International Journal of Current Science Research and Review
ISSN: 2581-8341
Volume 09 Issue 02 February 2026
DOI: 10.47191/ijcsrr/V9-i2-01, Impact Factor: 8.048
IJCSRR @ 2026
www.ijcsrr.org

Institutional Capacity and the Productivity of R&D: Evidence from Patent Outcomes Across Countries

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ABSTRACT: Innovation is a key driver of economic growth. However, countries with similar research and development spending show very different patent outputs. This raises questions about what makes innovation efficient. This study examines whether government effectiveness affects the relationship between R&D spending and patent production in different countries. Using panel data from 111 countries from 2000 to 2020, we use two-way fixed effects models and System Generalized Method of Moments estimation to address potential issues of innovation persistence and reverse causality. The main variable we are looking at is the natural logarithm of one plus resident patent applications. The main independent variables are R&D expenditure as a percentage of GDP and the government effectiveness index, both measured two years earlier. The results show that R&D investment significantly increases patent activity. Specifically, a one percentage point increase in R&D intensity is associated with about a 39% increase in patent output. Conversely, the relationship between research and development (R&D) and governmental efficacy is both negative and statistically significant, suggesting that the incremental impact of R&D on patent output decreases as the quality of governance improves. This unexpected result probably reflects technological catch-up processes; nations with less robust institutions tend to experience swift patent expansion during periods of capacity building, whereas advanced economies characterized by strong governance increasingly prioritize quality over sheer volume. Dynamic models demonstrate considerable persistence in patenting behavior, as evidenced by a lagged dependent variable coefficient of 0.623, thereby validating path-dependent innovation processes. These observations imply that effective innovation policy requires aligning research investments with institutional capacities and the prevailing developmental context, rather than prioritizing either independently. This research provides empirical support for the influence of governance capacity on national innovation systems.

KEYWORDS: dynamic panel models, innovation, institutional quality, government effectiveness, patents, R&D expenditure.
JEL Classification: O31, O38, O43, C23

INTRODUCTION

Innovation is a catalyst for sustained economic expansion, increased productivity, and fundamental shifts in national economies (López-Rubio, Roig-Tierno, and Mas-Verdú 2022; Metaiche 2024). Patent activity serves as a crucial metric for innovation, reflecting the generation of novel knowledge and the outcomes of inventive endeavors (WIPO, 2025). Governments allocate substantial resources to research and development, anticipating that these expenditures will foster increased innovation and technological advancement. Nevertheless, empirical findings indicate that R&D investment alone does not guarantee robust patent outcomes, particularly across countries with varying institutional frameworks (Wang, 2013). A perplexing trend becomes apparent when assessing the conversion of R&D inputs into patent outputs. Nations that allocate comparable resources to R&D frequently exhibit significantly disparate patenting rates (Tebaldi and Elmslie, 2013).

This inquiry prompts crucial considerations regarding the determinants of innovation efficiency. This research endeavors to elucidate this conundrum by investigating government effectiveness as a pivotal institutional factor that shapes the productivity of R&D investments in patent generation. Government effectiveness encompasses the quality of public services, the effectiveness of policy implementation, and the credibility of government commitments (Acemoglu, Johnson, and Robinson, 2004). These elements are posited to affect innovation by fostering regulatory stability, efficient resource allocation, and the safeguarding of intellectual property (Cheng, Wang, and Choi, 2024). This study analyzes the interplay between R&D expenditure and government effectiveness in determining patenting activity within resident populations across various nations over an extended period. The objective is to transcend mere input quantification and to ascertain how institutions shape national innovation outcomes.

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The relationship between research and development investment and innovation output has been the subject of considerable investigation, employing innovation production functions that posit patents as the product of accumulated knowledge inputs (Saharti, 2025). Subsequent research has built upon this foundation by incorporating considerations of spillovers, human capital, and technological opportunities (Bakhtiar, 2021). While patent counts are widely utilized as a standard metric for inventive output, researchers recognize the inherent limitations stemming from variations in patent quality (WIPO, 2025). Furthermore, recent scholarship highlights the influence of institutions on innovation outcomes. Specifically, institutional quality shapes innovation incentives by influencing the enforcement of property rights, regulatory predictability, and transaction costs (Acemoglu, 2025). Empirical investigations have demonstrated robust correlations between governance indicators and innovation performance, especially within developing and transition economies (Casadella and Uzunidis, 2017; Tebaldi and Elmslie, 2013).

However, researchers typically treat institutions as background controls rather than as central mechanisms in the R&D-innovation relationship (Wang, 2013). This study bridges the innovation production function literature and institutional economics by explicitly modeling government effectiveness as both a direct driver of patenting activity and a moderator of the productivity of R&D investment. Unlike single-snapshot analyses, this study uses a dynamic panel framework to capture how innovation persists over time and to address issues of causal direction (Li et al., 2021). This approach aligns with recent methodological advances in macro-innovation studies that employ dynamic panel estimators to handle unobserved heterogeneity and endogeneity (Ullah, Akhtar, and Zaefarian, 2018; Wintoki, Linck, and Netter, 2012).

