https://doi.org/10.1590/jatm.v18.1446

ORIGINAL PAPER

Defense Expenditure and Technological Innovation in Brazil: Evidence from a Dynamic Distributed Lag Model

Daniel Barcellos Silva[1], Sueli Sampaio Damin Custódio[1], Gilberto Mohr Corrêa[1], Daniel Alberto Pamplona[1,*]

1. Departamento de Ciência e Tecnologia Aerospacial – Instituto Tecnológico de Aeronáutica – Mestrado Profissional em Propriedade Intelectual e Transferência de Tecnologia para Inovação – São José dos Campos/SP – Brazil.

*Corresponding author: pamplona@ita.br

ABSTRACT

The formulation of public policies to promote innovation should be supported by empirical evidence, ensuring greater reliability in their design and implementation. The role of the State in supporting an innovation ecosystem has been widely recognized as essential for economic and social development. In this context, the present study examines whether military investments in Brazil are associated with patent production. Using annual data from 2001 to 2019, a dynamic distributed lag specification is estimated to assess whether defense expenditures are related to changes in technological innovation over time. The results indicate a positive association between government defense spending and the number of patents filed, particularly with a 1-year lag. Given the limited sample size (19 annual observations), the findings should be interpreted as exploratory evidence of a lagged relationship. Overall, the results are consistent with a positive temporal association between defense expenditure and patent activity, without implying causal inference.

Keywords: Defense expenditures; Patent applications; Technological innovation; Research and development.

INTRODUCTION

The participation of the State in promoting public policies for scientific, technological, and innovation development is a key aspect for understanding how an economy is structured and performs. Likewise, the normative framework of a country defines how institutions interact and cooperate in this process (Van Hemert and Nijkamp 2010). A global overview focusing on nations with characteristics similar to Brazil becomes an important instrument for diagnosis. Such comparative analysis helps identify best practices and successful models in the fields of science, technology, and innovation (ST&I).

Although national innovation systems have been widely discussed in the academic literature, there is still a need to understand how public investments translate into measurable innovation outcomes (Edquist 2019; Lundvall 1992). Despite the relevance of defense-related research and development (R&D), empirical evidence on its impact on innovation in emerging economies remains limited. In particular, there is limited time-series evidence examining the relationship between defense expenditure and aggregate innovation outcomes in Brazil. In this study, patent deposits are used as a proxy for technological innovation, as they reflect measurable outcomes of inventive activity and allow international comparison. This gap motivates the present study, which contributes to this discussion by exploring patent data as a proxy for technological development.

Received: Oct. 04, 2025 | **Accepted:** Apr. 30, 2026
Peer Review History: Single Blind Peer Review.
Section editor: Raul Bonadia Rodrigues

Despite this growing body of literature, three gaps remain. First, there is limited empirical evidence for emerging economies. Second, there is a lack of Brazil-specific studies linking defense expenditure to innovation outcomes. Third, there are still few time-series approaches that capture the temporal dynamics of this relationship.

The article investigates the role of the State and public institutions in the ST&I policy landscape. Specifically, it examines whether defense investments affect patent production, aiming to assess the temporal relationship between one of the most used indicators of innovation and a strategic public action with strong potential to promote technological progress. Proper measurement and dissemination of public policy outcomes are fundamental principles of public administration (Lavertu 2016; Van Dooren 2018). Demonstrating how defense investments – a core responsibility of the State – can generate social returns through scientific and technological development is both legally relevant and socially meaningful (Caviggioli *et al.* 2023).

This discussion is framed within the broader landscape of Brazil's ST&I policies. It evaluates how government investments in national defense, as part of the State's duty to guarantee sovereignty, may also foster innovation. Furthermore, it highlights the institutional mechanisms that shape this process and discusses how they contribute to the public interest.

Defense R&D is often associated with the development of dual-use technologies. In this type of technology, innovations are originally developed for military purposes and later applied in civilian sectors. Examples include applications in aerospace, energy, and advanced manufacturing industries.

