Lisbon School of Economics & Management
Universidade de Lisboa

MASTER
ECONOMICS AND MANAGEMENT OF SCIENCE, TECHNOLOGY AND INNOVATION

MASTER'S FINAL WORK
DISSERTATION

INNOVATION IN THE NEW SILK ROAD – AN ECONOMETRIC ANALYSIS

DUARTE GONÇALVES NÓBREGA MOITA

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SUPERVISION:
PROFESSOR RICARDO FIGUEIREDO BELCHIOR

JUNE - 2025

To my wife and to my parents

Quand la Chine s’éveillera... le monde tremblera

Napoléon Bonaparte (1816)

GLOSSARY

BRI – Belt and Road Initiative

CRISP-DM - Cross-Industry Standard Process for Data Mining

DID – Difference-in-Differences

EIS – European Innovation Scorecard

EU – European Union

FEM – Fixed Effects Model

GDP – Gross Domestic Product

GII – Global Innovation Index

GNI – Gross National Income

INSEAD - Institut Européen d'Administration des Affaires

IPI – Intellectual Property Indicator

JEL – Journal of Economic Literature

KAM – Knowledge Assessment Methodology

LM – Lagrangian Multiplier

MoU – Memorandum of Understanding

OLS – Ordinary Least Squares

POLS – Pooled Ordinary Least Squares

PPP – Purchasing Power Parity

R&D – Research & Development

REM – Random Effects Model

USA – United States of America

VCE - Variance-Covariance Estimator

WIPO – World Intellectual Property Organization

ABSTRACT

The Belt and Road Initiative (BRI), launched by the People's Republic of China in 2013, represents the most ambitious global infrastructure and economic development strategy to date. By channelling substantial investments into transportation, energy, and digital infrastructure across Asia, Europe, and Africa, the BRI has reshaped global trade patterns, promoted regional economic integration, and influenced geopolitical alignments. Yet, its impact on innovative performance remains insufficiently explored.

This study provides an empirical assessment of the BRI's influence on innovative outcomes in participating countries. Employing both descriptive and inferential statistical methods, it analyses a range of indicators - including GDP per capita, intellectual property filings, and the Global Innovation Index (GII) - to ensure methodological rigor and comparability. The findings indicate a positive correlation between BRI participation and increase in patent, trademark, and industrial design filings. However, the analysis also reveals persistent innovation disparities between advanced and developing economies, suggesting limited convergence.

In addition, the study critically evaluates the GII as a metric for innovation measurement, highlighting methodological limitations and potential Western-centric biases. To address these issues, it proposes the use of alternative frameworks such as the European Innovation Scoreboard (EIS) and the Knowledge Assessment Methodology (KAM) for future cross-country comparisons.

The thesis concludes by emphasising that complementary investments in human capital and business sophistication are essential to unlocking the full innovation potential of the BRI and narrowing global disparities in innovation capacity.

Keywords: Belt and Road Initiative; China; Innovation; Development

JEL Codes: C23; F40; O31

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ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to those who supported and inspired me throughout the journey of this master's thesis.

Primarily, to my wife, whose wise counsel and unwavering support have been a guiding light. Your perspective has been invaluable.

To my parents, thank you for your constant encouragement throughout this journey.

I am deeply grateful to this thesis supervisor, Professor Ricardo Figueiredo Belchior, for the reliable and trustworthy guidance provided throughout this process. Your mentorship has been instrumental in shaping the direction and quality of this work.

A special thank you to Professor Manuel Mira Godinho, whose insights enriched my understanding and helped refine ideas.

To Sofia Vale, thank you for your assistance with economic indicators - your expertise brought clarity and analytical depth. To David Vale, thank you for reviewing the thesis with an academic eye - your critical insights and careful reading greatly enhanced the quality of this work. To Cláudia Ribeiro, I'm grateful for your valuable help in exploring Far East history and culture - your contributions added depth and context to this thesis. My sincere appreciation also goes to Inês Branco, whose enthusiasm sparked my interest in the New Silk Road - your inspiration marked the beginning of this journey.

I also want to thank my fellow master's students, especially André Ribeiro and Juan Portillo, who were always willing to help and share information. Your camaraderie and collaboration made this journey more enriching.

Last but not least, to the other three members of the exceptionally fun work group "The Marocos" - my former colleagues and now dear friends, Emanuel Rodrigues, João Magrinho, and Ricardo Santana - thank you for transforming our academic challenges into moments of joy and pride. The work we produced together was not only meaningful but also a testament to the power of teamwork and friendship.

To all of you, my sincere thanks.

1. INTRODUCTION

Launched by the Chinese government in 2013, the Belt and Road Initiative (BRI) has emerged as a cornerstone of China’s foreign policy and global development strategy. As of 2024, 151 countries have formalised their participation by signing a Memorandum of Understanding (MoU) with China (Nedopil Wang, 2024). Collectively, these nations represent approximately 75% of the world’s population and contribute to over half of the global Gross Domestic Product (GDP) (Caridi, 2023).

The Initiative aims to foster economic development by enhancing global trade networks, reducing poverty, mitigating environmental impact, and promoting sustainable growth. Furthermore, it seeks to advance key sectors such as agriculture, science, technology, education, infrastructure, and international economic cooperation (Shahriar, 2019). The ambition for economic and technological development aligns with China's substantial investment in research and development (R&D) over the past two decades. According to the National Bureau of Statistics of China, the financial allocation for R&D in 2023 is nearly 17 times greater than the budget designated for this purpose twenty years ago (NBS, 2025).

A significant share of this scientific and technological investment is directed toward strengthening innovation capacity (Mira Godinho, 2013). Given that technological progress is an explicit goal of the BRI, it is pertinent to assess whether the nations participating in the Initiative are experiencing measurable advancements in innovation, and whether these developments can be directly attributed to BRI-related policies and investments.

To accomplish this objective, a comprehensive descriptive and inferential statistical analysis utilising panel data is conducted, examining the relationship between the year of a country’s accession to the BRI and variations in intellectual property output, GDP per capita, and the Global Innovation Index (GII). The GII, formulated by the World Intellectual Property Organization (WIPO), is further assessed through its seven foundational pillars: Institutions, Human Capital and Research, Infrastructure, Market Sophistication, Business Sophistication, Knowledge and Technology Outputs, and Creative Outputs.

This thesis is structured into five chapters. Chapter 1 introduces the study by outlining its contextual background, research objectives, and scope. Chapter 2 provides a review of relevant literature, offering theoretical foundations and justifications for the investigation. Chapter 3 elaborates on the methodological framework employed to address the research question. Chapter 4 presents the empirical findings derived from the applied methodology. Chapter 5 follows with a critical analysis and discussion of the results. Finally, Chapter 6 synthesises the study’s key contributions, summarises its principal insights, and suggests directions for future research.

2. REVIEW OF THE LITERATURE

2.1. Overview

The ancient Silk Roads served for centuries as the backbone of global trade, leveraging on infrastructure growth and military protection to ensure the swift and safe passage of goods and people between the Mediterranean region and China (Mclaughlin, 2016; Nyamdaa, 2023), driving economic and societal development and fostering innovation across its whole extension (Chan, 2018). Moreover, locations crossed by these roads were developed in the most diverse ways: scientifical, political, artistical or even gastronomical, to name a few (Chan, 2018).

Nowadays, the Belt and Road Initiative (BRI), often referred to as the "New Silk Road", is a Chinese-led effort to construct a global infrastructure network inspired by the philosophy of the ancient trade routes. Its primary objective is to connect energy and raw material suppliers with China while simultaneously creating export pathways to affluent European markets (Liu et al., 2020). Once again, the construction of a unified large market and the exchanges of goods and ideas is expected to boost global economy and innovation (Liu et al., 2020).

The term “Silk Road” itself was coined only in 1877 by a German geographer and traveller called Ferdinand von Richthofen. He used it to describe the extensive network of Eurasian trade routes that historically linked Europe with the Middle East, Central Asia, and the Far East (Sidaway & Woon, 2017). By land or by sea, in the back of a camel or inside a wooden boat cargo hull, much more than silk was transported on these routes, but the exquisite fabric was a captivating choice. It not only was one of the most appreciated items to reach the European markets, where it was traded for very high prices (Hildebrandt, 2023), but it also indicates that the road by land started in China as this country kept the monopoly of the sericulture for centuries (Sidaway & Woon, 2017).

2.2. The Ancient Silk Road

The Silk Road's formal establishment is often associated with the Han Dynasty in China, when Emperor Wu sent Zhang Qian on an exploratory mission in 138 BC, which is seen as the foundation for opening trade with the West (Wood, 2002). It was then that goods and ideas started to be carried between the two great civilisations of Rome and China. The excellent Roman roads as well as the enforced "Pax Armada" led to a development of this commercial route and many cities that were on the way flourished (Mclaughlin, 2016). Some of them, like Palmyra and Petra, grew considerably wealthy (Young, 2001).

However, it is pertinent to mention the political and administrative actions implemented by Persian Emperor Darius I during the 6th century BC, as they played a pivotal role in facilitating the Silk Road emergence and subsequent expansion (French, 1998). Darius ruled his empire at its zenith, during a period at which it stretched from Greece and Egypt all the way up to the Himalayas (Bedford, 2007). To facilitate the efficient flow of people and goods and assert control over his empire, Darius built a network of roads, the "Royal Roads", being the largest one over 2,500 kilometres long, connecting Sardis and Susa, in present-day Turkey and Iran, (Daniel, 2012). By introducing a universal currency, the Daric, and setting two official languages, Aramaic and Persian, the Emperor further boosted trade in his empire (Olmstead, 1948). Darius literally paved the way for the ample exchanges between Han's China and Rome that were still four centuries away.

Following the gradual decline of Roman territorial control in Asia and the concurrent rise of Arab influence in the Levant, the Silk Road experienced a significant deterioration in safety and accessibility, leading to a marked reduction in its use (Britannica, 2025). Nevertheless, commercial exchange between the East and West persisted. From the 10th century onward, the maritime republics of Venice, Genoa, and Pisa emerged as prominent centres of trade, leveraging their expansive naval fleets to facilitate the movement of goods across ports in Europe and North Africa (Abulafia, 2011). During the 13th and 14th centuries, the route witnessed a resurgence in security and activity, largely attributable to the administrative and military oversight of the Mongol Empire. The Mongols established a period of relative peace and stability - commonly referred to as the “Pax Mongolica” - by maintaining strict control over their vast territories (Chan, 2018). It was within this context that the Venetian explorer Marco Polo undertook his renowned journey to China (Polo, 2016).

