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INVESTMENT IN HIGHER EDUCATION AND INNOVATION IN BRAZIL: AN ARDL TIME-SERIES ANALYSIS (2001–2019)

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Abstract

This study examines the relationship between investment in higher education and innovation in Brazil from 2001 to 2019, using patent applications as a proxy for innovation. The analysis employs Autoregressive Distributed Lag (ARDL) models to capture short- and medium-term dynamics.

The results indicate that institutional factors, particularly the 2004 Innovation Law, are consistently associated with increased patent activity. Higher education investment shows a positive short-term association in some specifications, although results are not robust across models. Conversely, R&D expenditure outside universities presents a negative association, which may reflect structural characteristics of the Brazilian innovation system rather than inefficiency.

Given the exploratory nature of the analysis and potential endogeneity issues, findings should be interpreted as associative rather than causal. Overall, the study highlights the importance of institutional frameworks in shaping innovation outcomes and suggests that financial investments alone may be insufficient without systemic coordination.

Keywords: Innovation; Higher education; Patent applications.

1. Introduction

The relationship between scientific knowledge, higher education, and

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technological innovation has received growing attention in recent decades, especially in countries seeking to improve their competitiveness through structured science and technology policies (Wu & Liu, 2021; Yang et al., 2025).

In this context, patent generation is often considered one of the main indicators of innovation, reflecting the ability to transform knowledge into protected technological assets with potential economic value (Nguyen & Doytch, 2022; Park et al., 2023).

Universities, as key centers of scientific production, play an essential role in this process, not only by training highly qualified professionals but also by contributing directly to technological knowledge creation (Karataş et al., 2024; Motohashi et al., 2025).

In Brazil, this relationship becomes even more relevant due to the predominant role of the public sector in scientific production (Andrade et al., 2024). Public universities account for most national publications and also appear among the main patent applicants, showing an innovation system strongly driven by the State (McManus et al., 2024a; Silva, 2024).

However, the country still presents low innovation indicators, suggesting a possible gap between investment in higher education and intellectual property outcomes. This issue has motivated researchers to examine how and to what extent financial resources directed to higher education affect inventive activity, often measured by patent applications (Kuhl & Cunha, 2013; Mary da Silva Quintino et al., 2021; Tukoff-Guimarães et al., 2021).

There is a growing recognition of the important role that universities play in the national innovation systems. More specifically, in the triple helix model, innovation emerges from the interaction between universities, industry, and government. Government plays a key role through public investment in higher education by supporting research capacity and human resource information (Etzkowitz; Leydesdorff, 2000; Etzkowitz, 2003). However, there is still a lack of studies that explicitly connect educational investments to innovation outcomes, particularly in emerging economies where strong public dominance and low private R&D may limit the translation of financial inputs into innovation.

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Considering this scenario, this paper aims to analyze, through time-series methods, the relationship between total investment in higher education and innovation in Brazil from 2001 to 2019. The study seeks to understand whether and how these investments, both in current terms and with temporal lags, influence the generation of protected innovations while controlling for relevant institutional and structural factors. The next section presents the literature review that provides the theoretical foundation for this relationship.

2. Literature review

Higher Education Institutions (HEIs) are central pillars of national innovation systems because they play a strategic role in training human resources, conducting scientific research, and generating applicable knowledge (Anouze et al., 2024; Rapini et al., 2024). Beyond their educational mission, universities have expanded their role as innovation agents, especially after regulatory milestones that strengthened the culture of intellectual property and academic entrepreneurship (McManus et al., 2024b).

Empirical studies show that universities with higher levels of innovation management maturity and stronger integration with the productive sector are more likely to generate patents, license technologies, and create spin-offs, even in contexts of limited resources (Urdaneta Montiel et al., 2024). In Brazil, this dynamic has been observed through the activities of the Technology Innovation Centers (NITs), established after the Innovation Law (No. 10.973/2004). These centers helped formalize intellectual property procedures within universities and increased awareness of technology transfer practices (Pires & Da Silva, 2023; Terra et al., 2023).

