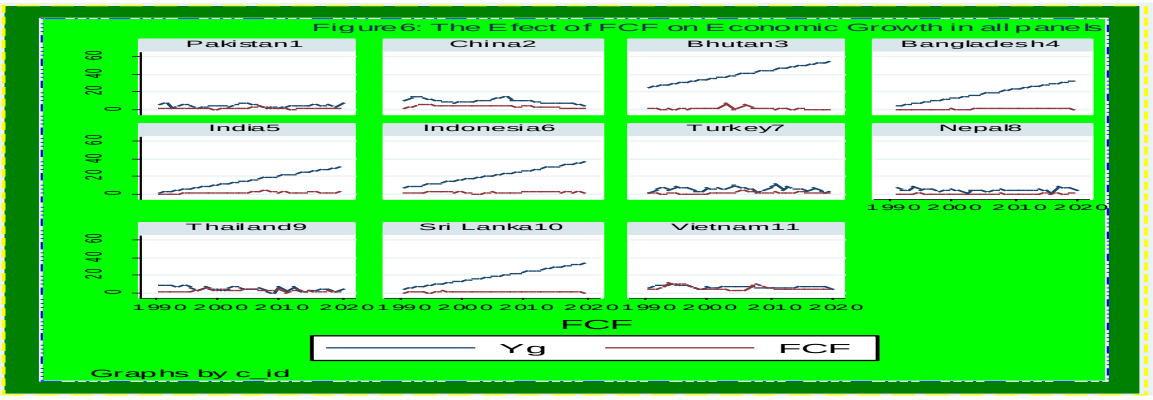
3.2 Econometric Model Specification

To examine the relationship between fixed capital formation and economic growth, the following baseline model is specified:

$$\boldsymbol{Y_{it} = \alpha_1 + \alpha_2 FCF + \alpha_5 X_{it} + \gamma_1 D_1 + \gamma_2 D_2 + \mu_{it} + \varepsilon_{it} \ldots\ldots\ldots eq.1}$$

where (i) denotes country, (t) denotes time, (X_{it-} is a vector of control variables, and ε_{it} is the error term. $\boldsymbol{\mu_{it}}$ is the error correction term capturing the speed of adjustment toward long-run equilibrium, and $\boldsymbol{\varepsilon_{it}}$ represents the long-run elasticity of economic growth with respect to fixed capital formation.

Graphical Representation of the FCF and Economic Growth in panel model



The figure indicates that countries with high levels of fixed capital formation—such as China, and India have experienced rapid economic growth in recent decades due to substantial investment in infrastructure, manufacturing, and technology, which has enhanced productivity, employment, and overall demand. Fixed capital formation has also supported local industry development by attracting foreign investment through favorable policies, including tax incentives, improved infrastructure, and human capital development. However, excessive investment may pose risks such as over-investment and environmental degradation, highlighting the need for effective regulations.

3.7 PANEL ARDL MODEL

Autoregressive Distributed Lag is abbreviated as ARDL. The long-term relationship between variables can be studied using time-series econometric techniques. It is possible to estimate dynamics between short-run and long-run variables using ARDL models based on non-stationary or integrated variables as well as the dynamics between non-stationary and integrated variables. ARDL is composed of autoregressive terms, delayed terms, and errors. When independent variables return their past values to the dependent variable, a distribution lag term captures the effect of the past values on the current value, whereas an autoregressive term does the same for the dependent variable. With the error correction term, independent variables are able to achieve long-run equilibrium despite deviations from their long-run equilibrium relationship.

ARDL models are widely used in macroeconomics, finance, and other social sciences to study the relationships between variables such as exchange rates, interest rates, inflation, and economic growth.

IV. RESULTS AND DISCUSSION OF PANEL MODEL

The mainstay of this study to empirically analyzed and observed the panel data, in a practical manner, which has been explained in a theoretical manner in the previous chapters. In this chapter, we reveal and discuss the empirical results of the study as.