By the late 15th century, the Silk Road experienced a major disruption due to the emergence of alternative maritime trade routes. The Portuguese successfully navigated a sea passage from Europe to India via the Cape of Good Hope, offering a faster, safer, and more cost-effective means of transporting goods compared to the traditional overland caravan routes. This maritime corridor continued to expand eastward, culminating in the Portuguese arrival in Japan in 1543 (Tsumura, 2024).

Concurrently, the 15th century also witnessed notable maritime activity from the East. Under the reign of Emperor Yongle of the Ming Dynasty, China sponsored a series of seven major naval expeditions. These voyages, led by Admiral Zheng He and his renowned "Treasure Fleet" - comprising some of the largest wooden ships ever constructed - extended as far as the East African coast, reaching present-day Kenya, approximately 15,000 kilometres from Beijing (Folch, 2008; Stokes, 2001). However, following Zheng He’s death in 1433 and the earlier passing of Emperor Yongle, China adopted isolationist policies, bringing its remarkable era of maritime exploration to an end (Folch, 2008).

In 1434, one year later, Gil Eanes successfully navigated past Cape Bojador, situated approximately 1,500 kilometres from his departure port of Lagos, Portugal (Ravenstein, 1900). It was not until 1488 - 54 years later - that the Portuguese explorer Bartolomeu Dias achieved the milestone of rounding the Cape of Good Hope. (Ravenstein, 1900).

On the 16th century the centre of the European trade shifted from Venice to Lisbon. A relatively unremarkable place became the most global city of Renaissance Europe (Exenberger, 2004). It was a reference in naval construction, in cartography, in navigational instruments, in nautical and geographical studies. Boats arrived and departed from its port loaded with merchandise that was negotiated along four continents - Europe, Africa, Asia and America (Exenberger, 2004). Spices such as pepper from the coasts of Africa, cinnamon, ginger, cardamom and cloves from India and Indonesia changed the European culinary (Albala, 2024). But other locations across the Road saw changes too.

Chili pepper, the main ingredient for curry, was introduced in India by Portuguese that brought it from South America (Nagaraju & Kumar, 2020). The Indian Vindaloo curry dish got its name from the Portuguese "Vinha d'alhos" (Garlic's wine) (Brookshaw, 2013). In Japan, Portuguese introduced the fried vegetables (tempura) and words like *pan* (bread) or *koppu* (glass) have Portuguese origin (Maher, 2021).

The Land of the Rising Sun serves as a compelling example of how the Silk Road facilitated the transmission of innovations with significant political consequences. When the Portuguese arrived in Japan during the 16th century, they encountered a nation fragmented by ongoing conflicts among feudal lords. The introduction of firearms - specifically the arquebus - by the Portuguese, provided a decisive military advantage to certain factions. This technological innovation played a pivotal role in altering the dynamics of warfare in Japan and contributed to the eventual unification and stabilisation of the country (Brown, 1948).

Throughout the history of the Silk Road, numerous instances of intercultural exchange and mutual influence across regions and disciplines can be identified. Commodities such as cotton and wool were exported eastward, while silk - emblematic of the route - was transported westward, significantly influencing textile production and fashion in Europe (Sheng, 2010). The arts were similarly shaped by these exchanges. During the Renaissance, European artists highly valued ultramarine blue, a pigment more expensive than gold, derived from the semi-precious stone lapis lazuli. This mineral, sourced exclusively from mines in present-day Afghanistan, reached Europe via the Silk Road's extensive trade networks (Kirby, 2017; Berke, 2007). Architectural influences also reflect this cultural diffusion. For instance, the design of Saint Mark's Basilica in Venice draws inspiration from the Church of the Holy Apostles in Constantinople, incorporating elements characteristic of Middle Byzantine, Romanesque, and Islamic architectural traditions (Yarwood, 1987).

During the following three centuries, the maritime Silk Road was intensively used by the major colonial powers with interest in Africa and Asia - Portugal, Spain, Netherlands, France and England - while the land paths declined sharply (Wood, 2002).

The 20th century saw the imperial powers wane, while Japan rose to become the largest economy of the Silk Road by that century's end. Nevertheless, that trend didn't continue on the 21st century, being its GDP in 2024 practically the same as the one in 1998. On the other hand, China saw it's GDP multiplying by 15 times between 2000 and 2024. Today China is the second largest economy in the world and Japan is the third. The GDP of the European Union (EU) has already been surpassed by the one of China alone, and the trend shows that China's economy shall continue to grow faster than the EU one (World Bank, 2025). The economic centre of gravity of the Silk Road has shifted from west to east (Quah, 2011).

2.3. The New Silk Road

To ensure that its output continues to grow, China recognises the strategic necessity of securing reliable access to energy resources and raw materials (Downs E. S., 2004; Chen et al., 2024). In the case of oil alone, China ranks as the world's second-largest importer - trailing only the United States - and accounts for approximately 16% of global oil consumption (Energy Institute, 2024). On the other hand, while part of its output is going to be consumed internally by its vast internal market of 1.4 billion people, the rest is going to fuel the country's economy in the form of exports, being the affluent European countries a key target to guarantee (Christiansen & Maher, 2017). The geopolitical strategies required to maintain and expand these logistical networks form the foundation of the BRI, also referred to as the New Silk Road (Chan, 2018).

Most of the oil imported by China originates from the Middle East, Brazil, and Angola (Downs E. , 2025). This oil is transported via maritime routes, passing through strategic chokepoints such as the Strait of Malacca. Any disruption or restriction in these passages could significantly impede the transit of oil shipments. In response, China has pursued the development of alternative infrastructure to mitigate such vulnerabilities. Notable examples include the proposed Kra Isthmus Canal in Thailand, which would allow vessels to bypass the Strait of Malacca (Amponstira, 2020), as well as overland oil pipelines from Russia and Kazakhstan (Cutler, 2014). These initiatives aim to reduce dependence on singular transit routes and enhance energy security.

In parallel, China is diversifying its energy portfolio by investing in alternative sources such as natural gas and electricity. In the case of electricity, particular emphasis has been placed on expanding renewable energy generation, aligning with both environmental goals and long-term energy resilience (Leung et al., 2014).

On top of the energy, there are the raw materials and semi-finished goods that China needs to create their finished products. This will further justify the bi-lateral investments that are being done on the supplying countries in mining infrastructures, state-of-the-art ports, modern railways and many other structures that are required by the upstream logistic chain (Zou et al., 2022).

The downstream segment of the BRI has not been overlooked. Notably, both the maritime and overland corridors of the BRI converge in the German inland port city of Duisburg, which has emerged as a critical logistics hub in the Initiative’s European operations. The port's infrastructure enables seamless intermodal transfers, allowing goods arriving via river vessels to be efficiently loaded onto trains. This facilitates the rapid distribution of Chinese rail-borne imports across Europe, while also enabling the export of European goods to China via the same rail networks (Benedikter & Nowotny, 2020).

At the heart of the BRI’s geostrategic calculus lies Central Asia - a region of considerable importance due to its geographic proximity to China, its abundance of energy resources (Zhou et al., 2020), and its pivotal role in connecting East and West through transcontinental rail infrastructure (Benedikter & Nowotny, 2020). Furthermore, Central Asia serves as a critical link between western China and the Pakistani port of Gwadar. This port enables oil tankers - primarily originating from Kuwait, located approximately 2,000 kilometers away - to offload their cargo into pipelines that extend directly to China’s Xinjiang province. This route offers a significant logistical advantage over the traditional maritime path to Beijing, which spans roughly 13,000 kilometers and passes through the congested and geopolitically sensitive Strait of Malacca (Ahmad, 2023).

These strategic considerations likely influenced China’s decision to officially launch the BRI in Kazakhstan - the largest and most centrally located of the Central Asian republics - in 2013.

This Initiative can be seen as a second moment of the Chinese globalisation. If up to this point, China was interested in capturing foreign direct investment and in being the final part of a western controlled value chain, from this moment onwards, China is aiming for the leadership of those value chains, leveraging other countries advantages in its own companies and expanding through their own innovations and acquisitions (Wei et al., 2017). By going up in the value chain, China will be less and less the factory of the world, to become partially the office of the world and partially the factory of China, satisfying the increasing internal market that is now several times richer than at the beginning of the century (Ilhéu & Simões, 2017).

To realise these ambitions, the BRI has committed to investing several billion dollars globally. Its portfolio encompasses a wide array of infrastructure projects, including the development of railways, highways, pipelines, power plants, dams, mining operations, technological infrastructure, as well as maritime and aviation facilities (Yang et al., 2020). The BRI spans numerous sectors - ranging from agriculture and tourism to healthcare and financial services - although the energy and transportation sectors have consistently accounted for over 50% of total investments since the Initiative's inception (Nedopil Wang, 2024).

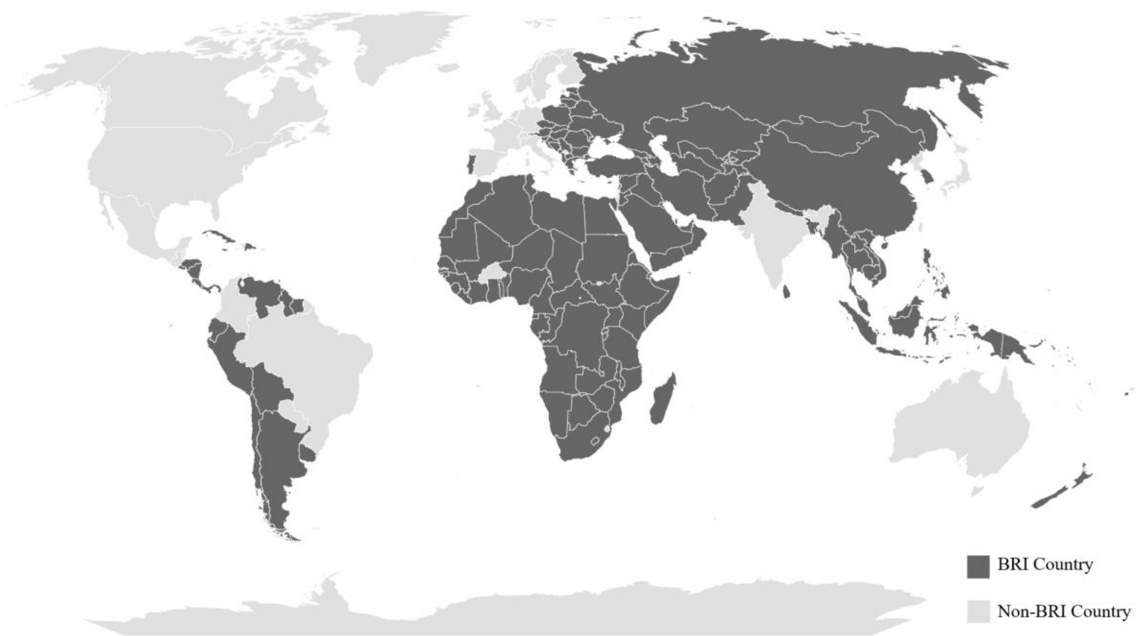

Figure 1 - Countries of the Belt and Road Initiative

Source: Green Finance & Development Centre (2025)

The Initiative's influence has expanded rapidly. For instance, in 2014 - the year following its launch - Chinese scholars published 492 academic articles on the BRI. By 2015, this number had surged to 8,400 (Rolland, 2017). By 2025, most countries worldwide had formally joined the BRI, as illustrated in Figure 1.