International literature emphasizes the role of the State as a driver of innovation, particularly in developing countries. Public investment in higher education and basic science is considered a key condition for the emergence of disruptive technologies and for strengthening national competitiveness (Huynh et al., 2025; Ilyina, 2022). The “entrepreneurial state” argues that many radical

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innovations originated from public teaching and research institutions supported by consistent government investment (Schou, 2024).

In the Brazilian case, public funding of universities has a direct impact on patent generation capacity since most research infrastructure and qualified human capital are concentrated in public institutions (Andrade et al., 2024; McManus et al., 2024b; Vasconcelos et al., 2023). However, the effectiveness of this investment depends on an ecosystem capable of transforming research into technological applications protected by intellectual property. This involves not only budget allocation but also the existence of coordinated public policies and mechanisms to encourage protection and commercialization of research results (Botelho & Almeida, 2024; Schou, 2024).

Although the Brazilian legal framework has advanced with the Innovation Law and the Legal Framework for Science, Technology, and Innovation (CT&I), the literature points to several institutional barriers that still limit effective technology transfer in universities. Among the main challenges are the shortage of trained professionals in NITs, the weak innovation culture among researchers, and excessive bureaucracy in licensing and partnership processes with companies (Aparecida Da Silva & Sartori, 2022; Fernandes et al., 2024; Ribeiro et al., 2022; Santiago & Lauriano, 2023).

Pamplona and Pamplona (2025) investigated the spatial distribution of patent filings in Brazil between 1997 and 2021, highlighting regional disparities and concentration patterns in innovation activity. Building on this national context, the present study focuses on the temporal dimension of innovation, examining how investments in higher education and R&D relate to patent generation over time.

Studies also show that, although many NITs are formally established, few have reached the maturity needed to act as effective bridges between universities and the productive sector (Pires & Da Silva, 2023; Ramos et al., 2025; Silva, 2024; Spier & Silva, 2025). There is also strong regional inequality in university innovation performance, which concentrates most patent applications in southeastern states such as São Paulo and Minas Gerais (Neto et al., 2024; Vasconcelos et al., 2023)

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3. Methodology

This study adopts an exploratory quantitative approach based on secondary time-series data for Brazil covering the period from 2001 to 2019. The main objective is to examine the association between investment in higher education and innovation, using patent applications as a proxy.

Before model estimation, the statistical properties of the series were evaluated. Unit root tests were conducted using the Augmented Dickey-Fuller (ADF) and Phillips-Perron procedures to determine the order of integration of each variable. The results indicated that the variables are integrated at levels I(0) and first differences I(1), which justifies the use of the Autoregressive Distributed Lag (ARDL) approach.

Following this, the existence of a long-run relationship among variables was tested using the bounds testing procedure proposed by Pesaran et al. When evidence of cointegration was identified, an Error Correction Model (ECM) representation was considered to capture short-run dynamics and adjustment toward equilibrium.

Model selection was based on information criteria, particularly the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC), in order to avoid overfitting and reduce risks associated with data mining. Instead of exhaustively reporting all estimated specifications, this study presents the models that best balance statistical adequacy and theoretical coherence.

The main variables included in the models are:

- **Higher Education Investment (En_Sup_Tot):** proxy for public expenditure in postgraduate education;
- **R&D Outside Universities (PD_sem_EN):** captures non-academic innovation efforts;
- **Scientific and Technical Activities (ACTC):** reflects broader scientific infrastructure;
- **Innovation Law (dummy variable):** captures institutional effects after 2004;
- **Patent Applications:** dependent variable.

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All monetary variables were deflated using the IPCA index (base year 2019). Due to the relatively small sample size, model specification followed a parsimonious approach, limiting the number of lags and regressors.

The results should be interpreted as **associative rather than causal**, given potential endogeneity issues and data constraints.

