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Analysis of Public-Private Partnership Projects in India registered by the World Bank 1990-2021

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INFORMACIÓN Y RESUMEN

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Abstract:

Public-private partnerships (PPPs) refer to long-term contractual agreements between public and private partners for the provision of public infrastructure or service exploitation, in which the private entity normally assumes significant risk.

The aim of this paper is to analyse the relationship between investment amount and type of primary sectors involved in PPP projects in India, including differences in the allocation of such investment across the sectors. To achieve this, the paper first explores conceptual foundations to understand sectoral-investment patterns in PPPs within the Indian context, followed by a specific empirical study.

To perform this study, two variables have been selected from which hypothesis contrasts were made using chi-square and ANOVA tests. The results obtained provide insight into the uneven distribution of investment and the possible causes that make certain sectors more attractive to investors.

Resumen:

Las colaboraciones público-privadas (CPP) son acuerdos contractuales a largo plazo entre socios públicos y privados para la provisión de infraestructura pública o la explotación de servicios, en los que la entidad privada suele asumir un riesgo significativo.

El objetivo de este trabajo es analizar la relación entre el monto de la inversión y el tipo de sectores primarios involucrados en proyectos de CPP en India, incluyendo las diferencias en la distribución de dicha inversión entre los sectores. Para ello, el trabajo explora primero los fundamentos conceptuales para comprender los patrones de inversión por sector en las CPP dentro del contexto de India, y posteriormente se realiza un estudio empírico específico.

Para llevar a cabo este estudio, se han seleccionado dos variables a partir de las cuales se contrastaron hipótesis mediante test de chi-cuadrado y ANOVA. Los resultados obtenidos ofrecen una visión sobre la distribución desigual de la inversión y las posibles causas que hacen que ciertos sectores resulten más atractivos para los inversores.

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1. INTRODUCTION

Public-Private Partnership ("PPP") is a broad concept which encompasses various definitions depending on the legal, economic, and institutional framework in it is applied. Nevertheless, international organisations, such as World Bank, describe PPP as "a long-term contract between a private party and a government entity, for providing a public asset or service, in which the private party bears significant risk and management responsibility and remuneration is linked to performance" (World Bank, 2017).

At a European level, a Directive was required by the Parliament to create a standardised regulatory framework for PPP. Therefore, in 2004, the European Commission published the "Green Paper on Public-Private partnerships and community law on public contracts and concessions" referring to PPP as a form of cooperation between public authorities and the world of business with the aim to ensure the funding, construction, renovation, management or maintenance of an infrastructure or the provision of a service (COM, 2004).

This Green Paper distinguishes two varieties of nature within the PPP: "purely contractual", where the collaboration between public and private sector is established through contractual agreements, and "institutional", in which a jointly managed entity is formed with the participation of both, public and private, partners.

On the one side, the "purely contractual" partnership is composed by two types: "concessive model" and "other types of set-ups". The concept of concession explains the direct relationship between the private sector and the final user: the private partner provides a service to the public, "in place of", though under the control of, the public partner (COM, 2004). Moreover, the compensation scheme for the joint contractor involves fees charged to the final users, with a possibility of additional government subsidies if required.

Regarding "other types of set-ups", the private sector is responsible for building and managing infrastructure on behalf of the public authority. One common example of infrastructure could be a hospital or a school. In this case, the remuneration consists of regular payments from the public partner, which can be fixed or variable, depending on factors such as the availability of the works or the level of its use (COM, 2004).

On the other side, “institutionalised” PPPs aim to deliver a work or service to the public interest through a jointly between private and public partners. It is often used to administer public services at a local level in the form of water supply services or wate collection services. This cooperation allows public authorities to be involved in the decision-making as well as retaining significant control over the development of the projects, which can be adapted when needed. At the same time, it enables the public partner to learn how to manage the service, while relying on the support of a private partner.

An institutionalised public-private partnership can be established either through the creation of a jointly-owned entity by the public and private sectors, or by transferring control of an existing public undertaking to the private partner (COM, 2004).