2.4. The Pathway for Innovation

The BRI operates through multiple vectors that are closely linked to innovation. Given its primary focus on infrastructure development, it is unsurprising that one of its most significant contributions to innovation stems from the construction of physical infrastructure - such as transportation networks, telecommunications systems, and energy facilities - as well as enhancements in digital infrastructure. These developments serve as foundational elements of National Innovation Systems by facilitating the movement of people, the exchange of ideas, and the allocation of resources (Audretsch & Feldman, 2004).

Moreover, countries participating in the BRI experienced a cumulative GDP growth of 39.6% within five years of joining the Initiative, according to calculations by Xie et al. (2023) based on World Bank data. This economic growth constitutes another channel through which the BRI positively influences innovation, given the well-established positive correlation between per capita GDP and national innovation output (Dutta et al., 2017). Xiao (2024) further demonstrated that the institutional openness and scientific and technological cooperation fostered by BRI policies have contributed to increases in both per capita GDP and GII.

Human capital development is another critical dimension of the BRI. In 2020, 180,000 students - primarily from BRI member countries - participated in talent exchange programs in China, while in the same year approximately 990,000 Chinese students went abroad to proceed with their advanced studies, mainly in USA (Top International Managers in Engineering, 2021).

International innovation collaboration between China and BRI partner countries has also intensified. This is evidenced by the growing share of cooperative patents within

China’s total patent output. However, the BRI has not significantly increased the proportion of cooperative patents in the total patent output of partner countries. Nonetheless, it has effectively strengthened their innovation infrastructure and capabilities (Xiao et al., 2023).

Overall, evaluations of the BRI’s impact on innovation tend to be favourable. For instance, Zhou et al. (2023), employing the Difference-in-Differences (DID) methodology, found a positive effect of the BRI on innovation levels in participating countries. Similarly, Zhao (2023) observed that while innovation efficiency in BRI countries remains slightly lower than in non-BRI countries, the former are improving at a faster rate, indicating a convergence trend likely influenced by the Initiative.

These empirical findings highlight the BRI’s transformative capacity in shaping innovation trajectories across its member countries. They also lay a robust foundation for examining the broader strategic vision that underpins the Initiative. Distinguished by its unprecedented scale, inclusivity, and scope, the BRI stands apart from other international efforts aimed at promoting scientific and technological progress. It is precisely these defining characteristics that warrant a focused analysis of the feasibility of President Xi Jinping’s 2017 proposition - articulated during the opening ceremony of the Belt and Road Forum for International Cooperation - to “transform the BRI into a pathway for innovation.”

3. METHODOLOGY

The approach designed and applied in this study utilises data science techniques.

Data science is an interdisciplinary academic field (Donoho, 2017) that uses statistics, scientific computing, scientific methods, processing, scientific visualisation, algorithms and systems to extract or extrapolate knowledge from potentially noisy, structured, or unstructured data (Dhar, 2013). It also integrates domain knowledge from the underlying application domain (Danyluk et al., 2021), is multifaceted and can be described as a science, a research paradigm, a research method, and a discipline (Mike et al., 2023).

This work adopts the widely recognized CRISP-DM data mining framework, which is also adaptable to data science applications (Shimaoka et al., 2024). It involves five logical steps:

1. Objective Understanding
2. Data Acquisition
3. Data Preparation
4. Modelling
5. Evaluation

3.1. Objective Understanding

This study aims to systematically assess the effects of the BRI on the innovative activity of participating countries through a reproducible and repeatable analytical framework. To evaluate innovation performance, the research examines the influence of BRI on the progression of three key indicators. The first is GDP per Capita, which exhibits a strong positive correlation with innovation (Hausken & Moxnes, 2019). The second is the Intellectual Property Indicator (IPI), a metric developed specifically for this study, which aggregates the number of patents, trademarks, and industrial designs produced in each country, normalised per million inhabitants. The third indicator is the GII, a widely recognised tool for measuring national innovation capacity and efficiency through input and output criteria (Guillén & Deckert, 2021). Established in 2007 by Cornell University, INSEAD, and the WIPO, the GII is regarded as a leading reference for academics, business leaders, and policymakers, providing comprehensive insights into the strategic utilisation of intangible assets, including intellectual property and other innovation-related resources (Lager & Bruch, 2021).

The GII consists of two primary sub-indices: the Innovation Input Sub-Index and the Innovation Output Sub-Index, both of which reflect the innovative activities within an economy. These sub-indices are assigned equal weight in the computation of the overall GII score for each country, ensuring a balanced assessment of both the foundational conditions for innovation and the measurable outcomes of innovative efforts (Dutta et al., 2023). The structural framework of the GII is illustrated in Figure 2.

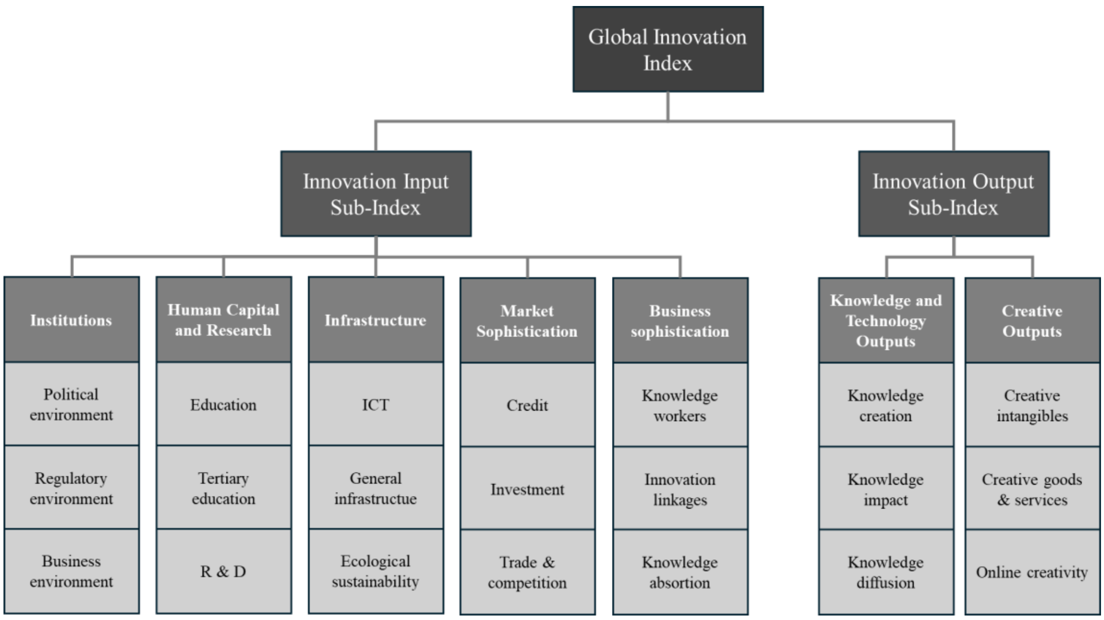

Figure 2 - The Global Innovation Index Framework

Source: Dutta (2012), p.43.

As outlined, the GII is structured around five input pillars - Institutions, Human Capital and Research, Infrastructure, Market Sophistication, and Business Sophistication - and two output pillars - Knowledge & Technology Outputs and Creative Outputs. Each of these pillars is further divided into three sub-pillars, which collectively encompass approximately 80 indicators that form the foundation of the index. Table I provides illustrative examples of indicators associated with each pillar. A country's GII score, ranging from 0 to 100, is derived through the normalisation of the values associated with these 80 underlying metrics.

TABLE I

EXAMPLE INDICATORS FOR THE GII PILLARS

Innovation Pillar	**Example Indicators**
Institutions	• Regulatory quality, • Policies for doing business
Human Capital & Research	• Researchers per million population, • Global corporate R&D investors
Infrastructure	• Environmental performance, • Information and communication technology access
Market Sophistication	• Finance for start-ups, • Venture capital received
Business Sophistication	• Knowledge-intensive employment, • University-industry R&D collaboration
Knowledge & Technology Outputs	• Patent applications, • Hi-tech manufacturing
Creative Outputs	• Trademark applications, • Global brand value

Source: WIPO (2023)

This study seeks to examine the extent to which the BRI influences not only the overall GII but also each of its constituent input and output factors.

The rationale for analysing the impact of the BRI on GDP per Capita and the Intellectual Property Indicator, in addition to the GII, stems from their ability to capture absolute innovation evolution. In contrast, the GII primarily reflects the relative convergence or divergence of innovation capabilities across nations. As the GII assigns each country an annual score between 0 and 100, it functions primarily as a ranking mechanism, positioning countries according to their relative innovative performance rather than providing an absolute measure of innovation growth or decline. Consequently, a nation's GII score may decrease despite improvements across all 80 monitored variables if leading countries achieve even greater advancements, thereby widening the innovation gap.

3.2. Data Acquisition and Preparation

Given the objective outlined in the preceding section, the WIPO's GII Database was selected as a primary data source due to its broad coverage and widespread recognition in the literature. The dataset includes information from 109 countries over a 13-year period, spanning from 2011 to 2023. This timeframe incorporates two years - 2011 and 2012 - prior to the launch of the BRI, thereby providing a baseline of observations unaffected by its potential influence. In this context, the compilation by Brás (2023) proved particularly useful, offering a structured panel dataset of the GII and its seven pillars for the period 2011 to 2022, which substantially streamlined the data collection process.

Data referring to the number of patents, trademarks and industrial designs applied by residents and per million inhabitants comes from WIPO's IP Statistics Data Centre. By summing up these three measures we get the Intellectual Property Indicator (IPI).

The BRI effect is given by a dichotomic variable that is derived from the signature's date of the MoU with China to cooperate under the BRI framework. This date is extracted from Green Finance & Development Centre's report "Countries of the Belt and Road Initiative" (2025), and only its year is used. If the year of the signature is equal or lower than the observation's year, then *BRI effect* would be equal to 1, and 0 otherwise.