4.1. Declare dateset to be Panel Data

It means that our panel data model must be strongly balanced.

Table 1.1 Declare dateset to be Panel Data

```
. xtset c_id Years, yearly
panel variable:     c_id (strongly balanced)
time variable:        Years, 1991 to 2020
delta:  1 year
```

In the above table we have discussed that before the application of different diagnostic tests of panel data its will be important to find whether the dateset is strongly balanced or unbalanced. So our panel dateset is strongly balanced for the periods of 1991 to 2020.

4.2. Descriptive (summary) statistics

Comparing the variables in the model requires a description of each variable's characteristics as well as its characteristics in the model. By calculating the standard deviation, we can see how the data varies.

Table 4.2. Results of the Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Yg	330	13.523	11.966	-1.274	54.122
GDPPC	330	2251.09	2581.011	140.631	12507.595
GDPSQ	330	41.465	23.095	11.859	111.837
PDebtR	330	2.729	2.42	.123	20.333
POP	330	2.732	5.448	.081	32.231
FCF	330	1.827	1.836	.004	11.939
FDI	330	1.82	1.837	.004	11.939
INF	330	9.219	13.61	.188	105.215
Fincrisis	330	.1	.3	0	1

Source: Author's calculation

The descriptive statistics reported in Table 4.2 show that the mean values of economic growth (Yg) and GDP per capita (GDPPC) are 13.52 and 2251.09, with corresponding standard deviations of 11.97 and 2581.01, while their minimum values are −1.27 and 140.63 and maximum values are 54.12 and 12,507.59, respectively. GDP squared has a mean value of 41.46 and a standard deviation of 23.09, with minimum and maximum values of 11.86 and 111.84. Public debt and foreign direct investment record mean values of 2.73 and 1.82 and standard deviations of 2.42 and 1.84, with minimum values of 0.12 and 0.00 and maximum values of 20.33 and 11.94, respectively. Population has an average value of 2.73, while fixed capital formation, inflation, and financial crisis have mean values of 1.83, 9.22, and 0.10, with corresponding standard deviations of 5.45, 13.61, and 0.30. The minimum values for these variables are 0.08, 0.00, 0.19, and 0.00, whereas their maximum values are 32.23, 11.94, 105.22, and 1, respectively.

4.3. Regression analysis

Table 4.3: Results of the regression

Yg	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
GDPPC	-.006	.001	-9.94	0	-.007	-.005	***
GDPSQ	.776	.06	12.91	0	.658	.894	***
PDebtR	.514	.216	2.38	.018	.089	.938	**
POP	-.269	.103	-2.61	.009	-.473	-.066	***
FCF	1.01	.238	4.25	0	.542	1.477	***
INF	-.101	.033	-3.05	.002	-.166	-.036	***
Constant	-7.78	1.724	-4.51	0	-11.171	-4.389	***

Mean dependent var	13.292	SD dependent var	12.223
R-squared	0.429	Number of obs	330
F-test	39.157	Prob > F	0.000
Akaike crit. (AIC)	1973.535	Bayesian crit. (BIC)	2000.128

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

Source: Author's Calculation

Table 4.3 presents the regression results explaining the relationship between economic growth (Yg), the dependent variable, and six independent variables: GDP per capita, GDP squared, public debt–to–GDP ratio, population, fixed capital formation, and inflation. For each explanatory

variable, the table reports the estimated coefficient, standard error, t-statistic, p-value, and the 95 percent confidence interval, where the coefficients measure the marginal effect of a one-unit change in an independent variable on economic growth, holding other factors constant. The standard errors indicate the precision of the estimates, the t-values are obtained by dividing coefficients by their standard errors, and the p-values test the null hypothesis that the coefficients are equal to zero, with smaller p-values indicating statistical significance. The significance levels of the coefficients are denoted by *, **, and *** at the 1 percent, 5 percent, and 10 percent levels, respectively. In addition, the table reports overall model diagnostics, including the mean and standard deviation of the dependent variable, R-squared showing the proportion of variation explained by the model, the number of observations, and the Akaike and Bayesian information criteria, where lower values indicate a better fit of the model to the data.