These spillovers strengthen national innovation systems and contribute to industrial competitiveness. In Brazil, defense-related R&D plays a strategic role, particularly in the aerospace sector, which depends on cooperation among public institutions, universities, and defense industries. Such interaction facilitates the diffusion of technologies initially developed for military purposes into civilian markets, reinforcing the dual-use innovation ecosystem. Understanding how defense investment translates into innovation is therefore relevant not only for the defense community but also for the broader development of Brazil's industrial and technological capabilities.

Finally, the article seeks to ensure transparency in data and results derived from these policies, strengthening public perception that defense spending can promote technological innovation. Examining whether defense investments and patent production are temporally associated is, therefore, the central goal of this study. It aims to clarify institutional roles in the innovation process and assess how defense spending supports the State's mission of advancing scientific and technological progress.

Given the short annual time series available (2001–2019), the empirical analysis focuses on identifying temporal associations rather than establishing structural causality. The study, therefore, examines whether defense expenditure is positively associated with patent production and whether this relationship presents a lagged pattern over time.

Despite the extensive literature on national innovation systems, few studies have examined the specific contribution of defense expenditure to technological innovation in emerging economies. This study seeks to fill this gap by analyzing the relationship between military spending and patent production in Brazil. Using a dynamic time-series regression with distributed lags, the research investigates whether public defense investments generate measurable innovation outcomes and how their effects evolve over time.

In addition to this introduction, this article is structured into four main parts. The literature review presents the theoretical framework and discusses the main studies that connect public policies, defense investments, and technological innovation. The methodology section describes the methodological approach, data sources, and econometric models used in the analysis. The results and discussion section presents and discusses the empirical results, highlighting the temporal dynamics between defense expenditures and patent production. Finally, the conclusion provides the main conclusions and policy implications derived from the study.

Literature review

The use of patent production as an indicator of technological innovation in Brazil is consistent with the international literature, which recognizes its relevance and reliability for measuring a country's economic and innovative performance. Patent data allow comparisons across countries and over time, especially when linked to specific public policies (Kim and Lee 2015). Dang and Motohashi (2015) show that patent statistics can be used to assess the effects of government support on innovation. However, patent indicators also present limitations, as they do not capture informal innovation, may vary in quality, and are influenced by institutional and legal incentives. Therefore, patent data should be interpreted as a proxy for inventive activity rather than a comprehensive measure of innovation performance.

According to Albuquerque *et al.* (2005), the technological innovation process is enabled by the flow of information and infrastructure provided by the institutions that compose the innovation system. In this context, universities, research institutions, and the education system play a key role. The author argues that R&D activities should be distributed among the productive, educational, and funding sectors so that technological opportunities become consistently available to industry, which is the main focus of economic development policy.

De Oliveira *et al.* (2023) expand this discussion by addressing the concept of "knowledge spillover," highlighting the importance of science diffusion among the actors of the triple helix – university, government, and industry – as a key factor for innovation. According to the authors, such spillover effects are intensified by public investments, especially in strategic projects such as those related to defense, which often generate positive externalities in other sectors of the economy.

Within this framework, public investment plays an important role in supporting innovation, especially in strategic sectors such as defense.

Beyond the Brazilian context, empirical studies in countries such as the United States, Israel, and South Korea have documented positive associations between defense-related R&D and broader technological development, particularly in high-technology sectors (Broude *et al.* 2013; Lee *et al.* 2013; Moretti *et al.* 2025). These experiences suggest that military expenditure may act as a catalyst for innovation through research and industrial partnerships, although these effects vary across countries and institutions.

In the Brazilian context, Pamplona and Pamplona (2025) empirically demonstrated this phenomenon through a spatial analysis of patent filings between 1997 and 2021. Using choropleth and kernel density estimation maps, the authors identified the existence of consolidated innovation clusters in the South and Southeast regions and verified the "spillover effect" of innovation toward the Northeast after 2012. Their results reinforced the relevance of territorial factors and public policies aimed at the internalization of scientific and technological institutions and the strengthening of regional R&D capacities. These findings support the idea that innovation policies and defense-related investments can act as spatial diffusion mechanisms, generating cumulative regional effects on technological development.