4. Results and discussion

Table 1 presents the results of the main models used in this study. Several model specifications were tested based on different lag structures and variable combinations. Model selection followed information criteria (AIC/BIC), and the final models presented here represent those with the best statistical fit and theoretical consistency. For simplicity, we focus on the three best-performing models, selected according to their statistical fit, theoretical consistency, and diagnostic tests. These models capture the most representative dynamics between higher education investment, R&D activities, and patent generation.

Table 1 – Best Model Results

Variable	**Model 1 (Full + Law)**	**Model 2 (Lagged + Law)**	**Model 3 (Education + Law)**
Intercept	9932.10*** (p = 0.0004)	9182.11** (p = 0.0175)	9428.86*** (p = 0.0007)
patent_lag1	−0.199 (p = 0.453)	−0.178 (p = 0.654)	−0.139 (p = 0.615)
En_Sup_Tot	−0.033 (p = 0.793)	−0.012 (p = 0.935)	0.145** (p = 0.024)
En_Sup_Tot_lag1	0.193 (p = 0.130)	0.118 (p = 0.396)	—
PD_sem_EN	−0.089** (p = 0.049)	—	−0.069 (p = 0.116)
PD_sem_EN_lag1	—	−0.025 (p = 0.726)	—
ACTC	0.050 (p = 0.259)	−0.014 (p = 0.836)	0.012 (p = 0.747)
ACTC_lag1	—	−0.014 (p = 0.836)	—
Innovation_law	1936.16** (p =	1604.35* (p = 0.085)	1753.17** (p = 0.026)

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Variable	Model 1 (Full + Law)	Model 2 (Lagged + Law)	Model 3 (Education + Law)
	0.013)		
Adjusted R^2	0.563	0.416	0.508
F-statistic	4.87*** (p = 0.0096)	3.14 (p = 0.043)	4.72** (p = 0.011)
Residual SE	652.1	753.9	691.9
Durbin–Watson	1.72* (p = 0.06)	1.69* (p = 0.06)	1.71* (p = 0.06)
Jarque–Bera	0.55	0.55	0.87

Notes: p-values in parentheses. Significance codes: *** p<0.001; ** p < 0.05; *p < 0.10.

DW ≈ 2 indicates no first-order autocorrelation; JB p > 0.05 indicates normal residuals

The estimated models reveal statistically significant associations between institutional variables and patent activity. In particular, the Innovation Law presents a positive and robust coefficient across specifications, suggesting that institutional frameworks may be associated with increased innovation outcomes.

Given the exploratory nature of the analysis and potential endogeneity issues, the results should be interpreted as associative rather than causal. The coefficient associated with higher education investment (En_Sup_Tot) is positive and statistically significant in one specification, indicating a possible short-term association with patent activity. Nevertheless, the lack of robustness across models and the non-significance of lagged terms suggest that the impact of educational investment may be more complex and delayed.

R&D expenditure outside universities (PD_sem_EN) shows a negative association in some models. Rather than indicating inefficiency, this result should be interpreted cautiously. It may reflect structural characteristics of the Brazilian innovation system, such as sectoral differences in patent propensity, longer innovation cycles, or weaker linkages between firms and intellectual property systems.

Overall, the findings suggest that institutional stability and policy frameworks are more consistently associated with patent activity than isolated financial inputs. Given the exploratory nature of the analysis and potential endogeneity issues, the results should be interpreted as associative rather than causal. These findings can be further interpreted within the framework of National Innovation Systems, where innovation outcomes depend not only on resource allocation but also on the interactions between institutions, firms, and knowledge producers. In this context,

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the concept of absorptive capacity helps explain why financial investments do not always translate into innovation outputs, particularly in environments with weak institutional coordination.

The bounds test results indicate the presence of a long-run relationship among the variables, supporting the use of the ARDL framework.

5. Conclusion

This study explored the relationship between investment in higher education and innovation in Brazil using time-series models. The results indicate that institutional factors, particularly the Innovation Law, are consistently associated with patent activity.

While higher education investment shows some positive associations, the evidence is not robust enough to support strong conclusions regarding its direct impact on innovation outcomes. These findings reinforce the idea that innovation is a complex and systemic process, influenced by institutional, structural, and sectoral factors.