It is also important to consider why PPPs have gained sustained popularity over the time. This is due to several advantages which make them highly attractive for both partners, but especially for the public sector. For instance, A PPP makes possible the transfer of risks to private entities (Wang et al., 2012). It also allows the state to benefit from the skills, experience and technology innovation of the private partner, which could enhance the operational efficiency of the public assets (Li et al., 2005; Edkins and Smyth, 2006). Another advantage is that the public sector can reduce its operational responsibilities by outsourcing non-core activities to the private sector (Sabry, 2015) and focus on important matters such as regulation and supervision (Kwak et al., 2009). Moreover, the private sector is enabled to explore multiple uses of the facilities which the public sector might not fully exploit because it does not compete on the market (Valdimarsson, 2007).

Neverthless, public-private partnerhsips entail some disadvantages as well. It is said that of the main reasons PPPs fail is the lack of clear goals (Osborne, 2000). This issue may be even worsened when partners pursue “hidden” agendas, that is, prioritising their own interests instead of the common goals. Then, it is also crucial to bear in mind extra costs resulting from this collaboration such as whole-life and maintenance costs (Turhani and Shqau, 2011), resource costs (including staff time spent on meetings and negotiations) (Osborne, 2000) or those costs arising from corruption (Hopkin and Rodríguez-Pose, 2007). Another important challenge is unequal power among partners (Osborne, 2000) as some partners might hold more control over the others in terms of funding or political influence. This can cause problems because they might try to impose their own aims upon the rest.

Despite these disadvantages, public-private partnerships are still a key instrument for development, especially when the public infrastructe needs go beyond the government capacities. India is a clear example of this practice and presents an interesting opportunity for analysis for several reasons.

Firstly, India is one the world's fastest-growing major economies and it is forecasted to reach an economic growth rate of 6.4% by 2026 (IMF, 2025). Since, this country is experiencing a rapid economic growth and urbanisation, the current public infrastructure cannot cover the demand of the total population. The participation of the private sector in the development of the public infrastructure is also necessary (Phuyal, 2020). Thus, PPPs become essential to foster economic growth and accelerate GDP growth (Yadav, 2015).

Secondly, India has increasingly adopted PPPs since 1990s, after its economic liberalisation. It had helped to create value for money, reduce costs, attract skilled professionals, and encourage innovation (Yadav, 2015).

Furthermore, PPP projects are nowadays applied across numerous sectors, including not only transport and energy, but also others such as healthcare, education or agriculture (Asian Development Bank, 2024).

Given the wide range of sectors involved in PPP projects in India, it is relevant to examine how investment is distributed among the main sectors. This paper seeks to explore whether the amount of investment varies significantly depending on the types of primary sectors.

For this purpose, the paper is divided into five sections. The first section comprehends an introduction of the concept of public-private partnerships. Later, the second section presents a theoretical framework to explain sectoral-investment patterns in public-private partnerships in India. Thereafter, based on data extracted from the World Bank regarding PPP projects taken place in India between the years 1990 and 2021, a descriptive statistical analysis and two statistical methods (chi-square test of independence and ANOVA) are carried out to assess the possible relationship and differences between the total investment and the type of primary sector. The fourth section displays the results obtained. Finally, the last section outlines the key relevant points and main conclusions drawn from the study.

2. THEORETICAL FRAMEWORK

This section provides a theoretical justification for the existence and use of public-private partnerships, based on the Transaction Cost Theory, Principal-Agent Theory and Game Theory.

2.1. TRANSACTION COST THEORY

To begin with, two coordination mechanisms are traditionally known, the market and the hierarchy. The first one refers to a form of coordination where individuals achieve an equilibrium through pricing mechanisms (interaction between supply and demand), whereas, in the second one, coordination arises from authority, where legislation and control are key (Osborne, 2000).

The Transaction Cost Theory, introduced by Ronald Coase and further developed by Oliver Williamson, explains the boundaries between these two coordination mechanisms and recognises the existence of transaction costs. These are intrinsic costs associated with using the price mechanism, that is, costs resulting from the participation in the marketplace (Coase, 1937). Transaction costs can be divided into two categories: contracting (or direct) costs and residual (indirect) costs. The contracting costs refer to the resources utilised in identifying, negotiating and enforcing the contract that regulates a transaction, and the residual costs represent the potential wealth that is lost when entering an imperfect contract.