Corroborating this analysis, Miranda *et al.* (2019) emphasize that the Innovation Law (Lei nº 10.973/2004), enacted in 2004, required adjustments to clarify the relationships between universities and the productive sector, to encourage researcher participation, and to provide laboratory infrastructure for research, development, and innovation projects with companies. These points were later addressed in the New Legal Framework for Innovation (Lei nº 13.243/2016).

Similarly, De Oliveira *et al.* (2023) highlights the importance of government investment in fostering "knowledge spillovers" from universities to entrepreneurial ecosystems and in promoting innovation projects within firms, as a mechanism for regional development. This view is reinforced by Dall'Agnol and Diniz (2024), who discuss the importance of defense projects for maintaining the defense industrial base and supporting firms, especially those located in innovative clusters.

From another perspective, Silva and Olavo-Quandt (2019) underline the relevance of "technology parks," due to their legal role as favorable environments for the dissemination of innovation culture and networked collaboration among triple helix actors. Their governance models enable cooperation between industry, government – represented here by the defense sector – and universities, facilitating a synergistic process that promotes innovation.

In a comparative analysis of emerging nations that successfully managed technological change, Salami and Soltanzadeh (2012) examine the cases of Brazil, China, South Korea, South Africa, and India, emphasizing the crucial role played by governments in designing and implementing ST&I policies. Such policies have driven economic growth by providing institutional structures adapted to the internal characteristics of each nation.

Another aspect to be considered in this systemic innovation dynamic is the inherent complexity of transforming knowledge into learning and, consequently, into new products or processes. Therefore, government intervention through innovation policies is justified when this transformation process fails. This requires mapping the key functions of the innovation system (Khan 2022).

From the perspective of the innovation system based on the triple helix model, Das Neves *et al.* (2024) highlight the role of the State in developing the legal environment and innovation policies, as well as its participation through public research institutions that conduct studies and provide technologies for industrial application.

Finally, Oliveira (2016) provides a historical analysis of Brazil's ST&I policy, from the creation of the National Council for Scientific and Technological Development (Conselho Nacional de Desenvolvimento Científico e Tecnológico) through the military government period. The author reflects on the evolution of this system, in which the scientific community, media, political actors, and funding agencies have shaped the Brazilian scientific environment based on the science-push model, which defines research agendas according to academic interests, often disconnected from the productive sector's needs.

Taken together, these studies demonstrate that public investment, particularly in defense-related research, can generate technological advances that go beyond military applications, reinforcing innovation ecosystems and creating broader socio-economic benefits.

However, there is still limited empirical evidence examining this relationship using time-series approaches in emerging economies such as Brazil.

The following section describes the methodological design and econometric procedures used to test the temporal association between defense investment and innovation in Brazil.

METHODOLOGY

This study applied a time series approach to examine the dynamics between national defense investment and patent production in Brazil from 2001 to 2019. The objective was to assess whether, and to what extent, public spending on defense is associated with technological innovation, measured through patent filings, while accounting for other relevant institutional and temporal factors.

Data and variables

The analysis used secondary data from two main sources. Patent data were obtained from the Intellectual Property Database (Banco de Dados de Propriedade Intelectual [BADEPI]) of the National Institute of Industrial Property (Instituto Nacional da Propriedade Industrial [INPI]). The raw dataset includes individual patent deposit records. Only patent filings in which Brazil was declared as the country of the applicant were considered. These records were aggregated by year to construct the dependent variable, defined as the total number of patent applications filed annually in Brazil from 2001 to 2019. No restriction by technological field, International Patent Classification, or sector was applied. Data on defense expenditure were collected from the Stockholm International Peace Research Institute (SIPRI), which compiles internationally comparable military spending indicators. Military expenditure values correspond to constant (2024) U.S. dollars (millions), allowing comparisons over time by removing the effects of inflation. The time span was determined by the availability and consistency of annual data across both BADEPI and SIPRI databases. The length of the series is primarily constrained by the BADEPI patent database, which provides consistent records for the variables used only for the period analyzed. This limitation reflects the structural availability of consistent annual data for Brazil. Expanding the dataset would require combining heterogeneous sources or redefining variables, which could compromise internal consistency.