Based on innovation theory and institutional economics, the study tests three hypotheses. **First, higher R&D expenditure as a share of GDP increases resident patenting activity with a time lag.** Furthermore, **a positive correlation exists between government effectiveness and patent output, even after controlling for R&D investment levels.** Thirdly, **government effectiveness serves as a positive moderator in the relationship between R&D expenditure and patenting; thus, R&D investment yields a greater number of patents in nations characterized by robust governance** (Donges, Meier, and Silva, 2023). These hypotheses are consistent with the perspective that innovation outcomes are contingent not only on the magnitude of investment but also on the institutional context that dictates how those investments are applied (Acemoglu, Johnson, and Robinson, 2004).

To empirically assess these hypotheses, the study employs panel-data econometric techniques, specifically those derived from the innovation-production function paradigm. Resident patent applications are utilized as the principal indicator of innovation output and are adjusted to account for skewness and the presence of zero values. R&D expenditure and government effectiveness are incorporated with time lags to account for the gradual nature of innovation processes and to mitigate simultaneity bias (Barros et al., 2020). The baseline analysis uses two-way fixed effects models, controlling for unobserved country characteristics and global time trends. To directly assess whether institutions amplify R&D effectiveness, interaction terms between R&D expenditure and government effectiveness are included. Recognizing that innovation is dynamic and path-dependent, the study applies the System Generalized Method of Moments (Kiviet, Pleus, and Poldermans, 2017). This technique addresses problems arising from innovation persistence and reverse causality between R&D investment and patenting outcomes, issues that violate the strict exogeneity assumption required for traditional panel estimators (Li et al., 2021; Ullah, Akhtar, and Zaefarian, 2018).

The study expects to find that R&D expenditure positively affects patenting activity, but with significantly stronger effects in countries with higher government effectiveness. The interaction between R&D and government effectiveness should be positive and statistically significant, indicating that institutional quality enhances the efficiency with which R&D inputs convert into innovation outputs (Tebaldi and Elmslie, 2013). These findings would suggest that innovation policy effectiveness depends critically on governance capacity. Simply increasing R&D spending may yield limited returns in weak institutional environments, while improvements in government effectiveness can substantially amplify the innovation returns from existing investments (Sube et al., 2025). By providing systematic empirical evidence on the institutional foundations of patenting activity, this study contributes to the literature on national innovation systems and offers practical insights for countries seeking to strengthen innovation-led development (López-Rubio, Roig-Tierno, and Mas-Verdú, 2022; Metaiche, 2024).

LITERATURE REVIEW

The relationship between innovation and economic prosperity has occupied a central place in growth theory for decades. Understanding what drives a nation's capacity to innovate requires examining not only the direct inputs into knowledge production

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but also the broader institutional environment that shapes how effectively these inputs translate into tangible outcomes. The innovation production function serves as the conceptual basis for elucidating the relationship between research inputs and the generation of patented inventions. Initial research demonstrated a systematic correlation between patent output and both accumulated knowledge and research expenditures (Saharti, 2025). Over time, this framework has been expanded to encompass various facets of national innovative capacity, including knowledge spillovers from international sources, the quality of human capital, and technological infrastructure (Bakhtiar, 2021; López-Rubio, Roig-Tierno, and Mas-Verdú, 2022). Despite acknowledged limitations, patent counts have become the predominant empirical metric for assessing innovation output. Patents, however, differ significantly in their economic and technological significance, and firms may opt for secrecy rather than patent protection for specific innovations (WIPO, 2025).. Moreover, patent data derived from individual national offices may exhibit home bias, thereby favoring domestic applicants.

Notwithstanding these reservations, resident patent applications remain the most accessible and comparable metric for assessing inventive activity across nations and historical periods.

Although research inputs are undeniably significant for innovation, an expanding body of research indicates that institutional quality is a crucial determinant of how effectively these inputs are utilized. The theoretical rationale is underpinned by several key mechanisms. Robust property rights protection mitigates the uncertainty surrounding the returns from research and development, thereby generating strong incentives for individuals and companies to undertake high-risk innovation endeavors (Acemoglu, Johnson, and Robinson, 2004). A reliable and predictable judicial system is essential for ensuring dependable contract enforcement, which is critical for intricate collaborative innovation processes involving multiple stakeholders. Furthermore, superior regulatory quality and the absence of excessive market interventions foster competitive environments that compel firms to innovate to achieve a competitive edge.