4.4. Correlation Analysis

It show that there is exist a linear relationship among the variables with the dependent variable. If there is no linear relationship so there is the problem of multicolinearity occurs which means that the regressor are not linearly correlated with each others.

Table 3. Matrix Correlation

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Yg	1.000								
(2) GDPPC	-0.063	1.000							
(3) GDPSQ	0.035	0.970	1.000						
(4) PDebtR	0.218	-0.173	-0.136	1.000					
(5) POP	-0.222	-0.160	-0.159	0.015	1.000				
(6) FCF	-0.139	0.029	0.048	-0.123	-0.131	1.000			
(7) FDI	-0.127	0.041	0.065	-0.109	-0.133	0.955	1.000		
(8) INF	-0.135	0.015	0.048	0.283	-0.004	-0.149	-0.151	1.000	
(9) Fincrisis	-0.065	-0.099	-0.107	0.071	-0.019	0.045	0.047	0.100	1.000

Source: Author's Calculation

The correlation matrix results is given in the above table 3 are showing that GDP per capita, FDI, population, Fixed capital formation, Inflation and Financial crisis are negatively while GDP Squared and public debt are positively correlated with Economic growth (Yg). Similarly public debt, Population, and Financial crisis are negatively while Fixed Capital Formation,FDI, Inflation are positively correlated with Economic growth (Yg).Similarly public debt, population and Financial crisis are negatively, while Fixed Capital Formation,FDI, Inflation are positively correlated with Economic growth (Yg). Economic growth (Yg) is negatively correlated with foreign direct investment and foreign direct capital, while inflation and financial crises are positively correlated. A positive correlation can be found between GDP and inflation, while a negative correlation exists between GDP and inflation, which is the case for the FCF and the

financial crisis. Similarly, the FCF and the inflation are negatively correlated with GDP (Yg). A similar relationship exists between inflation and economic growth (Yg), while a relationship exists between financial crisis and economic growth (Yg).

It is not possible to establish a linear relationship between variables and dependent variables due to the fact that all coefficients are positive or negative in nature. So it show that there is the problem of multicolinearity problem. So we must be apply multicollinearity tests.

4.5. Unit Root Testing

Table 1. Unit Root IPS tests results

Im-Pesaran-Shin unit-root test for Yg,GDPPC,GDPSQ,PDebtR,FDI,POP,FCF,INF,Fincrisis

Ho: All panels contain unit roots Number of panels = 11

Ha: Some panels are stationary Number of periods = 30

AR parameter: Panel-specific Asymptotics: T,N -> Infinity

Panel means: Included sequentially

Time trend: Not included

ADF regressions: 1 lag

Table I. Unit root IPS tests results

Variables	W-t-bar	Statistic	P-value
Yg	,,	-0.3243	0.3729
GDPPC	,,	5.9540	1.0000
GDPSQ	,,	5.0783	1.0000
PDebtR	,,	-0.1678	0.4334
FDI	,,	-4.90	0.00
POP	,,	1.3557	0.9124
FCF	,,	-4.5620	0.0000
INF	,,	-4.4367	0.0000
Fincrisis	,,	-8.0415	0.0000

Source: Author's Calculation

According to the above IPS table, FCF, FDI, and inflation are stationary variables at levels, but GDP Growth, GDP per capita, GDP square, and Public Debt are non-stationary variables at levels. By converting all variables to stationary level, we transform them to non-stationary level.

II) LLC (Levin-Lin-Chiu) Test for the assumption of homogeneous slopes as well as it require that the data shuold be strongly balanced because it is not used due to very few holes in the data sets and though stata adjusted the data as stongly balanced. LLC also find out the stationarity of the variables on the basis of p-value< 0.05%, otherwise if p-value>0.05% so it show the variables are non-stationarity then we take first defference to make the variables values stationary.