The dependent variable (*patent*) represents the total number of patent applications filed each year in Brazil. To capture potential inertia in the innovation process, a 1-year lag of this variable (*patent_lag1*) was included, reflecting the persistence typical of cumulative R&D activity.

The main explanatory variables are the current level of defense investment (*mil*) and its 1-year lag (*mil_lag1*). The inclusion of both captures possible delayed effects of government spending on innovation outcomes, since technological projects in defense generally exhibit long development cycles.

A dummy variable was also introduced to model the institutional effects of the Innovation Law (Law No. 10.973/2004). This variable equals 0 for years prior to the law and 1 for subsequent years. Alternatively, a linear trend variable (*ramp*) was tested to capture gradual policy effects, as detailed in the model specifications. The analysis does not restrict patents to defense-related classifications, as the objective is to capture aggregate innovation dynamics potentially influenced by defense investment.

Econometric specification

Several time-series regression models were estimated using the *dynlm*, *lmtest*, and *tseries* packages in the R statistical software (version 4.3.0).

The specification corresponds to a dynamic distributed lag regression estimated in a time-series framework. This study does not employ a full autoregressive distributed lag approach, as the bounds-testing procedure is not applied. Instead, a parsimonious distributed lag specification is adopted, which is more appropriate given the short time series available.

The general specification of the estimated models can be expressed as follows:

$$Patent_t = \beta_0 + \beta_1 Patent_{t-1} + \beta_2 Mil_t + \beta_3 Mil_{t-1} + \beta_4 Trend_t + \beta_5 Control_t + \varepsilon_t \quad (1)$$

where *Trend* refers to either the *ramp* or the "Innovation Law dummy," depending on the specification. Additional control variables were tested in alternative specifications, including overall R&D expenditure and selected macroeconomic indicators, as described in the Results section.

The inclusion of the lagged dependent variable was intended to control for first-order autocorrelation, which is common in innovation time series. A 1-year lag structure was adopted based on theoretical considerations and previous studies indicating delayed effects of public R&D expenditure on innovation outcomes. Given the limited sample size ($n = 19$), the models included a limited number of explanatory variables to reduce the risk of overfitting. In this context, the modeling strategy prioritizes parsimony and internal consistency rather than increasing model complexity. This approach is consistent with small-sample time-series applications, particularly in studies involving national-level data in emerging economies. Different model combinations were tested to ensure robustness, as described in the Results section.

Model diagnostics

The stationarity of the time series was assessed using the augmented Dickey–Fuller (ADF) test (Dickey and Fuller 1979) and the Kwiatkowski–Phillips–Schmidt–Shin test (KPSS) (Kwiatkowski *et al.* 1992), with lag specifications of 1 and 2. Given the limited sample size (19 annual observations), both tests were interpreted jointly.