Information on the country's region and income group, listed in Table II and Table III, as well as the GDP per Capita in Purchasing Power Parity (PPP) in constant 2021 international dollars, come from the World Bank Open Data website.

TABLE II

WORLD BANK REGIONS

Region
Europe and Central Asia
North America
East Asia and Pacific
South Asia
Latin America and the Caribbean
Middle East and North Africa
Sub-Saharan Africa

Source: World Bank

TABLE III

WORLD BANK INCOME GROUPS

Income Level	GNI per capita
Low-income economies	$1,145 or less
Lower-middle-income economies	between $1,146 and $4,515
Upper-middle-income economies	between $4,516 and $14,005
High-income economies	more than $14,005

Source: World Bank

All data was combined in Excel before being uploaded into Stata. A matrix with 1417 observations and 13 columns was deemed eligible for data panel analysis.

3.3. Modelling

The methodology developed and used in this study employs the Panel Data analysis. Panel Data analysis is a statistical method, widely used in econometrics, to analyse a cross-sectional, time-series dataset, which ideally provides repeated measurements of a certain number of variables over a period on studied subjects, such as individuals, households, firms, cities, and countries. From here, a regression is run over these several dimensions, providing information on subjects' behaviour, both across subjects and over time (Baltagi, 2021).

For the current analysis, a panel data regression model is specified as follows:

$$(1) \quad Y_{it} = \beta_0 + \beta_1 BRI_{it} + \theta_t + \alpha_i + \varepsilon_{it} \quad ,$$

where Y_{it} represents the dependent variable, which corresponds to the indicators utilised to assess the impact of the BRI. These indicators include GDP per Capita, the IPI, and the GII.

The variable BRI_{it} serves as the independent variable, denoting whether country i at time t is a participant in the BRI. As already stated in the previous section, it is operationalised as a binary variable, where a value of 1 indicates participation and 0 signifies non-participation. The incorporation of this variable within the regression model enables a systematic assessment of the Initiative's impact on innovation performance and economic indicators, facilitating a comparative analysis between participating and non-participating nations.

The intercept term β_0 represents the baseline value of the dependent variable when the explanatory variable - BRI participation - is equal to zero. In essence, it captures the average level of innovation performance or economic development in the absence of BRI influence, assuming that the composite term $\theta_t + \alpha_i + \varepsilon_{it}$, further below explained, is equal to zero.

The coefficient of BRI participation β_1 is the heart of this model, as it quantifies the relationship between a country's engagement with the BRI and its innovation or economic performance. A positive value of β_1 would indicate that participation in the Initiative is associated with an increase in Intellectual Property Outputs or GDP per capita, while a negative value suggests a decline. The magnitude of β_1 provides insight into the strength of this association.

The model incorporates time-fixed effects (θ_t) to account for temporal variations, including exogenous global events such as the COVID-19 pandemic, which persisted for two years. Additionally, it incorporates nation-specific effects (α_i) to control for cross-country heterogeneity arising from structural differences, such as variations in political stability, educational attainment, and the availability of natural resources. The error term ε_{it} captures unobserved stochastic influences affecting the dependent variable.

This econometric specification enables the systematic evaluation of how BRI participation influences innovation and economic development across different nations over time. The method also exhibits enhanced statistical power relative to other techniques that fail to fully utilise temporal and entity-specific information. For instance, the Difference-in-Differences (DID) approach neglects data from periods other than the initial and final ones. On top of that, DID requires a representative control group, which may not be the case when evaluating a policy that already impacts the vast majority on a population. Conversely, panel data analysis necessitates the use of specialised econometric software, and the interpretation of its results can be complex and nuanced. Furthermore, the selection of the most appropriate regression model - such as the Pooled Ordinary Least Squares (OLS), Fixed Effects, or Random Effects Model - must be undertaken with methodological rigor to mitigate the risk of biased or inconsistent estimates. To guide this model selection process, several statistical tests are employed: the Lagrange Multiplier (LM) Test is used to determine whether the Random Effects Model is preferable to the Pooled OLS Model; the F-Test for restricted models is applied to assess the suitability of the Fixed Effects Model over the Pooled OLS; and the Hausman Test is utilised to decide between the Fixed Effects and Random Effects Models (Baltagi, 2021).

If the best model is either Pooled OLS or Fixed Effects, then the Classic Assumption Test must be carried out, checking for Multicollinearity, Heteroscedasticity and Autocorrelation (Baltagi, 2021).

For this study, the software Stata MP 13.0 was employed on both the validation tests and the execution of the regressions themselves.

3.4. Evaluation

Upon completion of all regressions, each dependent variable - whether GDP per capita, the IPI, the GII, or the score of one of its seven pillars - will be represented by a linear equation. The slope of this equation will indicate the statistical likelihood of its evolution in response to variations in the corresponding independent variable. Additionally, a series of complementary analyses, including descriptive statistics, histograms, and scatter plots, will further enhance our evaluative capabilities.

The findings of this analysis are thoroughly presented in the next chapter, with each table examined in detail. This discussion seeks to offer an in-depth understanding of the BRI's impact on innovation, emphasising key insights and their significance. The interpretations are aligned with the study's initial objectives, providing critical reflections on how these results enhance the existing body of knowledge and highlighting potential directions for future research.

4. RESULTS

4.1. Descriptive Statistics

Panel data comprises 109 countries and spans from 2011 until 2023. Nations started to join BRI by 2013 gradually, and by 2023, the last year of the analysis, 82 out of 109 countries were part of the Initiative, while 27 were not. During the analysed period only one country - Italy - joined and subsequently left BRI.

Table IV presents key insights from the data panel, focused on the Intellectual Property per Million Inhabitants Indicator.

TABLE IV

STATISTICS ON INTELLECTUAL PROPERTY PER MILLION INHABITANTS

Measure	**Year 2011**	**Year 2023**	**Δ%**
Mean	1003.76	1574.46	56.9%
Standard Error	127.81	162.21	26.9%
Median	384.30	939.30	144.4%
Mode	304.88	762.11	150.0%
Standard Deviation	1334.38	1693.51	26.9%
Sample Variance	1780561.68	2867962.65	61.1%
Kurtosis	3.49	4.66	33.7%
Skewness	1.80	1.77	-1.6%
Range	6512.30	9804.50	50.6%
Minimum	0.00	0.00	0.0%
Maximum	6512.30	9804.50	50.6%
Count	109.00	109.00	0.0%
Confidence Level (95%)	253.34	321.53	26.9%

Source: Own elaboration

It is visible that during the 13-year period between 2011 and 2023 the IPI has strongly increased. The mean has moved up by 56.9% while the median increased by 144.4% and the mode surged by 150%. The maximum value, referring in both the initial and end years to South Korea, grew by 50.6%. On the other hand, the skewness remained practically unchanged, with a concentration of this indicator on the lower end. This measure, together with the overall frequency profile, is better understood in Figure 3, where a smoothed curve for the 2011 and 2023 histograms is represented.

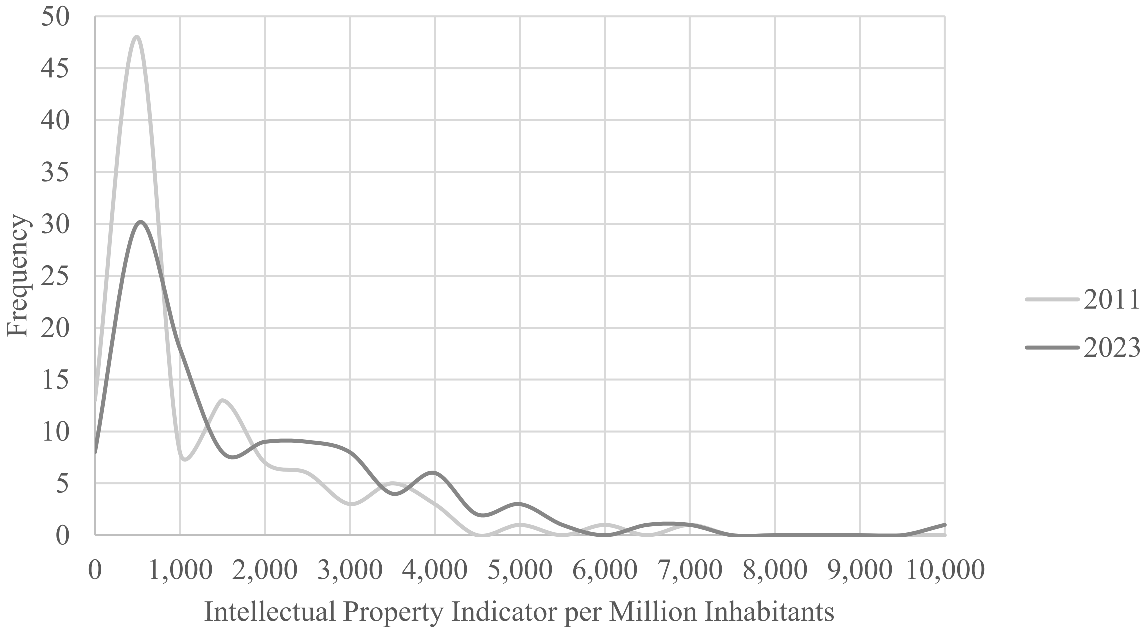

Figure 3 - Frequency profile for the Intellectual Property Indicator

Source: Own elaboration

Focusing now on the GII, Table V presents key measures derived from the same data panel as before. In here we can see that the GII global average has decreased by 7.9% between 2011 and 2023, the year in which it reached a value of 35.07 points. The median and mode also decreased at a higher rate than the mean one, respectively -10.3% and -23.4%, which, together with a skewness decrease of more than 20%, denotes a higher concentration on the low-end of the scale. The range has increased by 25.3%, but while the maximum value has increased 5.9%, the minimum value has decreased by 37.2%, which underlines once again the negative index evolution in this period.

TABLE V

STATISTICS ON GLOBAL INNOVATION INDEX

Measure	Year 2011	Year 2023	Δ%
Mean	38.08	35.07	-7.9%
Standard Error	1.02	1.34	31.3%
Median	35.85	32.16	-10.3%
Mode	30.45	23.32	-23.4%
Standard Deviation	10.69	14.03	31.3%
Sample Variance	114.28	196.86	72.3%
Kurtosis	-0.68	-0.74	8.7%
Skewness	0.62	0.49	-21.3%
Range	44.03	55.16	25.3%
Minimum	19.79	12.42	-37.2%
Maximum	63.82	67.58	5.9%
Sum	4150.43	3822.94	-7.9%
Count	109	109	0.0%
Confidence Level (95.0%)	2.03	2.66	31.3%

Source: Own elaboration

Figure 4 compares the smoothened curves of both the years 2011 and 2023 histograms. While two countries - Switzerland and Sweden - managed to increase its scores to above 2011 record high (already belonging to Switzerland), 14 others are now in values below 2011 minimum.