Finally, controlling corruption ensures that both public and private resources flow to their most productive uses rather than being diverted through rent-seeking behavior (Casadella and Uzunidis, 2017). Empirical studies have documented strong positive associations between various governance indicators and innovation performance across countries. Research focusing on developing and transition economies finds particularly pronounced effects, suggesting that institutional improvements may generate especially large innovation gains in contexts where governance quality is initially poor (Sube et al., 2025; Tebaldi and Elmslie, 2013). However, a critical gap in the existing literature is that most studies treat institutional variables as background control factors rather than as central mechanisms that fundamentally shape the innovation process. Institutions are typically included in regression models alongside research inputs, without explicit attention to how they might interact or moderate each other's effects. The extent to which institutional quality enhances the productivity of research investments has not been systematically examined. However, theoretical frameworks imply that this moderating influence should be significant. In contexts characterized by deficient governance, research funding may be ineffectively allocated, intellectual property may be inadequately safeguarded, and innovative enterprises may encounter unpredictable regulatory impediments. Consequently, even considerable research expenditures may not yield proportionate innovation outcomes. Conversely, robust institutions are expected to improve the efficiency with which research inputs are transformed into patented inventions by providing stable operational environments, dependable property rights, and effective coordination among innovation system participants (Metaiche, 2024).

Establishing reliable causal links between these factors poses significant methodological difficulties. A primary concern is endogeneity, a common issue in innovation research stemming from various sources. Unmeasured national attributes, including cultural perspectives on entrepreneurship or historical contexts, can simultaneously affect both institutional advancement and innovative potential. Furthermore, innovation and institutions likely develop in tandem, exhibiting a co-determined relationship over time. Countries that achieve innovation may, in turn, amass resources and political support to fortify governance institutions, thereby generating reverse causality that skews conventional regression analyses (Li et al., 2021).

Panel data methodologies present significant benefits in mitigating these issues. Country fixed effects account for unobserved heterogeneity that remains constant over time, whereas year fixed effects control for global shocks that impact all nations concurrently. Nevertheless, conventional fixed effects estimators are predicated on stringent exogeneity assumptions that are undermined when innovation exhibits persistence and when current institutional quality depends on prior innovation outcomes (Wintoki, Linck, and Netter, 2012). This dynamic endogeneity necessitates the application of more advanced econometric techniques. The Generalized Method of Moments framework, specifically System GMM estimation, addresses these challenges by

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using lagged values of endogenous variables as internal instruments and explicitly modeling the dynamic, path-dependent characteristics of innovation processes (Kiviet, Pleus, and Poldermans, 2017; Ullah, Akhtar, and Zaefarian, 2018).

Proper implementation requires careful attention to instrument validity through diagnostic tests, including Arellano-Bond tests for serial correlation and Hansen tests of overidentifying restrictions (Barros[1] et al., 2020). Despite substantial progress, the literature has not yet fully integrated institutional economics with innovation production function models, treating governance quality as a fundamental moderating mechanism rather than a mere control variable. This study addresses this gap by explicitly modeling government effectiveness as both a direct determinant of patenting activity and a factor that conditions the marginal productivity of research and development investments. By employing dynamic panel methods that properly account for persistence and endogeneity while testing interaction effects between research inputs and institutional quality, this study aims to provide more credible evidence on how governance capacity shapes national innovation systems. The central purpose is to determine whether and how government effectiveness moderates the relationship between R&D expenditure and patent output across countries, offering insights for policymakers seeking to enhance innovation-led development.

METHODS

This study adopts a country-level unbalanced panel data design to examine the determinants of innovation output, measured by resident patenting activity. The empirical strategy follows the innovation production function literature, which models innovation outcomes as a function of research inputs and institutional quality. Given the dynamic and path-dependent nature of innovation, the analysis combines static fixed-effects models with dynamic panel estimators to address unobserved heterogeneity and endogeneity. The panel structure consists of multiple countries observed annually over the period 2000–2020, a time window chosen to balance data availability and reduce missingness prevalent in earlier years.

The primary dependent variable is the number of patent applications filed by residents of a country in a given year. Patent counts are highly skewed and include zero observations, so the dependent variable is transformed as

$Y_{i,t} = \ln(1+Patents_{i,t})$

This transformation stabilizes variance while retaining observations with zero patenting activity. The main innovation input is research and development (R&D) expenditure as a percentage of GDP, which proxies for national innovation investment intensity. To account for the delayed effect of R&D on observable patent outputs, R&D expenditure is introduced with a two-year lag, consistent with the innovation literature. Institutional quality is captured through government effectiveness, an index that measures perceptions of public service quality, policy formulation and implementation, and government credibility. Higher values indicate more effective governance. Government effectiveness is also lagged by two years to mitigate simultaneity and reflect institutional persistence.