Table 4.2. Unit root LLC Tests Results

```
xtunitroot llc Yg, lags(1)

Levin-Lin-Chu unit-root test for Yg
---------------------------------
Ho: Panels contain unit roots                        Number
of panels =     11
Ha: Panels are stationary                            Number
of periods =     30

AR parameter: Common
Asymptotics: N/T -> 0
Panel means:  Included
Time trend:   Not included

ADF regressions: 1 lag
LR variance:     Bartlett kernel, 9.00 lags average (chosen by LLC)
```

Source: Author's Calculation

Yg, GDPPC, GDPSQ and Public debt are non stationary in the LLC table listed above. FCF,FDI,INF are stationary at levels, but Yg, GDPPC and GDPSQ are non stationary at levels. By using first difference, we transform all non-stationary variables to stationary levels.

4.6 OPTIMAL LAGS SELECTION

Choose the lags to use for each country per variable based on an information criteria and the unrestricted model.

```
Akaike's information criterion and Bayesian information criterion
-------------------------------------------------------------------------------------------
     Model |       Obs    ll(null)  ll(model)      df        AIC       BIC
-----------+-------------------------------------------------------------------------------
         .     |       330         .   -41.6484           7    97.29679    106.8679
                       330         .   -41.6484           7    97.29679   106.8679
-------------------------------------------------------------------------------------------
            Note: N=330 used in calculating BIC.
```

Source: Author's Calculation

So in the table of the Mean Group and Pooled Mean Group all the variables p-values are insignificant in short run except the two variables population and inflation p-value are significant. While taking the lags of the two variables which make the p-values of both are insignificant. So its means there is no needs for lags selection criteria.

4.7 COINTEGRATION TEST

Co-integration tests were conducted by Pedroni (1999,2004) when long run homogeneity was assumed. There is therefore no need to perform this step. In order to determine a correlation, the long-run coefficients and error correction term were statistically significant. Levels equations with a combined importance indicates cointegration or long-term relationships.

Table 4.7. Results of the co-integration test

Pedroni's cointegration tests:
No. of Panel units: 11 Regressors: 7
No. of obs.: 330 Avg obs. per unit: 30
Data has been time-demeaned.

Test Stats.	Panel	Group
v	-0.228	.
rho	0.947	
t	-3.723	-3.647
adf	-3.201	-2.874

A null of no cointegration is applied to all test statistics N(0),
Unless panel v is included, the line diverges to negative infinity.

Source: Author's Calculation

The cointegration test results reject the null hypothesis of no cointegration at the 1 percent significance level for both panel and group statistics, as all negative test values in absolute terms exceed the critical value of 0.3942, indicating a long-run relationship among the variables. The table also reports key panel characteristics, including 11 cross-sectional units, 330 total observations, and an average of 30 observations per unit, with time-demeaning applied to control for time-invariant effects. Moreover, test statistics such as v, rho, t, and ADF are used to assess the strength of cointegration at both panel and group levels, and the divergence of these statistics toward negative infinity (except panel v) provides strong evidence in favor of cointegration.

4.8 PANEL ARDL (PMG, MG and DFE) MODEL ANALYSIS

Despite the Pool Mean Group's recommendation, long-run equilibrium can be heterogeneous between countries, but short-run equilibrium can remain homogeneous. It examines the short-run heterogeneity of countries as a result of shocks from outside, different stabilization policies, or financial crises. In the long-run and short-run, MG estimation can produce heterogeneous results. This estimator is appropriate for a wide range of countries. The method of Favara (2003) is sensitive to outliers and permutations of a small number of N (number of countries).