Importantly, this study does not establish causal relationships. The results should be interpreted as exploratory evidence of associations within the Brazilian innovation system.

This study does not establish causal relationships, but rather provides exploratory evidence of associations within the Brazilian innovation system.

Future research should incorporate alternative innovation indicators, apply more robust econometric strategies (such as VAR/VECM), and explore sectoral heterogeneity to better understand the mechanisms linking education investment and innovation.

5.1. **Limitations of the Study**

This study presents several limitations that must be acknowledged.

First, patent applications were used as a proxy for innovation, which may not fully capture non-patented, incremental, or service-based innovations. Second, the relatively short time series reduces statistical power and limits the number of

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variables and lags that can be included. Third, potential endogeneity issues may affect the results, since investment in education and innovation outcomes may be jointly determined. Finally, the exploratory nature of the analysis means that the results should not be interpreted as causal relationships.

6. References

Andrade, E. P., Rocha, A. M., Luis, M., & Nascimento, F. (2024). *Contributions of Brazilian universities to technological innovation: a multivariate exploratory analysis*. DOI: https://doi.org/10.3895/rts.v20n60.16937

Anouze, A. L., Al Khalifa, M. M., & Al-Jayyousi, O. R. (2024). Reevaluating national innovation systems: An index based on dynamic-network data envelopment analysis. *Socio-Economic Planning Sciences*, *95*. https://doi.org/10.1016/j.seps.2024.102003

Aparecida Da Silva, J., & Sartori, R. (2022). Motivations and barriers of universityindustry cooperation: a comparison between Brazil and Ireland. Em *J. Technol. Manag. Innov. 2022* (Vol. 17, Número 2). https://doi.org/10.4067/S0718-27242022000200049

Botelho, A. J. J., & Almeida, M. (2024). Start-ups in the Brazilian Innovation Ecosystem. *Science, Technology and Society*, *29*(1), 120–139. https://doi.org/10.1177/09717218231220344

Etzkowitz, H.; Leydesdorff, L. The dynamics of innovation: from National Systems and “Mode 2” to a Triple Helix of university–industry–government relations. *Research Policy*, v. 29, n. 2, p. 109–123, 2000. https://doi.org/10.1016/s0048-7333(99)00055-4

Etzkowitz, H. Innovation in innovation: the Triple Helix of university–industry–government relations. *Social Science Information*, v. 42, n. 3, p. 293–337, 2003. https://doi.org/10.1177/05390184030423002

REMUNOM
ISSN 2178-6925

Received: 13/01/2026 - **Accepted:** 13/04/2026
Vol: 13.06
DOI: 10.66104/d6gv4f09
Pages: 1-12

Fernandes, D. R. A., Gadelha, C. A. G., & Maldonado, J. M. S. de V. (2024). Patents, access, and local production of medicines: reflections from experiences in the SUS1. *Saude e Sociedade*, *33*(1). https://doi.org/10.1590/S0104-12902024220791en

Huynh, A. N. Q., Vu, G. T. M., Bui, H. Q., & Hoang, H. V. (2025). Corporate investment efficiency in response to national innovation: the moderating role of state ownership. *Journal of Economics and Development*. https://doi.org/10.1108/JED-07-2024-0233

Ilyina, A. (2022). Mechanism of Innovation and Investment Development in Modern Economy. *Economic Affairs (New Delhi)*, *67*(4), 825–835. https://doi.org/10.46852/0424-2513.4s.2022.16

Karataş, A. R., Kazak, H., Akcan, A. T., Akkaş, E., & Arık, M. (2024). A bibliometric mapping analysis of the literature on patent analysis. *World Patent Information*, *77*. https://doi.org/10.1016/j.wpi.2024.102266

Kuhl, M. R., & Cunha, J. C. da. (2013). Obstacles to implementation of innovations in Brazil: how different companies perceive their importance. *Brazilian Business Review*, *10*(2), 1–24. https://doi.org/10.15728/bbr.2013.10.2.1