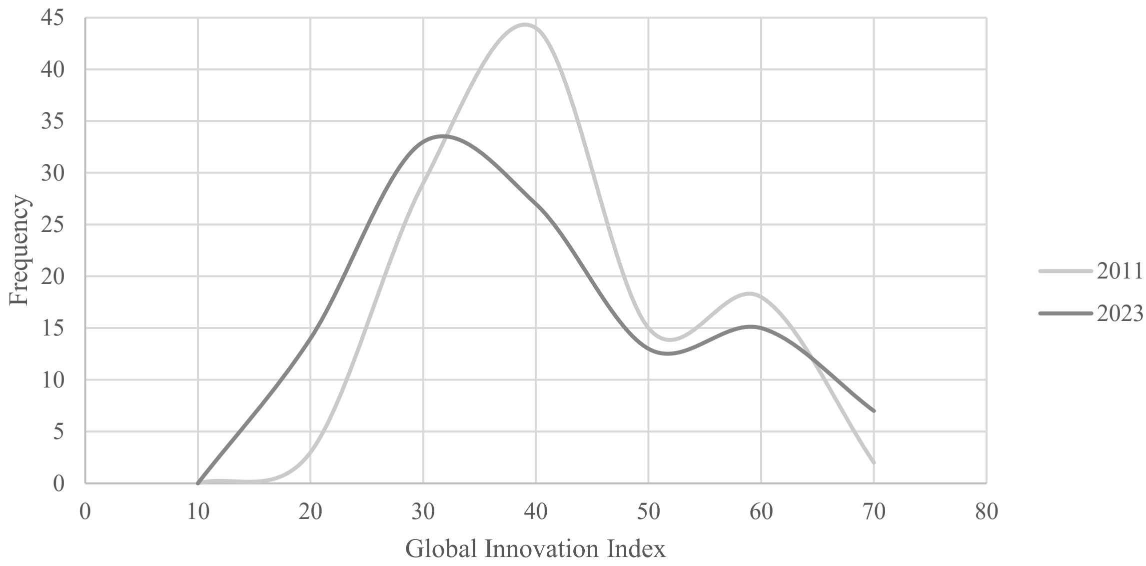

Figure 4 - Frequency profile for the Global Innovation Index
Source: Own elaboration

Figure 5 illustrates the changes in the average values of the GII constituent pillars between 2011 and 2023. Among these, only the infrastructure pillar showed a positive trend, increasing by 38% over the 12-year period. All other pillars experienced a decline, aligning with the overall decrease in the GII during the same timeframe.

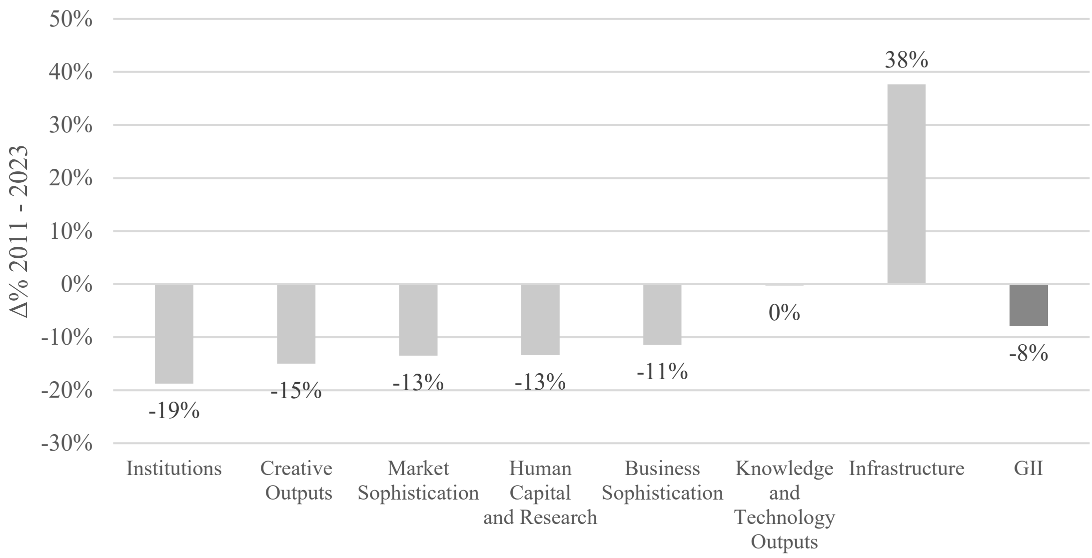

Figure 5 - GII constituent pillars average variation (2011-2023)
Source: Own elaboration

Income level significantly influences a country's GII score. Figure 6 and Figure 7 show that in the years 2011 and 2023 the vast majority of the 109 countries under study are organised around an ascending straight line where higher per capita incomes correspond to higher innovative activity.

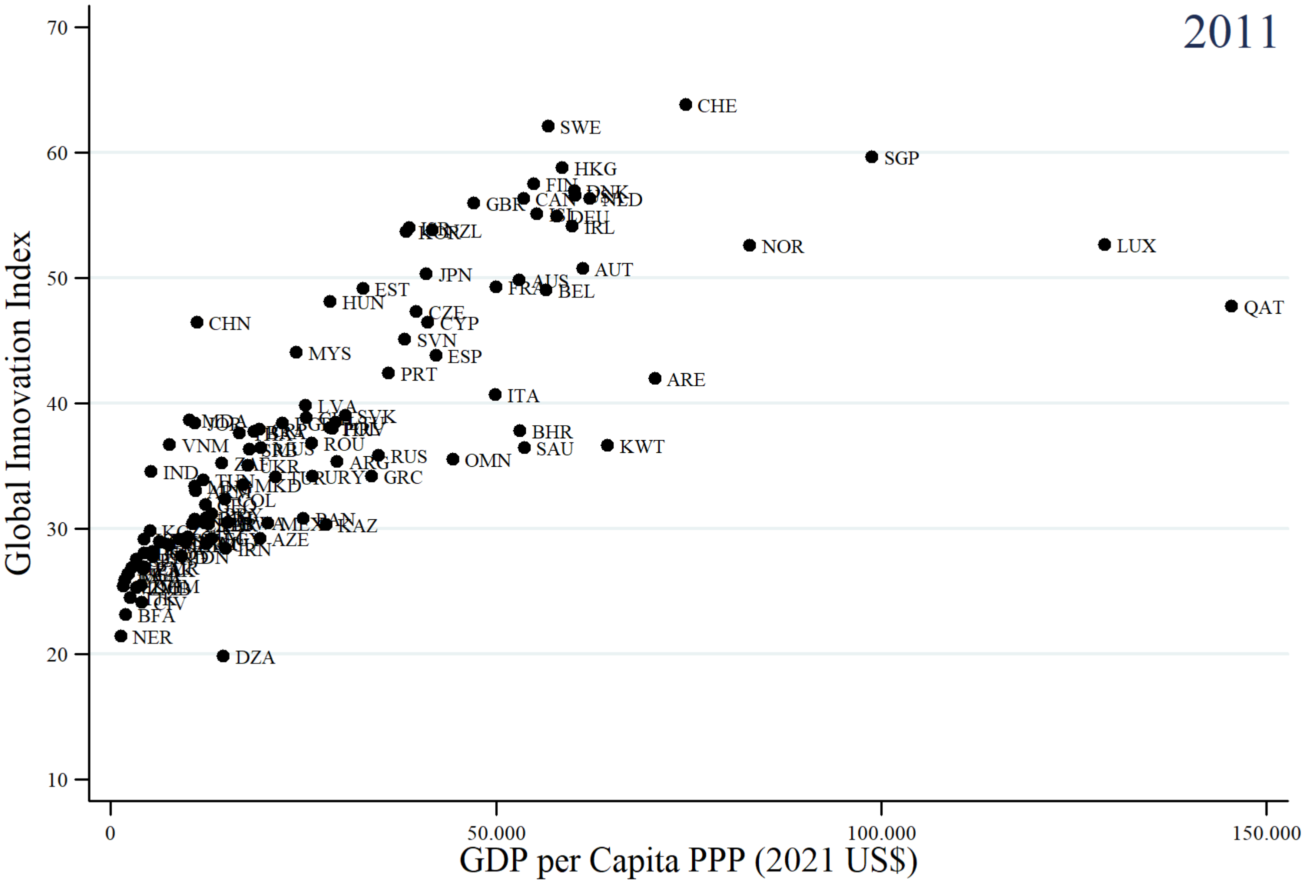

Figure 6 - GII vs GDP per capita (2011)