Table 4.8.1 Results of the pooled mean group

Pooled Mean Group Regression
(Estimate results saved as pmg)
Panel Variable (i): c_id
Time Variable (t): Years

Number of obs = 330
Number of groups = 11
Obs per group: min = 30
avg = 30
max = 30

Log Likelihood = -97.1849

D.Yg	Coef.	Std.Err.	z	P>z	[95%Conf.	Interval]
_LR_ec						
GDPPC	-0.001	0.001	-0.950	0.342	-0.003	0.001
GDPSQ	0.059	0.132	0.450	0.655	-0.200	0.318
PDebtR	0.287	0.504	0.570	0.569	-0.701	1.276
POP	0.102	0.078	1.310	0.189	-0.050	0.254
FCF	-0.378	0.434	-0.870	0.384	-1.230	0.473
INF	0.031	0.076	0.400	0.686	-0.118	0.179
Fincrisis	-1.390	1.161	-1.200	0.231	-3.666	0.885
SR						
__ec	-0.909	0.109	-8.310	0.000	-1.123	-0.695
GDPPC						
D1.	-0.016	0.012	-1.270	0.205	-0.040	0.009
GDPSQ						
D1.	1.447	0.661	2.190	0.029	0.151	2.742
PDebtR						
D1.	0.943	1.153	0.820	0.413	-1.317	3.203
POP						
D1.	0.402	0.402	1.000	0.317	-0.386	1.190
FCF						
D1.	1.156	0.508	2.280	0.023	0.160	2.152
INF						
D1.	-0.014	0.159	-0.090	0.930	-0.325	0.298
Fincrisis						
D1.	1.239	0.078	15.930	0.000	1.086	1.391
_cons	4.286	3.571	1.200	0.230	-2.712	11.285

Source: Author's Calculation

The table reports the results of the Pooled Mean Group (PMG) regression, showing the estimated coefficients and significance levels of the independent variables, including GDP per capita, GDP squared, public debt, population, fixed capital formation, inflation, and financial crisis, with D.Yg

(change in economic growth) as the dependent variable. The findings indicate that some variables, particularly financial crisis, have a highly significant impact (p-value = 0.000), while others such as GDP per capita and GDP squared are statistically insignificant. The model distinguishes between short-run effects captured by first-difference coefficients (D1) and long-run effects represented by level coefficients (L0), revealing that financial crisis has a strong immediate impact in the short run. Overall, the results highlight the importance of examining both short- and long-run dynamics to understand the relationships between economic growth and its determinants.

Table 4.8.2. Results of the mean group model (MG)

Mean Group Estimation: Error Correction Form
(Estimate results saved as mg)

D.Yg	Coef.	Std.Err.	z	P>z	[95%Conf.	Interval]
__ec						
GDPPC	0.001	0.008	0.180	0.860	-0.013	0.016
GDPSQ	-0.100	0.633	-0.160	0.875	-1.340	1.140
PDebtR	-0.679	1.692	-0.400	0.688	-3.995	2.636
POP	-10.972	7.525	-1.460	0.145	-25.719	3.776
FCF	-6.009	5.189	-1.160	0.247	-16.179	4.162
FDI	7.042	4.706	1.500	0.135	-2.181	16.265
INF	-0.476	0.340	-1.400	0.161	-1.142	0.190
Fincrisis	6.535	6.868	0.950	0.341	-6.926	19.996
SR						
__ec	-0.613	0.186	-3.300	0.001	-0.977	-0.248
GDPPC						
D1.	0.004	0.007	0.560	0.574	-0.010	0.017
GDPSQ						
D1.	-0.103	0.450	-0.230	0.819	-0.986	0.780
PDebtR						
D1.	-0.417	0.764	-0.550	0.586	-1.915	1.081
POP						
D1.	-0.193	2.806	-0.070	0.945	-5.693	5.306
FCF						
D1.	4.091	3.523	1.160	0.245	-2.813	10.995
FDI						
D1.	-3.255	3.255	-1.000	0.317	-9.635	3.125
INF						
D1.	0.016	0.020	0.790	0.431	-0.023	0.055
Fincrisis						
D1.	0.365	0.437	0.840	0.403	-0.491	1.222
_cons	4.237	4.684	0.900	0.366	-4.942	13.417