Each transaction should be regulated with the type of contract that is the most efficient and that minimises these transaction costs. Moreover, the extent of these costs varies depending on the specific characteristics of each transaction. Williamson identifies three: the uncertainty, the frequency of transactions and specific investments. When these features are high, the costs incurred in the market will also rise, and hierarchy might be seen as a more efficient alternative. However, hierarchy entails various drawbacks such as rigid and slow bureaucratic procedures. Thus, “hybrid contracts” such as public-private partnerships are crucial because they allow for lesser transaction costs while at the same time they provide greater flexibility.

These “hybrid contracts” are well established in India, especially in the sectors of transport and energy, where projects are often complex and have a long-term duration, resulting in higher of transaction costs. For instance, India’s National Infrastructure Pipeline (NIP) entails an investment plan of 111lakh crore (1.35 trillion USD dollars) during the period 2020-2025, composed by projects in different sectors (energy, roads, urban infrastructure, and railways) in the form of PPPs (Press Information Bureau, 2021). Many of these infrastructure projects, such as the Hyderabad Metro Rail or the Delhi International Airport, involve concession periods between 20 and 30 years characterised by political changes and constantly growth demand with very specific asset investments (Global Infrastructure Hub, 2021). In these cases, PPPs models like DBFOT (Design-Build-Finance-Operate-Transfer) or BOT (Build-Operate-Transfer) have become a key instrument to manage high transaction costs as well as allocating efficiently risks between public and private partners.

2.2. PRINCIPAL-AGENT THEORY

This collaboration creates a relationship between the public sector and private sector that falls as well under the framework of Principal-Agent Theory (Alchian and Demsetz, 1973), whereby the public partner (considered the principal) delegates the responsibility for providing a service or developing an infrastructure to a private sector (viewed as the agent). In this situation, conflicts of interests might arise due to differences in goals: the public sector wants to cover public needs and seeks social welfare, whereas the main priority of the private sector is to maximise profits. The partnership may be also characterised by an imbalance among both partners, in which one partner is more advantageous than the other because of better economic resources, skills or technical expertise and knowledge (Cheng and Yu, 2010).

Additionally, this agency relationship is affected also by information asymmetries as the public sector (principal) cannot monitor and control the actions of the private sector (agent). This can lead to inefficiencies and opportunistic behaviour such as adverse selection and moral hazard.

On the one side, the concept of adverse selection was formally introduced by George Akerlof in his paper "The Market for "Lemons": Quality Uncertainty and the Market Mechanism" in 1970. In the context of Principal-Agency Theory, it refers to an event where the public sector might choose an agent who might not be the most suitable to provide the public service or project. This occurs because the public partner does not know completely the ability of the private partner, neither during the selection process ("ex-ante") nor after signing the contract ("ex-post") (Amagoh, 2009).

On the other side, moral hazard takes place once the contract is signed. It happens when the agent prioritises its own interests because the principal cannot observe its everyday decisions and actions. For instance, moral hazard can be seen when private companies reduce the product quality to cut production costs or try to influence governments to obtain higher subsidies (Shrestha et al., 2019).

Moreover, although opportunism is often associated with agents, it can also arise among principals. Government principals such as politicians are assumed to act on the well-being of society, however, they are also driven by their own self-interest, especially when it comes to re-elections. Since public-private partnerships involve large capital investments, they become highly attractive to citizens. Therefore, public dissatisfaction can threaten the government's political support, and this can result in government's decisions which harm not only the agent but also the project success. One example is resisting adjustments to pricing before the election, even when the prices set are not enough cover costs (Shrestha et al., 2019).