Mary da Silva Quintino, H., Rodrigues Holanda, F. S., Rodrigues Moura, F., Ricardo de Santana, J., & Vidal, L. D. (2021). World efficiency in the potential production of new technologies under intellectual property assets. *Technology in Society*, *65*. https://doi.org/10.1016/j.techsoc.2021.101601

McManus, C., Baeta Neves, A. A., Audy, J. N., & Prata, A. T. (2024a). Innovation in Brazil: Universities, Embraer and Petrobras. *Anais da Academia Brasileira de Ciencias*, *96*(4). https://doi.org/10.1590/0001-3765202420230938

REMUNOM
ISSN 2178-6925

Received: 13/01/2026 - **Accepted:** 13/04/2026
Vol: 13.06
DOI: 10.66104/d6gv4f09
Pages: 1-12

McManus, C., Baeta Neves, A. A., Audy, J. N., & Prata, A. T. (2024b). Public research institutes in Brazil: evidence of research and innovation impact. Em *Innovation: The European Journal of Social Science Research*. Routledge. https://doi.org/10.1080/13511610.2024.2396505

Motohashi, K., Ikeuchi, K., & Kwon, S. (2025). Impact of national university patenting on innovation: Researcher analysis in Japan. *Technology in Society*, *81*. https://doi.org/10.1016/j.techsoc.2024.102806

Neto, N. B., Faria, L. de A., & de Melo, F. C. L. (2024). Identifying Technological Trends and Promoting Strategies to Boost Innovation and Technology Transfer: A Case Study on the Patent Portfolio of Brazilian Public Research Institutions. *Journal of Aerospace Technology and Management*, *16*. https://doi.org/10.1590/jatm.v16.1336

Nguyen, C. P., & Doytch, N. (2022). The impact of ICT patents on economic growth: An international evidence. *Telecommunications Policy*, *46*(5). https://doi.org/10.1016/j.telpol.2021.102291

Pamplona, D. A., & Pamplona, Y. de A. P. (2025). *Geography of innovation: Spatial distribution of patent filings in Brazil between 1997 and 2021. Revista Aracê*, 7(4), 19359–19371. https://doi.org/10.56238/arev7n4-214

Park, M., Leahey, E., & Funk, R. J. (2023). Papers and patents are becoming less disruptive over time. *Nature*, *613*(7942), 138–144. https://doi.org/10.1038/s41586-022-05543-x

Pires, E. A., & Da Silva, K. G. V. C. (2023). A atuação dos núcleos de inovação tecnológica nas universidades: o caso brasileiro. *Revista de Gestão e Secretariado (Management and Administrative Professional Review)*, *14*(9), 15331–15355. https://doi.org/10.7769/gesec.v14i9.2653

REMUNOM
ISSN 2178-6925

Received: 13/01/2026 - **Accepted:** 13/04/2026
Vol: 13.06
DOI: 10.66104/d6gv4f09
Pages: 1-12

Ramos, H. H. B., Moreira, R. M. G., Vieira, L. H. S., Berilli, S. da S., Bonjardim, L. C., Nardi, J. C., Gusmão, A. O., & Silva, L. F. (2025). Uma revisão introdutória sobre desafios e estratégias para transferência de tecnologia em icts públicas: um estudo sobre propriedade intelectual e ecossistemas de inovação no brasil. *Lumen et virtus*, *16*(47), 3264–3286. https://doi.org/10.56238/levv16n47-024

Rapini, M. S., Chiarini, T., & Stein, A. de Q. (2024). Universities in inclusive regional innovation systems: Academic engagement and uneven knowledge use in Brazil. *Journal of Regional Science*, *64*(1), 108–135. https://doi.org/10.1111/jors.12667

Ribeiro, P. C. C., Alves de Matos Freire, K., Chudoba, K. M., & Borges Renault, T. (2022). Business incubators in Brazil: realities and challenges. *Revista Gestão da Produção Operações e Sistemas*, *17*(4), 62. https://doi.org/10.15675/gepros.v17i4.2943