To account for scale and structural differences across countries, the model includes population density, lagged one year, as a proxy for urbanization and agglomeration effects. GDP growth lagged by 1 year is included where relevant to control for short-run macroeconomic conditions. Country and year fixed effects are included in all baseline specifications to control for time-invariant national characteristics and global shocks affecting innovation. The core empirical specification is a two-way fixed effects panel regression, estimated as:

$$\ln(1 + Patents_{i,t}) = \beta_1 RD_{i,t-2} + \beta_2 GovEff_{i,t-2} + \beta_3 Z_{i,t-1} + \mu_i + \lambda_t + \varepsilon_{it}$$

where i indexes countries and t indexes years, Zi,t-1 denotes the vector of control variables, μ_i captures country fixed effects, λ_t captures year fixed effects, and ε_{it} is the idiosyncratic error term. Standard errors are clustered at the country level to account for serial correlation and heteroskedasticity. To test whether institutional quality enhances the effectiveness of R&D investment, an interaction term between R&D expenditure and government effectiveness is introduced:

$$\ln(1 + Patents_{i,t}) = \beta_1 RD_{i,t-2} + \beta_2 GovEff_{i,t-2} + \beta_3 (RD_{i,t-2} \times GovEff_{i,t-2}) + \beta 4 Z_{i,t-1} + \mu_i + \lambda_t + \varepsilon_{it}$$

A positive and statistically significant interaction coefficient ($\beta 3$) indicates that higher government effectiveness increases the marginal productivity of R&D in generating patent outputs. Innovation processes exhibit strong persistence, as current patenting activity depends on past innovation capacity. Moreover, R&D investment may be endogenous due to reverse causality, in which more innovative countries invest more in R&D. To address these concerns, a dynamic panel model is estimated using the System Generalized Method of Moments (System GMM). The dynamic specification is:

$$\ln(1 + Patents_{i,t}) = \rho \ln(1 + Patents_{i,t-1}) + \beta_1 RD_{i,t-2} + \beta_2 GovEff_{i,t-2} + \beta_3 Z_{i,t-1} + \mu_i + \varepsilon_{it}$$

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System GMM combines equations in first differences and levels, using lagged values of endogenous variables as internal instruments. The lagged dependent variable and R&D expenditure are treated as endogenous, while institutional variables are treated as predetermined. Instrument proliferation is controlled by collapsing the instrument matrix and restricting lag depth. Model validity is assessed using Arellano-Bond tests for first- and second-order serial correlation and Hansen tests of overidentifying restrictions. As a robustness check, the analysis also employs Poisson Pseudo-Maximum Likelihood (PPML) estimation with country- and year-fixed effects. PPML is well-suited for count data with excess zeros and heteroskedasticity, and it does not require log-transforming the dependent variable. By combining fixed effects, interaction models, dynamic panel estimators, and count data methods, this empirical strategy provides a rigorous assessment of how R&D investment and government effectiveness jointly shape national patenting outcomes while addressing unobserved heterogeneity, persistence, and endogeneity.

RESULT

Table 1 presents descriptive statistics for the core variables used in this study. Patent counts exhibit extreme right skewness, with the mean far exceeding the median, which justifies the use of the logarithmic transformation ln(1 + patents) in all regression models. The government effectiveness index is roughly centered near zero with wide dispersion, typical of World Governance Indicator-style measures. R&D intensity shows substantial cross-country variation, ranging from 0.01% to 5.80% of GDP, reflecting diverse national innovation strategies and capacities.

Table 1. Descriptive Statistics (2000–2020)

Variable	N	Mean	SD	Min	25th	Median	75th	Max
Patent applications, residents	1,287	20,737.82	103,356.32	1	99.5	605	2,162	1,393,815
ln(1 + patents)	1,287	6.30	2.60	0.69	4.61	6.41	7.68	14.15
R&D expenditure (% GDP)	1,205	1.16	1.03	0.01	0.37	0.79	1.73	5.80
Government effectiveness	1,287	0.38	0.99	−2.27	−0.46	0.30	1.23	2.12
Population density	1,287	253.44	1,144.09	1.6	36.1	84.7	213.9	7,936.5

Note. Patent counts are highly skewed; all regressions use ln(1 + patents). R&D and government effectiveness enter models with a two-year lag; population density with a one-year lag.

Table 2 reports baseline two-way fixed effects estimates. The model specification is:

$$\ln(1 + Patents_{it}) = \beta_1 RD_{i,t-2} + \beta_2 GovEff_{i,t-2} + \beta_3 PopDens_{i,t-1} + \mu_i + \lambda_t + \varepsilon_{it}$$

After controlling for country- and year-fixed effects, lagged R&D expenditure shows a positive, statistically significant association with patenting activity ($\beta = 0.394$, $p = 0.032$), supporting the **first hypothesis**. Government effectiveness alone does not display a statistically significant direct effect in this baseline specification ($p = 0.743$). Population density, which proxies for agglomeration and urbanization effects, exhibits a strong positive relationship with patenting output ($p < 0.001$). These results suggest that while innovation inputs matter, scale and geographic concentration also play important roles in shaping patent productivity.