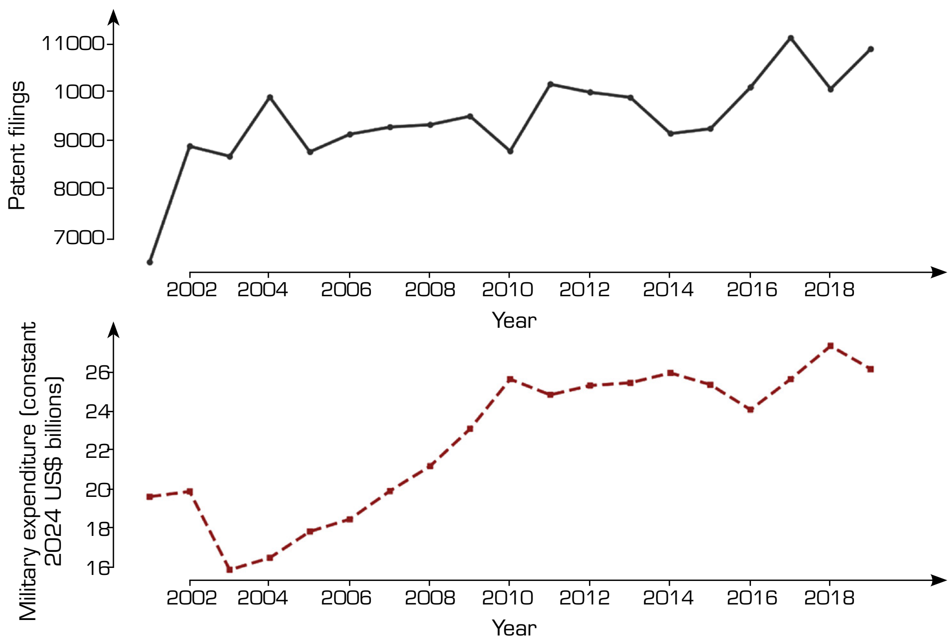
Following the recommendations of Gujarati and Porter (2009) and Enders (2015), greater weight was given to the KPSS results, since this test assumes stationarity as the null hypothesis and tends to perform better in small samples. Variables with KPSS p-values above 0.10 after first differencing were considered stationary and retained in the analysis, even if ADF results were inconclusive. This conservative approach avoids excluding potentially relevant variables and preserves the explanatory power of the model without compromising statistical validity.

Statistical significance was considered at the 5% level ($p < 0.05$), with 10% interpreted as marginal significance. Given the sample size, the results should be interpreted as indicative of temporal patterns rather than definitive statistical relationships. Overall, the presented modeling strategy aims to capture temporal and lagged associations between defense expenditures and patent activity, without claiming structural causality. The methodological design ensures comparability with previous research on innovation policy while maintaining a specific analytical focus on defense investment and its association with technological activity in Brazil.

RESULTS

Figure 1 presents the evolution of patent filings and defense expenditure in Brazil from 2001 to 2019. The figure provides a descriptive overview of the two-time series analyzed in the econometric models.

Patent data correspond to filings in which Brazil was declared as the country of the applicant, based on records from the INPI BADEPI database. Patent activity shows a general upward trend over the period, increasing from approximately 6,500 filings in 2001 to values above 10,000 in the final years of the series. Despite some short-term fluctuations, the trajectory suggests gradual growth in innovative activity. Military expenditure also exhibits an overall increasing pattern, rising from around US$ 20 billion at the beginning of the period to values above US$ 26 billion in the late 2010s.



Source: INPI (BADEPI) and SIPRI.

Figure 1. Evolution of patent filings and defense expenditure in Brazil (2001–2019). Defense expenditure is expressed in constant 2024 U.S. dollars.

Table 1 summarizes the best-performing dynamic distributed lag models estimated to explain the relationship between defense investment and patent production in Brazil. A total of 18 time-series models were initially tested with different combinations of lag structures and control variables.

Table 1. Best model results (dynamic distributed lag models for defense expenditure and patent production).

Variable	Model 1 (baseline model)	Model 2 (model with Innovation Law)	Model 3 (Model with socioeconomic controls)
Intercept	3914.39 (p = 0.036)	6462.22 (p = 0.003)	–71 790.0 (p = 0.091)
Patent (t–1)	0.349 (p = 0.124)	0.025 (p = 0.921)	–0.005 (p = 0.986)
Mil (t)	-	–0.194 (p = 0.113)	–0.004 (p = 0.979)
Mil (t–1)	0.104 (p = 0.090)	0.263 (p = 0.028)	0.245 (p = 0.166)
Innovation Law (2004)	-	1561.81 (p = 0.030)	-
CT_tot	-	-	–0.058 (p = 0.103)
HDI	-	-	116 200.0 (p = 0.061)
Ramp trend	-	-	–451.7 (p = 0.173)
Adjusted R^2	0.369	0.516	0.497
F-statistic (p-value)	6.26 (p = 0.010)	5.80 (p = 0.006)	3.96 (p = 0.020)
Residual standard error	783.9	686.2	700.1
Durbin–Watson (p-value)	2.21 (p = 0.54)	1.85 (p = 0.20)	2.05 (p = 0.20)
Jarque–Bera (p-value)	0.55 (p = 0.76)	1.36 (p = 0.51)	0.90 (p = 0.64)

Source: Elaborated by the authors.