Source: Own elaboration

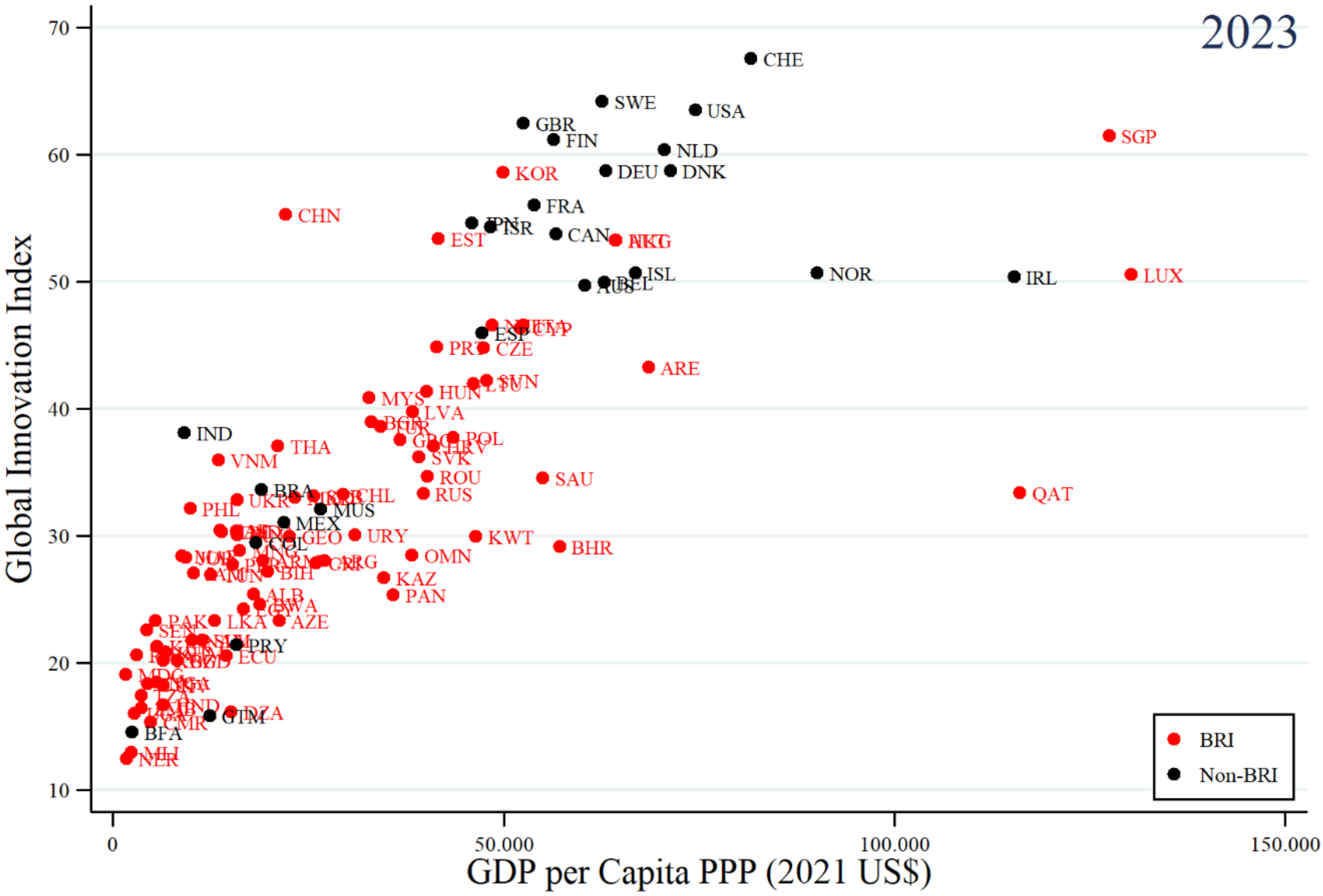

Figure 7 - GII vs GDP per capita (2023)

Source: Own elaboration

Once again, a clear divergence among countries in terms of the GII is observed over the analysed period. In 2011, only two countries scored above 60 points, while just one fell below the 20-point mark. By 2023, this divergence had significantly widened, with seven countries exceeding 60 points and fourteen scoring below 20 points.

The increasing divergence in the GII between BRI and non-BRI countries is further illustrated in Figure 8, which depicts the temporal evolution of the average GII trajectories for each group. These trends underscore the comparatively lower innovation capacities of countries that have progressively joined the BRI since its inception in 2013. This dynamic has contributed to a widening gap relative to non-BRI countries, which are predominantly high-income and have historically demonstrated strong innovation performance.

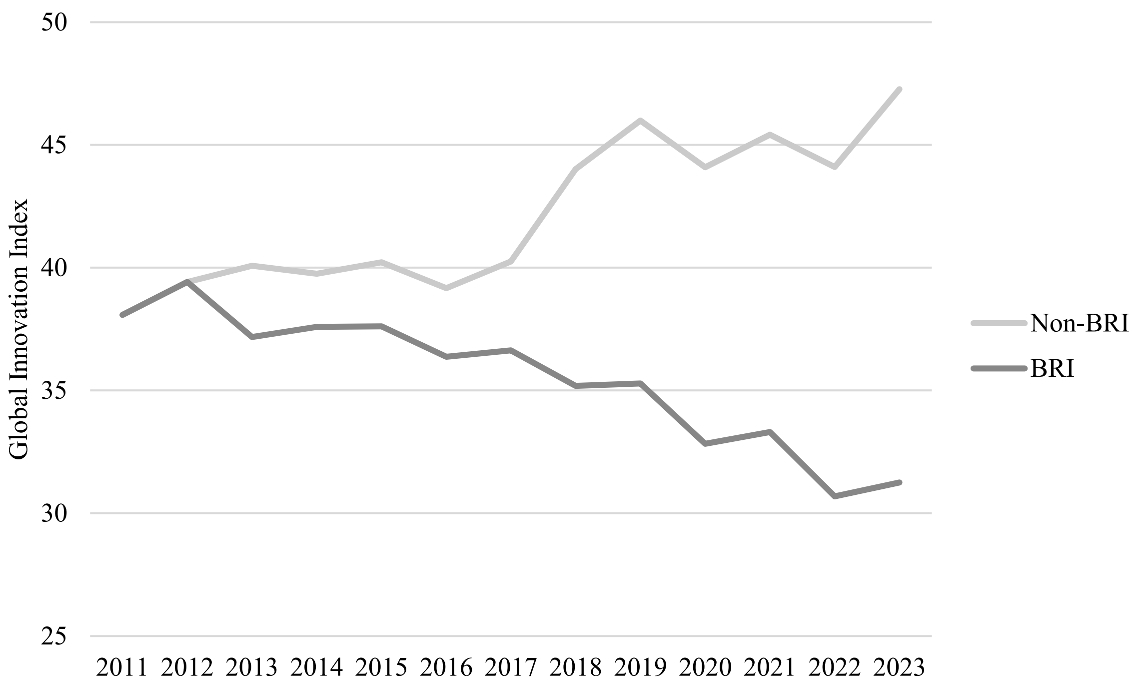

Figure 8 - Average GII Evolution

Source: Own elaboration

Accessorily, Figure 9 presents, for the same set of 109 countries, a box-and-whisker chart comparing GII scores across the four World Bank income categories for 2023. The data clearly shows that higher-income countries are more likely to achieve higher GII scores.

Region has also a substantial impact on GII, although the scores can often be more easily explained by the country's wealth than by its regional context.

Figure 10 presents the 109 countries under study on a box-and-whisker chart comparing GII scores across the seven World Bank's regions for 2023.

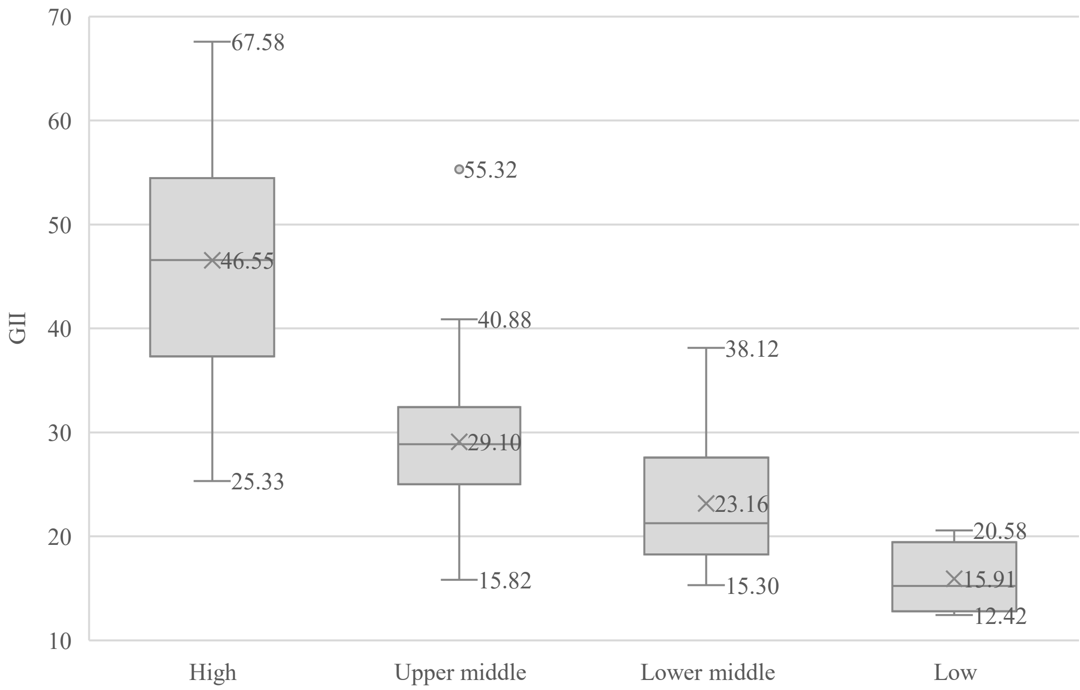

Figure 9 - Box-and -Whisker on GII vs Income Level (2023)

Source: Own elaboration

The two regions that have historically anchored both the ancient and modern Silk Road - Europe & Central Asia and East Asia & Pacific - exhibit remarkably similar GII profiles. Europe & Central Asia displays the broadest range in GII scores, which is expected given its diversity: it includes highly innovative and affluent countries like Switzerland and Sweden, alongside much less developed nations such as Tajikistan and Kyrgyzstan. Similarly, East Asia & Pacific is home to global innovation leaders like Singapore, South Korea, and China, while also encompassing countries with significantly lower GII scores, such as Cambodia and Mongolia. The average GII scores of the two regions are nearly identical.

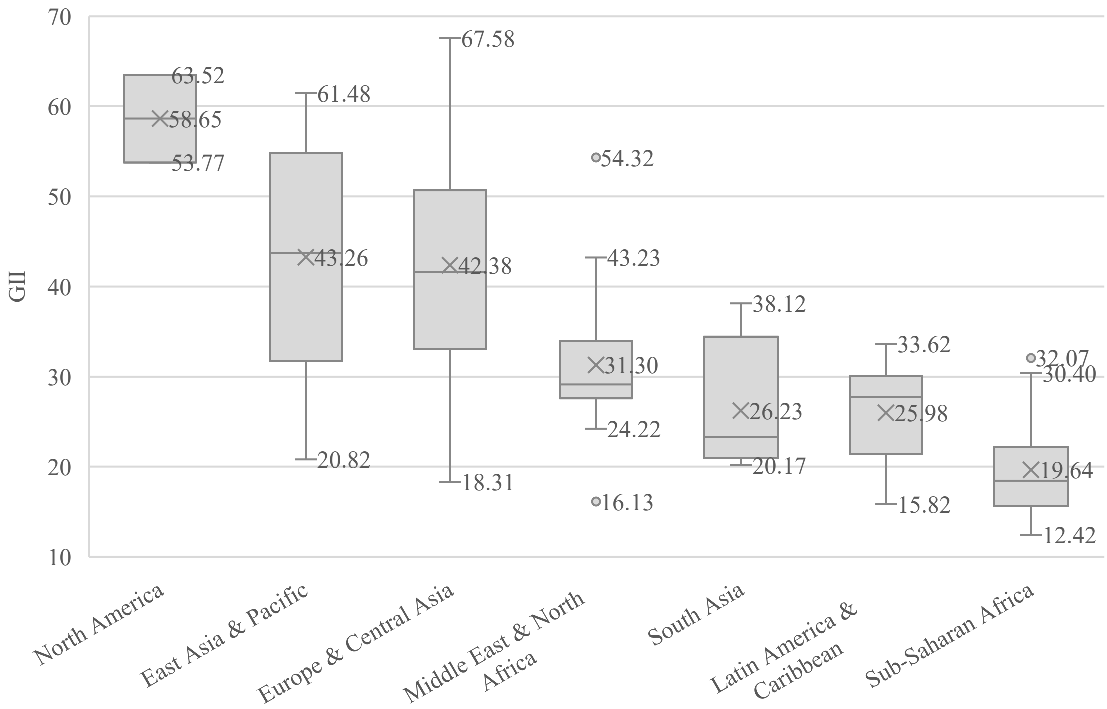

Figure 10 - Box-and-Whisker on GII vs World Regions (2023)

Source: Own elaboration

4.2. Relationship between BRI and GDP per Capita

As observed in the previous section, GDP per capita positively influences both IPI and GII. Therefore, it is important to analyse the association between the BRI and this indicator. Table VI shows the result of a panel data regression where the GDP per Capita PPP in 2021 US$ is the dependent variable, and BRI, a dichotomic variable representing the nation's presence or not in the Belt and Road Initiative, is the independent one. This analysis includes all years from 2011 to 2023 - the most recent year for which GDP data is currently available.