Table 2. Two-Way Fixed Effects Baseline Regression (Clustered SE)

Variable	Coefficient	SE	t	p
R&D (% GDP), t−2	0.394	0.183	2.150	0.032
Government effectiveness, t−2	−0.058	0.178	−0.330	0.743
Population density, t−1	0.00041	0.00007	5.950	<0.001
Country FE	Yes			
Year FE	Yes			
Observations	1,285			
Countries	111			

Note. Dependent variable: ln(1 + patents). Standard errors clustered at the country level. * $p < .10$, ** $p < 0.05$, *** $p < 0.01$.

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Table 3 introduces an interaction term between R&D expenditure and government effectiveness to test whether institutional quality moderates the productivity of innovation investments. The extended model is:

$$\ln(1 + Patents_{it}) = \beta_1 RD_{i,t-2} + \beta_2 GovEff_{i,t-2} + \beta_3 (RD \times GovEff)_{i,t-2} + \beta_4 PopDens_{i,t-1} + \mu_i + \lambda_t + \varepsilon_{it}$$

The interaction term is statistically significant ($\beta = -0.317$, $p = 0.014$), indicating that the marginal effect of R&D on patenting varies systematically with government effectiveness. The marginal effect of R&D is given by $\partial \ln(1 + Patents)/\partial RD = \beta_1 + \beta_3$ x GovEff, meaning the payoff to R&D investment depends on institutional capacity. Interestingly, the negative interaction coefficient suggests that the R&D effect diminishes as government effectiveness rises. While this runs counter to initial theoretical expectations, such patterns can emerge from several mechanisms. Countries with weaker institutions may be in catch-up phases, during which R&D generates rapid gains in patenting as they build foundational capacities. Conversely, countries with highly effective governments may already be operating near technological frontiers, where additional R&D yields diminishing marginal returns in raw patent counts or shifts toward quality over quantity. This finding aligns with literature on innovation dynamics in frontier versus follower economies and warrants careful interpretation in context.

Table 3. Two-Way Fixed Effects with Institutional Interaction

Variable	Coefficient	SE	t	p
R&D (% GDP), t−2	0.761	0.277	2.750	.006
Government effectiveness, t−2	0.233	0.261	0.890	.374
R&D × Gov. effectiveness, t−2	−0.317	0.129	−2.450	.014
Population density, t−1	0.00039	0.00007	5.890	<.001
Country FE	Yes			
Year FE	Yes			
Observations	1,285			
Countries	111			

Note. Interaction effects imply that the marginal impact of R&D on patenting varies with government effectiveness.

Table 4 presents robustness checks using dynamic panel methods and count data estimation. Panel A reports results from a dynamic model using Arellano-Bond style instrumental variables. This approach addresses endogeneity arising from innovation persistence and potential reverse causality between R&D investment and patenting outcomes. The lagged dependent variable is strongly significant ($\beta = 0.623$, $p < 0.001$), confirming substantial persistence in patenting activity across time. The dynamic specification is:

$$\ln(1 + Patents_{it}) = \rho \ln(1 + patents_{i,t-1}) + \beta_1 RD_{i,t-2} + \beta_2 GovEff_{i,t-2} + \beta_3 PopDens_{i,t-1} + \mu_i + \varepsilon_{it}$$

Model diagnostics support instrument validity. The Arellano-Bond test shows significant first-order serial correlation (expected in first differenced models) but no second-order serial correlation ($p = 0.703$), which is the critical test for instrument validity. The Sargan test of over-identifying restrictions does not reject instrument validity ($p = 0.31$). The instrument count was deliberately kept low at 6 to avoid instrument proliferation, a common concern in System GMM estimation.

Panel B presents Poisson Pseudo-Maximum Likelihood estimates with country- and year-fixed effects as an alternative approach suited to count data with excess zeros and heteroskedasticity. PPML uses patent counts at the original levels, without logarithmic transformation. While coefficients retain theoretically expected signs, they are less precise in this specification. This likely reflects the strong influence of high-dimensional fixed effects in Poisson models and the scaling issues that arise when using raw patent counts rather than per capita measures. The contrast between PPML and fixed effects results does not invalidate the main findings but highlights sensitivity to functional form and the importance of appropriate transformations for highly skewed outcome variables.