Significance codes: $p < 0.05$; $p < 0.10$. Durbin–Watson ≈ 2 indicates no first-order autocorrelation; Jarque–Bera $p > 0.05$ indicates normal residuals

Across the specifications, the lagged defense expenditure variable (Mil t−1) presents positive coefficients, with statistical significance at conventional levels in some models. This pattern suggests that changes in defense spending may be associated with changes in patent activity with a temporal lag. These results point to temporal patterns, although they should be interpreted with caution, given the sample size.

DISCUSSION

The present study employed dynamic time-series regression models with distributed lags to investigate the dynamics of the relationship between public defense investment and patent production in Brazil from 2001 to 2019. This modeling strategy allows the analysis of both contemporaneous and lagged relationships between variables, which is particularly relevant in innovation studies, where policy effects often materialize gradually over time.

The results show that the main variable of interest, defense investment with a 1-year lag (Mil [t−1]), presented positive and statistically significant coefficients in several model specifications. These findings indicate that the effects of defense expenditure on patentable innovation occur with a delay, which is consistent with the nature of technological innovation cycles, especially in strategic sectors. This pattern is consistent with the literature that emphasizes technological spillovers from defense-related R&D to broader innovation activity, particularly when mechanisms for knowledge diffusion are present.

Conversely, the current expenditure variable (Mil) was not significant in most specifications, indicating that the immediate effects of defense spending on patent activity are limited. The robustness of the lagged effect (Mil [t−1]) remained even after including relevant control variables such as total science and technology expenditure (CT_tot), the Human Development Index (HDI), and institutional variables associated with the Innovation Law (2004). However, in more complex specifications with interaction terms, some residual collinearity and potential moderating effects were observed for instance, between mil_lag1 and HDI or CT_tot, which were marginally significant in a few models.

Regarding institutional effects, both the dummy variable for the Innovation Law and the ramp variable – constructed to capture the gradual impact of the legislation – produced mixed results. The dummy was significant only in Models 8 and 12, while the ramp was marginally significant in Models 13 and 17. These outcomes indicate that the influence of Lei nº 10.973/2004 on innovation may have occurred indirectly or been mediated by structural factors not fully captured by the models.

The estimated models presented acceptable statistical fit, with adjusted R^2 values ranging from approximately 0.36 to 0.52 and statistically significant F-statistics in most cases. These results indicate that the models capture relevant temporal patterns in patent production in Brazil during the analyzed period.

Despite the consistency of the findings, some limitations must be noted. The small sample size ($n = 19$) and the aggregate nature of the data impose restrictions on generalization. These limitations reflect the availability of consistent national-level data and should be considered when interpreting the results. Moreover, more complex structural factors, such as sectoral policy differences or regional heterogeneity, were not incorporated into the models and may also influence innovation behavior.

In summary, the results indicate that defense investment, when considered with a time lag, is positively and significantly associated with patent production in Brazil. These findings should be interpreted as indicative of a temporal association rather than a causal relationship. Future research could expand the range of variables and employ complementary methods to further examine this relationship.

CONCLUSION

Based on the data analysis and the application of statistical techniques, supported by the literature review, the results indicate a positive association between military spending and technological innovation in Brazil. This relationship may be associated with public policies and projects that foster collaboration between universities and the defense industry. Such interaction has the potential to generate scientific and technological development, producing long-term economic and social benefits for the country.

This research sought to contribute to the discussion on the allocation of public resources as a way to evaluate innovation policies. Even with its limitations, the study provides evidence that empirical analysis of defense investment can support the accountability process of government actions, helping to assess the efficiency of national budget execution.