TABLE VI

PANEL DATA REGRESSION ON GDP PER CAPITA PPP

GDPperCapPPP$2021	Coef.	Robust St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
BRI	2326.912	462.091	5.04	0	1410.967	3242.857	***
Constant	29848.638	189.793	157.27	0	29472.435	30224.841	***

Mean dependent var	30804.363	SD dependent var	26461.795
R-squared	0.076	Number of obs	1417
F-test	25.357	Prob > F	.
Akaike crit. (AIC)	27009.580	Bayesian crit. (BIC)	27014.836

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

Source: Own elaboration

As BRI assumes only the values 0 or 1, the results demonstrate that the adherence to the Initiative corresponds statistically to an increase of 2,326.91 US$ to a country's GDP per Capita PPP. Due to the positive relation between GDP per Capita PPP and GII, this is a sign that joining the BRI is likely to be positive for its innovative activity.

The regression model selected was the Fixed Effects one, with robust standard errors. The model choice was based upon the results of the LM, F-Restricted and Hausman tests that can be found in Appendix 1, together with the tests for heteroscedasticity and autocorrelation.

4.3. Relationship between BRI and Intellectual Property Indicator

Replicating the analysis with the Intellectual Property Indicator as the dependent variable, the results once again indicate a positive effect associated with participation in the BRI. As presented in Table VII, countries participating in the BRI are estimated to produce, on average, 410.75 more patents, trademarks, and industrial designs, per million inhabitants, than their non-member counterparts.

TABLE VII

PANEL DATA REGRESSION ON INTELLECTUAL PROPERTY INDICATOR

IntellectualProp	Coef.	Robust St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
BRI	410.75	85.097	4.83	0	241.855	579.644	***
Constant	1337.027	35.669	37.48	0	1266.234	1407.819	***

Mean dependent var	1509.193	SD dependent var	1663.477
R-squared	0.084	Number of obs	1274
F-test	23.298	Prob > F	.
Akaike crit. (AIC)	19729.696	Bayesian crit. (BIC)	19734.846

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

Source: Own elaboration

The Fixed Effects Model was chosen for this regression based on the test results presented in Appendix 1.

4.4. Relationship between BRI and GII and its Pillars

To analyse the association between the BRI and the GII and its seven pillars, we begin by executing the LM, F-Restricted and Hausman tests on eight different data panels to access the best regression model. These eight data panels will all have the same independent variable – BRI – but the dependent variable will be the GII or each one of its sub-indexes – Institutions, Human Capital & Research, Infrastructures, Market Sophistication, Business Sophistication, Knowledge & Technology Outputs and Creative Outputs. The results of those tests are summarised in the Appendix 1 and they all point to the Fixed Effects Model.

The results of the regression are summarised in Figure 11, where we can see the β_{BRI} coefficient for GII and each one of its pillars. All the results are significant for an α=0.05 and the Stata regression tables can be found on Appendix 2.

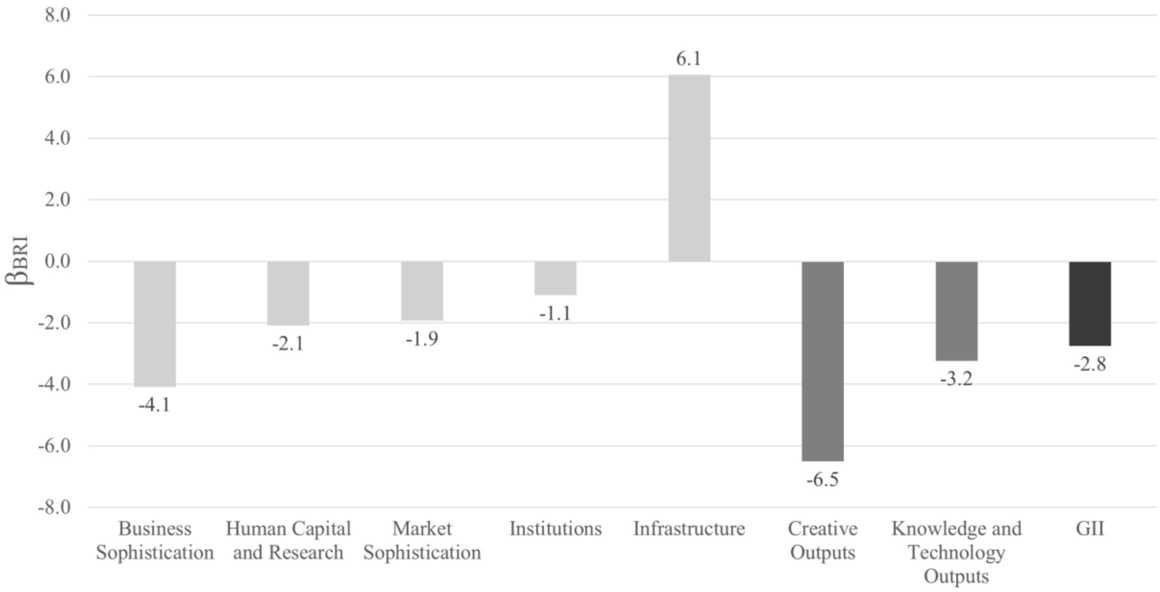

Figure 11 - BRI beta coefficient for GII and each one of its pillars

Source: Own elaboration

The GII coefficient of -2.8 points indicates that there is a diverging trend between BRI and non-BRI countries. As can be seen in Figure 1, non-BRI countries are mostly well developed and rich countries, located in Western Europe and North America, while BRI countries are mostly part of the global south.

What the panel data coefficient indicates is that joining BRI, although positive as it may be for the Intellectual Property Indicator and for the GDP per Capita, is not enough to ensure a catch-up in terms of GII. As a matter of fact, the only pillar where a convergence exists is in the Infrastructure, BRI countries being prone to a hike of 6.1 points in that pillar, while for all the remaining six pillars there is a negative evolution.

This result is in-line with the descriptive statistics, where we could see that in the period between 2011 and 2023 the best and worst performers grew apart. While in 2011 GII scores ranged between 19.79 and 63.82, in 2023 they varied between 12.42 and 67.58. And looking once again at Figure 7 is clear that many of the best performers are non-BRI countries, while many of the worst performers are BRI countries.

4.5. Relation between Input and Output Pillars

The BRI countries see both their pillars of the Innovation Output Sub-Index negatively impacted. Knowledge & Technology Outputs and Creative Outputs are losing ground towards non-BRI countries by 3.2 and 6.5 points, respectively. Together, these two pillars are the primary drivers of the GII's negative performance, as they collectively account for 50% of the total GII score. While in the first pillar we find metrics like the number of patents filed or the number of citations that local research documents receive abroad, the second is constituted by metrics such as the value of the brands or the number of trademarks applications presented.

It is therefore of interest to analyse what are the input pillars that most impact the output ones. For that, the covariance Table VIII has been built and in there we can see that Knowledge & Technology Outputs and Creative Outputs are particularly influenced by the Business Sophistication and Human Capital & Research pillars, having the Institutions pillar a secondary role, together with Institutions and Market Sophistications.

TABLE VIII

COVARIANCE BETWEEN GII PILLARS

	Institutions	Human Cap.	Infrastructure	Market soph.	Bus. soph.	Knowled. out.	Creative out.
Institutions	1.00						
Human Cap.	0.75	1.00					
Infrastructure	0.71	0.77	1.00				
Market soph.	0.71	0.63	0.61	1.00			
Bus. soph.	0.72	0.81	0.68	0.65	1.00		
Knowled. out.	0.64	0.79	0.68	0.64	0.83	1.00	
Creative out.	0.69	0.74	0.65	0.66	0.76	0.75	1.00

Source: Own elaboration

Being the BRI mainly an infrastructures construction initiative, it would therefore hardly contribute strongly to an increase in the Output Sub-Index and consequently for a meaningful GII catch-up trend.

5. DISCUSSION

The empirical findings reveal a positive correlation between the BRI and GDP per capita, corroborating the estimations presented by Xie et al. (2023). This positive association extends to the generation of intellectual property outputs - quantified in this study through the cumulative number of patent, trademark, and design filings - which is consistent with the findings of Zhou et al. (2023) based on a DID methodology.

Furthermore, the BRI's strategic emphasis on infrastructure development has been shown to facilitate innovation spillovers, as evidenced by Audretsch and Feldman (2004). However, the absence of proportional investments in human capital and business sophistication constrains its capacity to bridge the innovation gap between highly developed and less developed economies, a result that contrasts with the expectations derived from Zhao's (2023) findings.

Innovation convergence in this study is assessed using the GII, a widely adopted framework for evaluating national innovation performance (Dutta et al., 2023). Nevertheless, the GII may exhibit an inherent bias favouring Western innovation paradigms. Notably, two of its seven pillars - Knowledge Outputs and Creative Outputs - constitute 50% of the total score. These pillars contain indicators such as patent filings, high-tech exports, global brand recognition, and the valuation of intangible assets (Dutta, 2012). Enhancing these metrics typically requires substantial investment, which may be unattainable for many developing economies. In contrast, countries with well-established innovation ecosystems are better positioned to improve their performance under the GII. Consequently, using this evaluative framework, the convergence of innovation capabilities between developed and developing economies is, at best, likely to remain a protracted process.

