

CHAPTER 1

Investment, Trade, and Innovation Capacity in Economic Development: Panel Evidence across Income Groups

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ABSTRACT

This study examines the association between investment, trade, and patent-based innovation indicators and economic development across countries at different income levels. Using an unbalanced panel of 65 countries observed from 2010 to 2023, the analysis employs fixed-effects estimators with country and year controls to isolate within-country variation over time. GDP per capita is used as the primary indicator of economic development, while GDP growth is examined as a robustness check. The results indicate that gross capital formation is positively and significantly associated with income levels in high- and upper-middle-income economies, whereas this association is weaker in low- and lower-middle-income countries. Export exposure does not exhibit a positive association with income, and patent activity does not emerge as a statistically significant determinant of within-country income variation across income groups. Robustness checks using GDP growth yield consistent conclusions. Overall, the findings highlight the dominant role of investment dynamics relative to patent-based innovation indicators in explaining short- to medium-run patterns of economic development.

Keywords: Economic development; Investment; Patent activity; Fixed-effects panel; Income groups.

1.0 Introduction

Economic development is commonly linked to capital accumulation and trade integration, while innovation is increasingly viewed as a key driver of long-term income growth (Damasceno & Guedes, 2024; Gonzales, 2023). At the country level, innovation is frequently proxied using patent-based indicators due to their availability and cross-country comparability (Yıldız & Görkey, 2024). However, the extent to which patent activity captures economically meaningful innovation and whether it translates into observable income gains remains empirically unsettled (Uzuner *et al.*, 2025; Yıldız & Görkey, 2024).

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This study examines the association between patent activity and economic development within a panel framework that also accounts for investment and trade dynamics. Using an unbalanced panel of 65 countries observed from 2010 to 2023, fixed-effects estimators are employed to isolate within-country variation over time while controlling for unobserved country characteristics and global shocks. The analysis is conducted across the full sample and by income group to assess heterogeneity in development dynamics. By contrasting income-level outcomes with short-run growth measures, the paper provides evidence on the suitability of patent-based indicators for explaining economic development across stages of development (Gonzales, 2023; My Thi Thi & Tran Phu Do, 2024).

2.0 Literature Review

The relationship between economic development and its underlying drivers has traditionally emphasized capital accumulation and trade integration. Classical and neoclassical growth models highlight the role of investment in expanding productive capacity, while empirical studies consistently document positive associations between capital formation and income levels across countries (Choirunnisa & Yusfi, 2025; Roy, 2024). Trade openness has also been linked to development through specialization and market access, although evidence suggests that its impact depends critically on export composition and structural transformation rather than trade volume alone (Chabi & Saygılı, 2024; Monyela & Saba, 2024).

Innovation has increasingly been incorporated into development analyses, with patent-based indicators commonly used as proxies for national innovation capacity due to their availability and comparability (Gonzales, 2023; Yıldız & Görkey, 2024). At the country level, patents are often interpreted as observable outcomes of inventive activity and institutional support for innovation. However, empirical findings on the relationship between patent activity and economic development are mixed. While some studies report positive associations between patenting and income or productivity, others find weak or insignificant relationships once country-specific characteristics and time effects are controlled for (Bom & Stojanovikj, 2025).

A key limitation identified in the literature concerns the interpretation of patent counts as measures of economically relevant innovation. Patents vary widely in quality and economic value, and their contribution to development may depend on complementary factors such as absorptive capacity, industrial structure, and institutional conditions (Gonzales, 2023; Yıldız & Görkey, 2024). Moreover, innovation-related effects may materialize with substantial lags, complicating their identification in short- to medium-run panel settings (Bom & Stojanovikj, 2025; Monyela & Saba, 2024).

This study builds on the existing literature by jointly examining investment, trade, and patent activity within a fixed-effects panel framework and by explicitly exploring heterogeneity across income groups. By focusing on within-country variation over time and by comparing income-level and growth-based outcomes, the analysis contributes evidence to ongoing debates on the suitability of patent-based indicators for explaining economic development dynamics (Monyela & Saba, 2024; Yıldız & Görkey, 2024).

3.0 Data and sample

The study uses an unbalanced panel dataset covering 65 countries with annual observations from 2010 to 2023, yielding 910 country-year observations. Countries are grouped into three income categories based on World Bank classifications. Data was collected from the World Bank database.

- High income,
- Upper-middle income, and
- Low and lower-middle income (combined).

3.1 Variables used in the study

The analysis emphasizes within-country variation over time, rather than cross-sectional differences between countries.

Table 1: Variable Used in the Study

Category	Variable	Abbreviation	Description	Role in Model
Economic Performance	GDP per Capita	GPC	Gross domestic product per capita, used as the primary indicator of economic development	Dependent variable
Economic Performance	GDP Growth	GGW	Annual growth rate of gross domestic product, used to examine short-run growth dynamics and as a robustness check	Alternative dependent variable
Investment	Gross Capital Formation	GCF	Gross capital formation as a share of GDP, proxying domestic investment activity	Independent variable
Trade	Exports	EXP	Exports of goods and services, proxying trade exposure	Independent variable
Innovation Capacity	Patent Applications	PA	Number of patent applications, used as a secondary indicator of national innovation capacity	Independent variable

3.2 Econometric specification

To account for unobserved country-specific heterogeneity and global time shocks, the study employs a linear fixed-effects (within) estimator with country- and year-fixed

effects. Standard errors are clustered at the country level to correct for serial correlation and heteroscedasticity.