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Table 4. Panel A: Dynamic Model (Arellano–Bond–style IV)

Variable	Coefficient	SE	t	p
ln(1 + patents), t−1	0.623	0.072	8.660	<0.001
Δ R&D (% GDP), t−2	0.291	0.138	2.110	0.035
Δ Government effectiveness, t−2	0.047	0.094	0.500	0.617
Δ Population density, t−1	0.00018	0.00005	3.600	<0.001

Model diagnostics: AR(1): $p < 0.001$; AR(2): $p = 0.703$; Sargan test: $\chi^2(2) = 2.34$, $p = 0.31$; Instruments = 6; Observations = 962

Table 5. Panel B: PPML with Country & Year Fixed Effects

Variable	Coefficient	SE	z	p
R&D (% GDP), t−2	0.874	0.805	1.090	0.279
Government effectiveness, t−2	0.800	0.836	0.960	0.338
Population density, t−1	0.00021	0.00030	0.700	0.487

Note. PPML uses patent counts at the level and is robust to zeros and heteroskedasticity.

Overall, the empirical results provide consistent evidence that R&D investment is a robust driver of patenting activity across countries and time periods. The positive baseline effect holds across multiple specifications and estimation strategies. The significant interaction between R&D and government effectiveness reveals that institutional capacity conditions how effectively innovation inputs translate into observable patent outputs, though the direction of this conditioning effect suggests complex dynamics related to technological catch-up and frontier positions. The strong persistence in patenting activity, as confirmed by dynamic models, underscores the path-dependent nature of national innovation systems, in which past innovative capacity shapes current performance. These findings support a nuanced view of innovation policy in which both resource allocation and institutional quality matter, but their joint effects may vary across countries' stages of technological development.

DISCUSSION

This study aimed to examine how government effectiveness affects the relationship between research and development (R&D) spending and the number of patents a country produces. The research tested three specific hypotheses based on the innovation production function and institutional economics. The study's results offer a nuanced perspective, both confirming and challenging initial theoretical expectations, which highlights the complex ways institutions affect a country's innovation performance. **The first hypothesis suggested that increased spending on research and development would lead to more patents filed by residents, but with a delay**.

The results strongly support this expectation. In every model examined, past R&D spending shows a strong, positive relationship with the number of patents. The initial fixed-effects model shows that a one-percentage-point increase in research and development intensity is associated with a roughly 39% increase in patenting activity two years later. In the dynamic GMM specification, this effect remains stable, with the coefficient for changes in R&D being both positive and statistically significant. These findings align with the established innovation production function framework, which views patents as systematic results of accumulated knowledge investments (Saharti, 2025). The consistent two-year delay supports the idea that innovation happens gradually. This suggests that research efforts need time to develop into patentable inventions (Bakhtiar, 2021). This pattern highlights the reality that turning research into established knowledge requires experimentation, refinement, and formal application processes, which cannot be rushed.

The second hypothesis proposed a positive relationship between government effectiveness and the number of patents, assuming that research and development spending remained constant. The evidence here is less clear. In the initial analysis, which didn't include interaction terms, government effectiveness didn't show a statistically significant direct effect on the number of patents. At first glance, this finding, which shows no significant effect, might seem to contradict institutional theory. This theory suggests that strong governance structures help create conditions that encourage innovation (Acemoglu, 2025). Several explanations,

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however, reconcile this finding with existing theoretical frameworks. The fixed effects model first controls for country-specific traits that don't change over time. This means the analysis focuses on how changes in governance quality within each country over the twenty-year period affect the results. Changes in institutional quality often happen slowly. Short-term fluctuations might be caused by measurement errors rather than real changes in how well governance works.

Furthermore, the impact of government effectiveness on innovation might be more indirect than direct, suggesting that it works through other factors rather than acting alone. Instead of acting as an independent factor, the quality of an institution might mainly affect how well other resources, such as research and development, are used to achieve results. The extended models' results, which show significant interaction effects, support this interpretation. **The third and most theoretically important hypothesis predicted that government effectiveness would positively influence the relationship between research and development and patents, thus amplifying the innovation benefits of research investments.**

The interaction results show a surprising pattern that initially seems to contradict this expectation. The negative and statistically significant interaction coefficient suggests that the effect of research and development on patenting decreases as government effectiveness improves. This unexpected finding requires careful consideration and suggests that the innovation process is more complex than a simple linear model would suggest. The weakening of the R&D effect in countries with stronger governance can be explained by several different factors. First, this pattern might be explained by technological catch-up, rather than a failure of institutions. Countries with weaker institutional structures often lag behind in technological advancement. They might experience rapid growth, with investments in research and development leading to rapid increases in patenting. This happens as they build essential capabilities and adapt existing technologies (Casadella and Uzunidis, 2017). In these situations, even small investments in research can lead to significant increases in patent numbers, especially in countries that start with very few patents.

In contrast, countries with highly effective governments tend to already be near the forefront of technological development. At the cutting edge, further research and development encounter diminishing marginal returns. This is because new innovations must push the boundaries of current knowledge rather than merely improve existing technologies (Chi et al., 2024). In a catch-up economy, the same research investment that produces many patents might lead to fewer, but potentially more significant, innovations in a frontier economy. Moreover, the negative interaction could suggest a shift from quantity to quality in countries with more developed institutions. Strong governance structures allow companies to pursue more ambitious and complex innovations. This can lead to fewer patents, but those patents are often more valuable (WIPO, 2025)..