The results also indicate that the effects of defense-related investments are not immediate. They depend on structured interaction among the key actors – government, academia, and industry – as well as on the time required for innovation outcomes to materialize, as suggested by the lagged dynamics observed in the estimated models.

From a policy perspective, the results highlight the importance of stable and coordinated funding mechanisms among defense, academia, and industry. Strengthening the dual-use R&D ecosystem may be associated with improvements in Brazil's technological capabilities, particularly when defense-related projects generate spillovers to civilian sectors.

Therefore, public policies such as the implementation of the New Legal Framework for Innovation may be associated with improved outcomes as institutional relationships mature over time. Strengthening institutional linkages and encouraging knowledge dissemination can enhance technology creation, job generation, and tax revenue, resources that, once reinvested, can sustain a virtuous cycle of innovation and national development.

CONFLICTS OF INTEREST

Nothing to declare.

AUTHOR CONTRIBUTIONS

Conceptualization: Silva DB and Pamplona DA; **Methodology:** Silva DB, Custódio SSD, Corrêa GM, and Pamplona DA; **Formal analysis:** Silva DB and Pamplona DA; **Investigation:** Silva DB, Custódio SSD, Corrêa GM, and Pamplona DA; **Resources:** Pamplona DA; **Data curation:** Pamplona DA; **Writing – Original Draft:** Silva DB; **Writing – Review & Editing:** Silva DB, Custódio SSD, Corrêa GM, and Pamplona DA; **Visualization:** Silva DB and Pamplona DA; **Supervision:** Pamplona DA; **Project administration:** Pamplona DA.

DATA AVAILABILITY STATEMENT

The data will be available upon request.

FUNDING

Not applicable.

DECLARATION OF USE OF ARTIFICIAL INTELLIGENCE TOOLS

Artificial intelligence tools were used exclusively for language review and error checking.

ACKNOWLEDGEMENTS

The authors would like to thank the anonymous reviewers for their valuable comments and suggestions, which contributed to improving the quality of this manuscript

REFERENCES

Albuquerque EM, Silva L, Póvoa LM (2005) Produção científica e tecnológica das regiões metropolitanas brasileiras. Rev Econ Contemp 9:615-642. https://doi.org/10.1590/S1415-98482005000300006

Broude M, Deger S, Sen S (2013) Defence, innovation and development: the case of Israel. J Innov Econ Manag 12(2):37-57. https://doi.org/10.3917/jie.012.0037

Caviggioli F, De Marco A, Gkotsis P, Scellato G, Vezzani A (2023) Dual use inventions: identification and characterization using patent data. Econ Innov New Technol 32(6):804-825. https://doi.org/10.1080/10438599.2022.2026221

Dall'Agnol GF, Diniz EPL (2024) Innovation, industry, and defense: prospects and challenges for Brazil. Defence Stud 25(3):451-472. https://doi.org/10.1080/14702436.2024.2425317

Dang J, Motohashi K (2015) Estatísticas de patentes: um bom indicador para a inovação na China? Programa de subsídios a patentes impacta a qualidade das patentes. China Econ Rev 35:137-155. https://doi.org/10.1016/j.chieco.2015.03.012

Das Neves EA, Gomes FS, Sousa EF, Castro TR, Costa RJ (2024) Analysis of aspects regarding the regulations for licensing and technology transfer contracts in the innovation policies of science, technology and innovation institutions of the Brazilian Air Force. Rev INGI-Ind Geogr Inov 8(4):2796-2806. https://doi.org/10.51722/Ingi.v8.i4.339

De Oliveira RCS, Rito F, Marques H (2023) Spillover of knowledge and university: a review. Braz J Bus 5(1):746-765. https://doi.org/10.34140/bjbv5n1-050

Dickey DA, Fuller WA (1979) Distributions of the estimators for autoregressive time series with a unit root. J Am Stat Assoc 74(365):427-431.https://doi.org/10.1080/01621459.1979.10482531