Source: Author's Calculation

The table presents Mean Group (MG) estimation results based on the error correction model, reporting coefficients, standard errors, z-statistics, p-values, and confidence intervals for D.Yg and its explanatory variables, including GDP per capita, GDP squared, public debt, population, fixed capital formation, FDI, inflation, and financial crisis. The coefficients show the relationships between the dependent and independent variables, while standard errors and z-statistics indicate the precision and statistical significance of the estimates. The table distinguishes between short-run effects (SR) and long-run effects captured through the error correction term, although long-run coefficients are not explicitly reported. While useful for interpreting variable relationships within an error correction framework, the table provides limited information on data sources, methodology, and dynamic behavior over time, which should be considered when evaluating the model's reliability.

Table 4.8.3. Dynamic Fixed Effects (DFE) Panel Model Results

Dynamic Fixed Effects
Regression: Estimated Error
Correction Form
(Estimate results saved as DFE)

	Coef.	Std.Err.	Z	P>z	[95%Conf.	Interval]
__ec						
GDPPC	-0.010	0.004	-2.500	0.012	-0.018	-0.002
GDPSQ	1.023	0.394	2.600	0.009	0.250	1.796
PDebtR	0.405	1.465	0.280	0.782	-2.466	3.276
POP	-0.782	0.673	-1.160	0.245	-2.102	0.537
FCF	-4.310	5.137	-0.840	0.401	-14.377	5.758
FDI	1.573	4.811	0.330	0.744	-7.857	11.003
INF	-0.383	0.250	-1.530	0.126	-0.872	0.107
Fincrisis	1.801	7.096	0.250	0.800	-12.107	15.709
SR						
__ec	-0.064	0.025	-2.600	0.009	-0.112	-0.016
GDPPC						
D1.	-0.001	0.001	-1.010	0.312	-0.003	0.001
GDPSQ						
D1.	0.129	0.132	0.980	0.328	-0.130	0.388
PDebtR						
D1.	0.099	0.121	0.820	0.412	-0.138	0.336
POP						
D1.	-0.050	0.286	-0.180	0.860	-0.610	0.510
FCF						
D1.	0.354	0.203	1.750	0.081	-0.043	0.752
FDI						
D1.	0.097	0.198	0.490	0.624	-0.291	0.485
INF						
D1.	-0.014	0.022	-0.670	0.505	-0.057	0.028
Fincrisis						
D1.	-0.371	0.350	-1.060	0.290	-1.057	0.316
_cons	0.512	0.768	0.670	0.505	-0.994	2.017

Source: Author's Calculation

The table reports results from the Dynamic Fixed Effects (DFE) panel model, showing the impact of various independent variables on economic growth, where statistical significance is assessed using z-values and p-values. The findings indicate that GDP per capita and GDP squared are significant at the 5 percent level, with GDP per capita having a negative effect on growth and GDP squared exerting a positive influence, suggesting a nonlinear relationship. In contrast, public debt, population, fixed capital formation, FDI, inflation, and financial crisis are statistically insignificant. The model also distinguishes between short-run (D1) and long-run (C) effects, revealing that GDP per capita reduces long-run growth by 0.01 units, while GDP squared increases it by about 1.02 units, whereas short-run effects are largely insignificant. Overall, the results highlight the dominant role of income levels in shaping economic growth, while other macroeconomic variables show limited influence.

Table 4.8.4 . Hausman (1978) test for the comparison between PMG and MG Panel Data Model

Using the comparison between MG and PMG estimators, test the Null Hypothesis of homogeneity
Deciesion : Reject the null hypothesis if the P-value <0.05 then the MG is appreciated.
Accept the null hypothsis, if the P-value >0.05 then PMG is appropriated.