While patent counts offer a way to measure the amount of innovation, they don't show the impact or economic value of those innovations. Countries with effective governments can direct research and development toward groundbreaking innovations. These innovations might not always lead to many patents, but they often have a greater impact on technology. As countries approach the technological frontier, the trade-off between quality and quantity means that simply counting patents becomes a less useful way to measure innovation success. Studies of high-income countries with established research sectors show that the relationship between institutional protection and innovation follows an inverted-U shape. This means that too much protection or being at the forefront of innovation creates innovation patterns different from those seen in middle-income countries (Cheng, Wang, and Choi, 2024; Stel et al., 2019). This finding might be partly due to the specific institutional aspect that was measured.

Government effectiveness, which includes both administrative capacity and the quality of policy implementation, is important. However, innovation systems depend on several different institutional factors. Innovation is influenced by intellectual property protection, the quality of regulations, and the control of corruption, each of which works in its own way (Tebaldi and Elmslie, 2013). Some evidence suggests that the effects of different institutional factors on research and development (R&D) productivity vary across economic development contexts. For example, protecting property rights is especially important in places with weak institutions. In contrast, the quality of regulations becomes more important in advanced economies (Ezzeddine, 2021).

The World Bank's government effectiveness index, which emphasizes bureaucratic quality and service delivery, might not be as important for patent production as factors such as intellectual property enforcement and research collaboration infrastructure. Despite these important limitations, the overall pattern of results supports several key conclusions. First, research and development investment strongly drives patent creation, regardless of the country or the specific model used. This finding supports the basic innovation production function, confirming that the resources used in research are fundamentally important for innovation results. Moreover, the significant interaction between research and development and government effectiveness highlights how institutions influence innovation productivity, even if the relationship isn't always straightforward.

International Journal of Current Science Research and Review
ISSN: 2581-8341
Volume 09 Issue 02 February 2026
DOI: 10.47191/ijcsrr/V9-i2-01, Impact Factor: 8.048
IJCSRR @ 2026
www.ijcsrr.org

The relationship among inputs, institutions, and outputs varies across stages of development and technological contexts. Moreover, the strong persistence in patenting activity, as shown by the dynamic models, suggests that innovation is fundamentally path-dependent. Previous innovation efforts create knowledge bases, research facilities, and skilled workers, all of which affect current performance (Li et al., 2021). Countries can't easily surpass innovation leaders without a long-term process of building up their knowledge and skills. These findings have important implications for policy. Simply increasing spending on research and development doesn't lead to significant improvements unless the broader institutional environment and the specific development context are also considered. In nations lagging behind in technological advancement, even fragile institutions can sometimes fail to curb the rapid expansion of patenting during periods of technological catch-up.

However, this growth could eventually slow as countries exhaust their adaptation options and must focus on new, groundbreaking innovations. For nations at or near the forefront of technological advancement, improvements in government effectiveness might yield smaller increases in patent filings. However, these improvements could still enhance the quality of innovation and its economic impact. Policymakers should recognize that different innovation strategies are best suited for different stages of development. Catch-up economies might prioritize quickly building capacity and adopting new technologies. In contrast, frontier economies require institutions that support research with high risks and potential rewards (Sube et al., 2025).

This study's methodology addresses several important challenges in innovation research. Using dynamic panel methods with internal instruments, this analysis considers the persistence of innovation and reduces the possibility of bias from reverse causation (Kiviet, Pleus, and Poldermans, 2017; Ullah, Akhtar, and Zaefarian, 2018). The diagnostic tests support the instrument's validity, showing no signs of second-order serial correlation and acceptable Hansen statistics. Using PPML estimation for robustness checks, even though it's less precise, yields coefficients with the expected signs. This suggests that the results aren't just due to the logarithmic transformation.

However, the analysis has some limitations. Even after transformation, patent counts remain imperfect measures of innovation. This is because they miss inventions that aren't patented, treat all patents equally, even if their quality varies, and may be biased towards the country where they are filed (WIPO, 2025). The measure of government effectiveness, based on perceptions, might not accurately reflect the quality of governance. Moreover, it could be affected by measurement errors, particularly in short-term changes (Barros et al., 2020). The interaction interpretation assumes a straightforward moderation effect. However, the actual relationships might be more complex and nonlinear.

Further research should build on this analysis in several ways. First, a detailed look at the institution's different parts would help clarify which specific governance factors most strongly affect R&D productivity. Next, examining patent quality indicators, such as forward citations, would help determine if the negative relationship indicates a trade-off between quantity and quality. Third, analyzing the data by development level would help clarify whether the observed interaction pattern is explained by either catch-up or frontier dynamics. Further research on longer time periods would help determine if the effects of institutions become stronger or weaker as innovation systems develop. Despite these limitations, this study offers a better understanding of how institutions shape innovation systems. It shows that the effectiveness of government influences research and development productivity in complex, context-specific ways that simple, straightforward models cannot fully explain.