The baseline specification is:

$$GPC_{it} = \beta_1 PA_{it} + \beta_2 GCF_{it} + \beta_3 EXP_{it} + \alpha_i + \gamma_t + \varepsilon_{it}$$

where i indexes countries and t indexes years; α_i captures time-invariant country-specific effects; γ_t captures common global shocks; and ε_{it} is the idiosyncratic error term. As a robustness check, the same specification is re-estimated using GDP growth (GGW) as the dependent variable:

$$GGW_{it} = \beta_1 PA_{it} + \beta_2 GCF_{it} + \beta_3 EXP_{it} + \alpha_i + \gamma_t + \varepsilon_{it}$$

The models are estimated for:

- the full sample, and
- separately for each income group to examine heterogeneity in development and growth dynamics.

No causal interpretation is imposed; coefficients are interpreted as within-country associations over time.

4.0 Results

Table 2 reports fixed-effects estimates of GDP per capita for the full sample and by income group. Across specifications, Gross Capital Formation (GCF) shows a positive, statistically significant association with GDP per capita in the full sample and in high-income and upper-middle-income countries. In contrast, the coefficient on GCF is not statistically significant in low and lower-middle-income economies. Exports (EXP) display a negative or statistically insignificant association with GDP per capita across income groups, suggesting that aggregate export exposure does not systematically translate into within-country income gains after controlling for fixed effects.

Table 2: Fixed-Effects Estimates of GDP per Capita Across Income Groups

Variables	Full Sample	High Income	Upper-Middle Income	Low & Lower-Middle Income
Patent Activity (PA)	0.021 (0.027)	−0.028 (0.023)	0.011 (0.054)	0.085 (0.061)
Gross Capital Formation (GCF)	0.165 (0.073)**	0.269 (0.098)**	0.292 (0.128)**	−0.126 (0.096)
Exports (EXP)	−0.299 (0.110)**	−0.254 (0.138)	−0.311(0.163)*	−0.190 (0.180)
Country FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	910	434	294	182
Number of Countries	65	31	21	13
Within R ²	0.473	0.528	0.476	0.636

Notes: Robust standard errors clustered at the country level are reported in parentheses. * $p < 0.10$, ** $p < 0.05$. Dependent variable: GDP per capita. Log taken for PA, GCF, and EXP for comparability.

Patent Applications (PA) are not statistically significant in the full sample or in any income group. As a robustness check, Appendix A reports analogous fixed-effects estimates using GDP growth as an alternative dependent variable. These supplementary results do not alter the main conclusions regarding the limited explanatory role of patent activity.

5.0 Discussion

The results indicate that within-country changes in economic development are more closely associated with investment dynamics than with patent-based indicators of innovation (Yıldız & Görkey, 2024). Gross capital formation emerges as the most consistent correlate of GDP per capita, particularly in higher-income economies, underscoring the continued relevance of investment-led development mechanisms (Roy, 2024). In contrast, patent activity does not exhibit a statistically significant association with income levels once country-specific characteristics and global time effects are accounted for; this finding aligns with evidence that patent counts alone may not reliably predict economic growth (Bom & Stojanovikj, 2025; Yıldız & Görkey, 2024). This does not imply that innovation is unimportant for development; rather, it highlights the limitations of patent counts as proxies for short- to medium-run economic outcomes at the country level, since they may capture legal activity rather than commercialization or productivity gains (Yıldız & Görkey, 2024). The generally weak or negative association between exports and income further suggests that trade volume alone may be insufficient to explain development dynamics, emphasizing the role of export composition and structural upgrading.

6.0 Limitations

This study has several limitations. First, patent applications are an imperfect measure of innovation and do not capture quality or economic value. Second, the fixed-effects framework focuses on within-country variation, potentially understating long-run structural relationships that operate across countries. Third, the analysis employs a parsimonious set of explanatory variables, and other factors such as institutions or human capital are not explicitly modeled. Finally, innovation effects may materialize over longer horizons than those captured in the study period.

7.0 Conclusion

Using panel data for 65 countries over 2010–2023, this study examined the roles of investment, trade, and patent activity in shaping economic development across income groups. The results show that gross capital formation is consistently associated with higher

GDP per capita in higher-income economies, while patent activity does not emerge as an independent determinant of within-country income variation. These findings suggest caution in using patent counts as direct indicators of economic development outcomes and highlight the importance of distinguishing between innovation capacity measures and income-generating mechanisms. Future research may benefit from incorporating quality-adjusted innovation indicators and longer time horizons to better capture the development effects of innovation.

8.0 Future Research

Future research could extend this analysis in several directions. First, incorporating quality-adjusted innovation measures, such as citation-weighted patents or R&D expenditure, may provide a more nuanced understanding of the innovation–development relationship. Second, longer time horizons or dynamic panel approaches could be used to explore potential lagged effects of innovation on economic outcomes. Third, future studies may integrate institutional, human capital, and structural transformation variables to better capture the channels through which investment and innovation translate into development. Finally, country-level analyses or regional disaggregation could help uncover heterogeneous mechanisms that are masked in cross-country panel frameworks.

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Appendix A. Robustness Check Using GDP Growth (GGW)

Fixed-Effects (Within) Estimates by Income Group

Dependent variable: GDP Growth (GGW)

Estimator: Country and year fixed effects; standard errors clustered at the country level

Period: 2010–2023

Table A1: Fixed-Effects Regression Results with GDP Growth (GGW)

Variables	High Income	Upper-Middle Income	Low & Lower-Middle Income
Patent Applications (PA)	−0.099 (0.326)	−0.389 (0.474)	−0.421 (0.150)**
Gross Capital Formation (GCF)	6.279 (1.637)***	4.940 (2.526)*	3.906 (1.933)*
Exports (EXP)	6.711 (1.501)***	4.849 (1.752)**	1.003 (0.962)
Country Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	434	294	182
Number of Countries	31	21	13
Within R ²	0.560	0.480	0.504