In summary, while the BRI contributes to elevating the innovation capacity of participating countries, it does not suffice to enable them to catch up with non-BRI countries, many of which possess already mature and highly innovative economies. It is important to note, however, that this conclusion is contingent upon the use of the GII as the primary evaluative instrument, which may yield overly pessimistic assessments due to its structural bias.

6. CONCLUSION AND FUTURE WORK

The Belt and Road Initiative (BRI), launched by China in 2013, is a comprehensive global infrastructure and economic development strategy designed to enhance connectivity and cooperation among nations. It seeks to improve trade routes and facilitate investment in transportation, energy, and digital infrastructure across Asia, Europe, and Africa. Its impact on global economic structures is significant, as it has promoted regional economic integration, spurred infrastructure development in emerging economies, and altered geopolitical dynamics by expanding China's strategic influence. Moreover, the Initiative is shaping global trade patterns and diplomatic relations, making it a focal point in contemporary discussions of international development and economic policy. Despite its ambitious goals and growing global influence, the BRI has also raised several concerns among participating countries and international observers. While the BRI presents opportunities for economic growth and international collaboration, it has also been met with concerns regarding debt sustainability, environmental implications, and geopolitical tensions among participating countries.

This research presents a rigorous examination of the impact of the BRI on the innovative activities of participating countries, employing both descriptive and inferential statistical techniques alongside the CRISP-DM methodology. By adopting a systematic approach and leveraging well-established data sources, the study ensures the reliability and reproducibility of its findings. The methodological framework effectively quantifies the influence of the BRI, facilitating a comprehensive analysis of emerging trends and the associated advantages for member states.

The analysis underscores the significant impact of the BRI in shaping the global innovation landscape. The World Intellectual Property Organization (WIPO) has emerged as a pivotal institution for the dissemination of high-quality data, reinforcing its relevance in advancing scholarly research on innovation. In conclusion, the findings indicate a positive correlation between the BRI and economic indicators such as GDP per capita, as well as Intellectual Property Outputs, including patent and trademark filings. However, the study also highlights the Initiative's limitations in addressing the existing innovation gap between highly developed economies and less developed nations. While the BRI emphasises infrastructure development, a commensurate investment in human capital and business sophistication is required to mitigate the widening disparities. Without such complementary efforts, a persistent divergence is observed, wherein leading economies - predominantly non-BRI countries - continue to outpace less developed nations, despite the latter experiencing notable advancements in knowledge production and creative output facilitated by the BRI.

This research evaluated absolute innovation performance by analysing the combined metrics of patents, trademarks, and industrial designs. However, numerous additional parameters that are essential for a comprehensive assessment of innovation performance were not incorporated in this study. Further investigation is warranted to examine the specific contributions of the BRI to each of these individual dimensions of innovation.

Additionally, the assessment of innovation convergence was conducted utilising the Global Innovation Index (GII) as a standardised measure. The GII serves as a well-established benchmark for evaluating innovation, incorporating a diverse set of indicators within a comprehensive analytical framework. Its annual updates ensure the provision of both cross-country comparisons and longitudinal data, thereby facilitating research efforts aimed at monitoring and analysing the evolution of innovation across different economies. Nevertheless, this index may face criticism for its perceived Western bias in assessing innovation across countries. One concern is that the index relies heavily on macroeconomic and socio-political indicators that favour developed economies, particularly those in North America and Europe, while potentially underrepresenting alternative innovation models in emerging markets. Furthermore, the selection of data sources and methodologies may reflect a preference for Western-centric frameworks, which can overlook informal innovation systems and indigenous knowledge that contribute to technological advancement in non-Western regions. If this assertion holds, the GII ranking system appears to perpetuate existing global hierarchies rather than offering a genuinely impartial evaluation of innovation capacity. Consequently, it is advisable for future research to employ alternative indicators to assess the convergence of innovation across nations, such as the European Innovation Scoreboard (EIS) or the Knowledge Assessment Methodology (KAM) developed by the World Bank.

Lastly, a comprehensive analysis of the BRI impact on innovation across various nations would provide valuable insights. Conducting in-depth case studies that integrate both qualitative and quantitative methodologies could facilitate a nuanced understanding of how the Initiative has influenced innovation dynamics in specific contexts. Such studies could examine the experiences of Portugal and Luxembourg - the only two Western European nations currently participating in the BRI - as well as Italy, a G7 member that initially joined but later withdrew. Evaluating the effects of the BRI on key innovation indicators within these countries would contribute to a broader assessment of the Initiative's role in shaping technological and economic advancements.

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APPENDICES

Appendix 1 – Panel Data Model Selection

To identify the most suitable panel data regression model and verify its underlying assumptions, a series of diagnostic tests were conducted, including the Breusch-Pagan Lagrange Multiplier test, the Hausman test, the Wooldridge test, and the Breusch-Pagan/Cook-Weisberg test. These tests were applied to equations that consistently used the same independent variable - BRI - while varying the dependent variables, namely GDP per capita, IPI, GII, and each of its individual pillars. In all cases, the outcomes of the tests were identical and are summarised in Appendix Table I.

APPENDIX TABLE I

TESTS FOR PANEL DATA MODEL SELECTION

Test	H_0	p-value	Decision
Breusch and Pagan Lagrangian multiplier for random effects	There are no random effects (POLS preferred)	0.0000	H_0 can be rejected, therefore REM is preferred over POLS
Hausman	FEM and REM estimators are not very different (REM preferred)	0	H_0 can be rejected, therefore FEM is preferred over REM
Wooldridge	No first order autocorrelation in panel data	0.0000	H_0 can be rejected, therefore the presence of autocorrelation must be considered
Breuch-Pagan / Cook-Weisenberg	Constant variance	0.0000	H_0 can be rejected, therefore the presence of heteroskedasticity must be considered

α = 0.05

Source: Own elaboration

Based on the results of the Breusch-Pagan Lagrange Multiplier and Hausman tests, the fixed effects model (FEM) was identified as the most appropriate specification. Consequently, it was unnecessary to perform the F-test for model selection between Pooled Ordinary Least Squares (POLS) and FEM, as the established hierarchy - FEM being superior to the Random Effects Model (REM), and REM outperforming POLS - was already confirmed.

Additionally, the Wooldridge test and the Breusch-Pagan/Cook-Weisberg test indicated the presence of autocorrelation and heteroskedasticity, respectively. To address these issues, robust standard errors were applied using the Huber/White variance-covariance estimator (VCE) within the fixed effects framework in Stata (Wooldridge, 2025).

Appendix 2 – Panel Data Regression Results

APPENDIX TABLE II

BUSINESS SOPHISTICATION REGRESSION RESULTS

BusinessSophistica	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
BRI	-4.078	.555	-7.35	0	-5.177	-2.979	***
Constant	37.19	.228	163.27	0	36.738	37.641	***

Mean dependent var	35.515	SD dependent var	12.914
R-squared	0.121	Number of obs	1417
F-test	54.070	Prob > F	.
Akaike crit. (AIC)	8303.421	Bayesian crit. (BIC)	8308.678

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

Source: Own elaboration

APPENDIX TABLE III

HUMAN CAPITAL AND RESEARCH REGRESSION RESULTS

HumanCapitalAnd	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
BRI	-2.086	.429	-4.86	0	-2.936	-1.235	***
Constant	36.371	.176	206.35	0	36.022	36.72	***

Mean dependent var	35.514	SD dependent var	15.079
R-squared	0.044	Number of obs	1417
F-test	23.622	Prob > F	.
Akaike crit. (AIC)	7942.782	Bayesian crit. (BIC)	7948.038

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

Source: Own elaboration

APPENDIX TABLE IV

MARKET SOPHISTICATION REGRESSION RESULTS

MarketSophisticati	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
BRI	-1.934	.535	-3.61	0	-2.995	-.873	***
Constant	47.811	.22	217.46	0	47.375	48.247	***

Mean dependent var	47.017	SD dependent var	13.054

R-squared	0.014	Number of obs	1417
F-test	13.052	Prob > F	.
Akaike crit. (AIC)	9387.318	Bayesian crit. (BIC)	9392.574

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

Source: Own elaboration

APPENDIX TABLE V

INSTITUTIONS REGRESSION RESULTS

Institutions	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
BRI	-1.105	.533	-2.07	.041	-2.162	-.047	**
Constant	65.176	.219	297.53	0	64.742	65.61	***

Mean dependent var	64.723	SD dependent var	15.599
R-squared	0.007	Number of obs	1417
F-test	4.289	Prob > F	.
Akaike crit. (AIC)	8710.964	Bayesian crit. (BIC)	8716.220

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

Source: Own elaboration

APPENDIX TABLE VI

INFRASTRUCTURE REGRESSION RESULTS

Infrastructure	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
BRI	6.067	.458	13.24	0	5.159	6.975	***
Constant	40.136	.188	213.32	0	39.764	40.509	***

Mean dependent var	42.629	SD dependent var	13.133
R-squared	0.202	Number of obs	1417
F-test	175.422	Prob > F	.
Akaike crit. (AIC)	8558.480	Bayesian crit. (BIC)	8563.737

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

Source: Own elaboration

APPENDIX TABLE VII

CREATIVE OUTPUTS REGRESSION RESULTS

CreativeOutputs	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
BRI	-6.507	.611	-10.64	0	-7.718	-5.295	***
Constant	35.033	.251	139.51	0	34.536	35.531	***

Mean dependent var	32.361	SD dependent var	13.471
R-squared	0.181	Number of obs	1417
F-test	113.248	Prob > F	.
Akaike crit. (AIC)	8950.191	Bayesian crit. (BIC)	8955.448

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

Source: Own elaboration

APPENDIX TABLE VIII

KNOWLEDGE AND TECHNOLOGY REGRESSION RESULTS

KnowledgeAndTe	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
BRI	-3.23	.443	-7.29	0	-4.109	-2.351	***
Constant	30.217	.182	165.96	0	29.856	30.578	***

Mean dependent var	28.891	SD dependent var	13.716
R-squared	0.107	Number of obs	1417
F-test	53.090	Prob > F	.
Akaike crit. (AIC)	7836.356	Bayesian crit. (BIC)	7841.612

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

Source: Own elaboration

APPENDIX TABLE IX

GLOBAL INNOVATION INDEX REGRESSION RESULTS

GlobalInnovationI	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
BRI	-2.754	.291	-9.46	0	-3.331	-2.177	***
Constant	38.986	.12	326.19	0	38.749	39.223	***

Mean dependent var	37.855	SD dependent var	12.020
R-squared	0.177	Number of obs	1417
F-test	89.561	Prob > F	.
Akaike crit. (AIC)	6554.071	Bayesian crit. (BIC)	6559.328

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

Source: Own elaboration