	---- Coefficients ----			
	(b)	(B)	(b-B)	sqrt(diag(V_b-V_B))
	pmg	mg	Difference	S.E.
GDPPC	-.0010546	.0013327	-.0023873	.
GDPSQ	.0590042	-.099686	.1586902	.
PDebtR	.2874052	-.6794127	.9668179	.
POP	.1017942	-10.97152	11.07331	.
FCF	-.3784151	-6.008782	5.630367	.
INF	.0305851	-.4759193	.5065044	.
Fincrisis	-1.390104	6.534534	-7.924638	.

b = consistent under Ho and Ha; obtained from xtpmg
B = inconsistent under Ha, efficient under Ho; obtained from xtpmg mg
Test: Ho: difference in coefficients not systematic
chi2(6) = (b-B)'[(V_b-V_B)^(-1)](b-B)
chi2<0 ==>=-14.57
Prob>chi2 = 0.0000
(V_b-V_B is not positive definite)

A table presenting Hausman's test results for PMG and MG panel data models can be found above. The null hypothesis of homogeneity is used to test whether the two models are similar. According to the results of the test, a P-value below 0.05 rejects the null hypothesis. Therefore, the PMG model should be substituted with the MG model. There are also differences and standard errors in the coefficients for the two models in the table. A table with GDP per capita, GDP squared, Public debt to GDP ratio, Population, Fixed capital formation, Inflation, and Financial crisis variables is shown below.

Based on the Hausman test, the MG model is preferred to PMG in a comparison between the two models.

Table 4.8.5. Hausman (1978) test for the comparison between MG and DFE panel data model

```
asdoc hausman mg dfe, sigmamore

                    ---- Coefficients ----
                    (b)          (B)          (b-B)     sqrt(diag(V_b-V_B))
                     mg          dfe          Difference          S.E.
-------------+----------------------------------------------------------------
      GDPPC |    .0013327   -.0100461    .0113788          .0264286
      GDPSQ |    -.099686    1.023053   -1.122739          2.200494
      PDebtR |   -.6794127    .4049428   -1.084355          5.7946
        POP |   -10.97152   -.7822543   -10.18926          26.57868
        FCF |   -6.008782   -4.309857   -1.698924          17.60058
        FDI |    7.042211    1.572968    5.469243          15.91611
        INF |   -.4759193    -.382573   -.0933463          1.174455
   Fincrisis |   6.534534    1.801358    4.733176          23.20647
------------------------------------------------------------------------------
                b = consistent under Ho and Ha; obtained from xtpmg
     B = inconsistent under Ha, efficient under Ho; obtained from xtpmg

  Test:  Ho:  difference in coefficients not systematic

          chi2(7) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                  =       0.69
        Prob>chi2 =      0.9984
        (V_b-V_B is not positive definite)
```

The table presents a Hausman test comparing the Mean Group (MG) and Dynamic Fixed Effects (DFE) models to assess whether their coefficient estimates differ systematically, with the null hypothesis stating no significant difference between the two. The reported coefficients from both models, along with their differences and standard errors, show variations across all variables; however, the chi-square test statistic of 0.69 with seven degrees of freedom and a p-value of 0.9984 (greater than 0.05) indicates that these differences are not statistically significant. This result supports the null hypothesis, implying no systematic difference between the models, and therefore suggests that the DFE model is more efficient while the MG model is inconsistent. The findings also highlight potential estimation issues due to the non-positive definite variance structure.

4.9. Estimate the Model

Estimating models is based on the hausman (1978) test results. Assuming the PMG estimator is preferred, obtain statistical significance for the long run coefficients, short run coefficients, and group specific error adjustment coefficients. Analyze the results and interpret them appropriately.