Edquist C (2019) Towards a holistic innovation policy: Can the Swedish National Innovation Council (NIC) be a role model? Res Policy 48(4):869-879. https://doi.org/10.1016/j.respol.2018.10.008

Enders W (2015) Applied econometric time series. 4th ed. Hoboken: Wiley [accessed Aug 01 2025]. https://www.wiley.com/en-us/Applied+Econometric+Time+Series%2C+4th+Edition-p-9781118808566

Gujarati DN, Porter DC (2009) Basic econometrics. 5th ed. Boston: McGraw-Hill Irwin [accessed Aug 01 2025]. https://cbpbu.ac.in/userfiles/file/2020/STUDY_MAT/ECO/1.pdf

Khan MS (2022) Absorptive capacities approaches for investigating national innovation systems in low and middle income countries. Int J Innov Stud 6(3):183-195. https://doi.org/10.1016/j.ijis.2022.07.004

Kim J, Lee S (2015) Patent databases for innovation studies: a comparative analysis among USPTO, EPO, JPO and KIPO. Technol Forecast Soc Change 92:332-345. https://doi.org/10.1016/j.techfore.2015.01.009

Kwiatkowski D, Phillips PCB, Schmidt P, Shin Y (1992) Testing the null hypothesis of stationarity against the alternative of a unit root. J Econom 54(1-3):159-178. https://doi.org/10.1016/0304-4076(92)90104-Y

Lavertu S (2016) We all need help: "Big data" and the mismeasure of public administration. Public Adm Rev 76(6):864-872. https://doi.org/10.1111/puar.12436

Lee SG, Trimi S, Kim C (2013) Innovation and imitation effects' dynamics in technology adoption. Ind Manag Data Syst 113(6):772-799. https://doi.org/10.1108/IMDS-02-2013-0065

Lundvall BA (1992) User-producer relationships, national systems of innovation and internationalisation. In: National systems of innovation: Towards a theory of innovation and interactive learning. p. 45-67. https://doi.org/10.7135/upo9781843318903.004

Miranda Brenner-Barreto AL, Oliveira R, Costa L (2019) Innovation in universities: an analysis of the new legal framework. Rev Eniac Pesqui 8(1):84-97 [accessed Aug 01 2025]. https://www.researchgate.net/publication/330843484_Inovacao_nas_universidades_uma_analise_do_novo_marco_legal

Moretti E, Steinwender C, Van Reenen J (2025) The intellectual spoils of war? Defense R&D, productivity, and international spillovers. Rev Econ Stat 107(1):14-27. https://doi.org/10.1162/rest_a_01293

Oliveira JJ (2016) Ciência, tecnologia e inovação no Brasil: poder, política e burocracia na arena decisória. Rev Sociol Polit 24:129-147. https://doi.org/10.1590/1678-987316245907

Pamplona DA, Pamplona YAP (2025) Geography of innovation: spatial distribution of patent filings in Brazil between 1997 and 2021. Rev Aracê 7(4):19359-19371. https://doi.org/10.56238/arev7n4-214

Salami R, Soltanzadeh J (2012) Comparative analysis for science, technology and innovation policy: lessons learned from some selected countries (Brazil, India, China, South Korea and South Africa) for other LDCs like Iran. J Technol Manag Innov 7(1):211-227. https://doi.org/10.4067/S0718-27242012000100014

Silva MVG, Olavo-Quandt C (2019) Defense system, industry and academy: the conceptual model of innovation of the Brazilian Army. J Technol Manag Innov 14(1):53-62. https://doi.org/10.4067/S0718-27242019000100053

Van Dooren W (2018) Measuring public administration: A feasibility study for better comparative indicators in the EU. Publications Office of the European Union [accessed Aug 01 2025]. https://www.italiae.affariregionali.it/media/2505/ce.pdf

Van Hemert P, Nijkamp P (2010) Knowledge investments, business R&D and innovativeness of countries: A qualitative meta-analytic comparison. Technol Forecast Soc Change 77(3):369-384. https://doi.org/10.1016/j.techfore.2009.08.007