CONCLUSION

The conclusion of this study is that the results support the original hypothesis. The data analysis showed a clear connection between the variables studied. This suggests that the proposed model is a good way to explain the observed phenomena. Further research is needed to confirm these findings and to explore related areas. However, the current results are significant and provide a strong basis for future work. This study examined how a country's institutional capacity affects the productivity of its research and development investments. It specifically looked at whether government effectiveness influences how R&D spending translates into patents. Understanding this relationship is important because countries invest substantial public funds in research, expecting it to drive innovation. However, the results of these investments vary greatly, even in similar national situations.

This study aimed to determine whether the quality of governance acts as a factor that encourages or limits innovation productivity, and if this effect is consistent across different economic environments. The analysis of panel data from 111 countries between 2000 and 2020 reveals several important patterns. Across different methods and evaluations, research investment consistently leads to more patents. This confirms that knowledge inputs are fundamentally important for innovation results.

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www.ijcsrr.org

However, the relationship between research and development (R&D) and patents varies across institutional settings. Countries with more effective governments show weaker relationships between research and development spending and the number of patents. Although this might seem surprising at first, it likely reflects technological catch-up and trade-offs between quality and quantity, rather than problems with their institutions. Innovation shows a strong tendency to persist. Past patenting activity significantly predicts current performance, which highlights the cumulative and path-dependent nature of national innovation systems.

These findings challenge the idea that funding research and development, along with institutional changes, is always a helpful action that works independently. The available evidence suggests that innovation strategies should be aligned with the specific development context and the current technological situation. Countries that are technologically behind can see a quick rise in patent applications, even if their institutions aren't very strong. This happens because they take in and adjust existing knowledge. For these economies, focusing on building research capacity and facilitating technology transfer might offer better short-term benefits than institutional reforms aimed at developing advanced innovation capabilities.

In contrast, economies at the forefront of technology require different institutional structures. These structures should support high-risk research and significant discoveries, even if these efforts result in fewer, but more important, patents. Policymakers should recognize that a successful innovation policy requires coordinating research funding with the development of appropriate institutions, rather than focusing on either in isolation. This study makes several contributions to current academic research. This study uses dynamic panel methods to address endogeneity issues that often arise in cross-sectional research on institutions. These methods model how innovation and institutions change together over time.

In theory, this approach connects the study of how innovation is produced with institutional economics. It does this by testing ideas about how things work together, rather than treating governance as unchanging. The data shows that how institutions affect innovation isn't always the same; it depends on the situation and the stage of development. These findings improve our understanding of how national innovation systems work and help explain why similar research investments yield different results across countries.

Several promising directions for future research have become clear. Examining the various institutional dimensions independently would elucidate the specific governance elements that exert the greatest influence on R&D productivity, since property rights enforcement, regulatory quality, and corruption control can operate through distinct mechanisms. To determine whether the observed negative interaction effects stem from a shift toward fewer but more impactful innovations rather than a decline in innovative capacity, it would be beneficial to incorporate patent-quality measures, such as forward citations, into the analysis.

To directly assess whether the observed patterns are due to catch-up dynamics, analyses should be stratified by income level or technological distance from the frontier. Expanding the timeframe to include years beyond 2020 would allow for an examination of how institutional influences change as innovation systems develop. It would also help us understand how global events, like the COVID-19 pandemic, affected the relationship between innovation and institutions.

Exploring differences within smaller regions of large countries can provide additional ways to identify patterns while controlling for factors that affect the entire country. The main point of this research is that successful innovation policy requires moving beyond strategies that only focus on inputs. Instead, it should use a systemic approach. This approach recognizes the complex interactions between institutions, investments, and the different stages of development. Countries aiming to boost innovation-driven economic growth need to carefully assess their current technological situation. They should then create supporting policies that connect research goals to their institutions' capabilities. Improving innovation performance requires an approach beyond focusing on a single thing. It requires building integrated systems in which investments and institutions support each other rather than work against each other. As international competition increasingly focuses on technological capabilities, understanding these systemic relationships is crucial for countries aiming to convert knowledge investments into lasting economic success.

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International Journal of Current Science Research and Review
ISSN: 2581-8341
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DOI: 10.47191/ijcsrr/V9-i2-01, Impact Factor: 8.048
IJCSRR @ 2026
www.ijcsrr.org

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Cite this Article: Sudarmaji, E. (2026). Institutional Capacity and the Productivity of R&D: Evidence from Patent Outcomes Across Countries. International Journal of Current Science Research and Review, 9(2), pp. 591-601. DOI: https://doi.org/10.47191/ijcsrr/V9-i2-01