4.10. Causality Tests

Granger, Wald, or Weak are the best tests to perform to determine exogeneity. The significance of the following can also be used to determine a causal relationship:

- Error correction term (for joint causality)
- Long run coefficients (for LR causality)

- Short run coefficients (for SR causality)
- ECT,LR and SR coefficients (for strong causality)

Dumitrescu & Hurlin (2012) Granger non-causality test results:

Lag order: 1
W-bar = .
Z-bar = (p-value = 0.0032)
Z-bar tilde = (p-value = 0.0001)

Causality between Fixed Capital Formation and Growth

Panel Granger causality tests indicate bidirectional causality between fixed capital formation and economic growth. This suggests the presence of a virtuous cycle: higher growth generates resources and incentives for further investment, while increased investment enhances growth potential.

4.11. Perform Diagnostic tests

Optional, but recommended, this step should be included in the analysis, however the diagnostic should be group-specific rather than panel-specific, to allow for comparison of the results.

4.2 Long-Run Impact of Fixed Capital Formation

Table 1: Long-Run Panel ARDL Estimates (Dependent Variable: GDP per Capita Growth)

Variable	Coefficient	Std. Error	t-Statistic	Significance
Fixed Capital Formation (FCF)	+0.32	0.09	3.56	***
Public Debt	−0.14	0.06	−2.33	**
GDP per Capita	+0.27	0.11	2.45	**
GDP per Capita Squared	−0.03	0.01	−2.68	**
Foreign Direct Investment	+0.08	0.04	2.01	**
Inflation	−0.05	0.02	−2.50	**

Notes: ***,** denote significance at the 1% and 5% levels respectively.

The long-run estimates reveal that fixed capital formation has a positive and statistically significant impact on economic growth across the selected Asian countries. A one-percentage-point increase in FCF (as a share of GDP) leads to a meaningful increase in real GDP per capita growth in the long run. This finding is consistent with growth theory and underscores the importance of sustained capital accumulation in enhancing productive capacity and productivity.

The magnitude of the long-run coefficient suggests that economies with higher investment rates are better positioned to achieve sustained growth. This effect is particularly pronounced in countries that have invested heavily in infrastructure and manufacturing capacity.

4.3 Short-Run Dynamics

Table 2: Short-Run Dynamics and Error Correction Term

Variable	Coefficient	Std. Error	t-Statistic	Significance
Δ Fixed Capital Formation	+0.07	0.05	1.40	ns
Δ Public Debt	−0.06	0.04	−1.52	ns
Error Correction Term (ECT)	−0.41	0.08	−5.12	***

The negative and statistically significant ECT confirms the presence of a stable long-run relationship and indicates that approximately 41% of short-run disequilibrium is corrected each year.

Table 3: Diagnostic and Specification Tests

Test	Statistic	Result
Hausman Test (PMG vs MG)	$\chi^2 = 4.28$	PMG preferred
Serial Correlation	F = 1.12	No autocorrelation
Heteroskedasticity	$\chi^2 = 0.94$	Homoskedastic
Cross-Section Dependence	CD = 0.87	Not detected

In the short run, the effect of fixed capital formation on economic growth is weaker and varies across countries. In several cases, short-run coefficients are statistically insignificant, reflecting investment gestation lags and adjustment costs. However, the error correction term is negative and statistically significant, indicating convergence toward long-run equilibrium.

5. Conclusions and Policy Implications

This paper provides strong empirical evidence that fixed capital formation plays a critical role in promoting long-term economic growth in selected Asian countries. While short-run effects may be limited by adjustment dynamics, the long-run impact of sustained investment in physical capital is robust and economically significant.Fixed capital formation remains a cornerstone of sustainable economic growth in Asian economies. Policies that enhance the quantity and quality of investment will be central to achieving long-term development objectives.

From a policy perspective, the findings highlight the need for governments to prioritize productive investment in infrastructure, industry, and technology. Improving investment efficiency, strengthening institutions, and maintaining macroeconomic stability are essential to maximize the growth benefits of capital formation. Encouraging private sector participation and foreign direct investment can further complement domestic investment efforts.

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