Applying this theory can be useful to explain the sectoral-investment patterns in public-private partnerships in India. It helps to understand why certain sectors attract more private investment than others. For example, Figure 1 shows that the Energy and Roads (which belongs to the Transport sector, in aggregate terms) sectors receive the highest volume of investments in PPPs in India. This is mainly because these kinds of sectors usually provide stable cash inflows during long periods of time and are supported by a robust regulatory framework. Indeed, it is said that the expected internal rate of return for PPP projects in the Road sector is set around 12%-16% (Asian Development Bank, 2019).

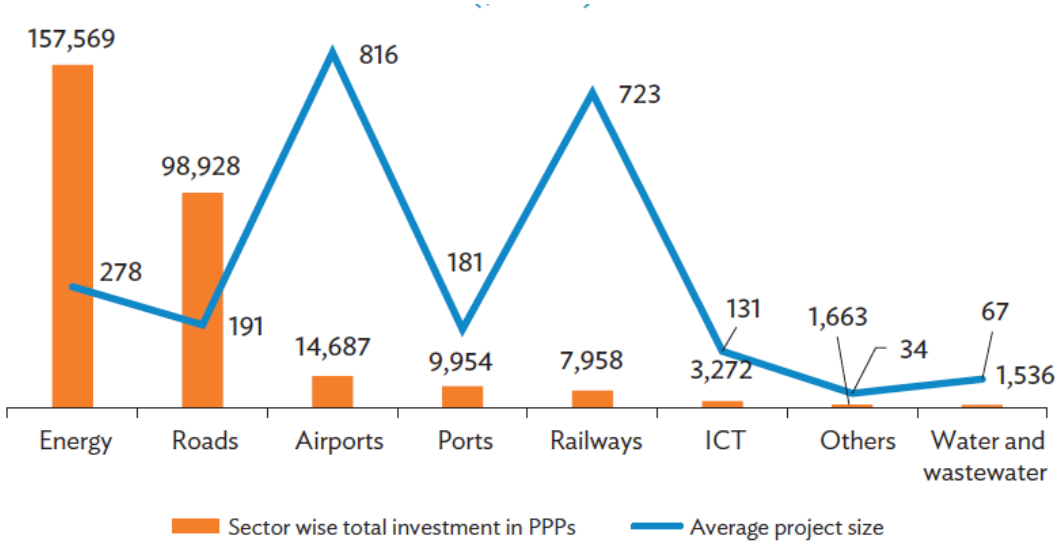

Figure 1: Investments in PPPs by Sector in India, 1990-2022 (in million USD) (Source: Asian Development Bank based on World Bank database)

Nevertheless, although these sectors attract private partners because of the considerable benefits, it is also important to bear in mind the risk of opportunistic behaviour that can arise while the partnership takes place. Throughout the history of PPP projects in India, there have been situations where one party (private or public) has tried to take advantage of gaps in regulation or in incomplete contracts. A well-known case in the Transport sector is the project of the Delhi-Gurgaon Expressway, an eight-lane national highway which connected the cities of Delhi and Gurgaon.

In this project, both, principal and agent, acted on their own interests. On the one side, the public partner imposed several changes driven by political and bureaucratic agendas which caused severe delays and doubled the initial budget. On the other side, the private partner chose to save costs instead of focusing on service quality, neglecting routine maintenance and ignoring small works to reduce traffic congestion (Garg and Mahapatra, 2017).

2.3. GAME THEORY

To tackle these challenges resulting from asymmetric information, it is essential that partners have a minimum level of trust in each other. This means that both, the public and the private partners, are committed to share and discuss their respective goals so that they can jointly find new solutions and approaches (Osborne, 2000). Nonetheless, the possibility of reaching a mutual strategy can only be achieved when each party believes that it will gain and benefit from the collaboration.

This dynamic relies on Game Theory. In particularly, it is closely connected to Prisoners' Dilemma. This experiment presents the scenario of two accomplices who have committed a crime and are interrogated separately. In this situation, they have two options: whether to confess or to defect. However, their decisions determine the outcome: if both confess, they receive a moderate sentence; if one defects while the other confesses, the betrayer will be free and the other will face a harsh penalty suffers; if both defect, they get low sentences.

Therefore, if both "prisoners" only care about themselves and are not worried about guilt or revenge from the other person, they will probably both confess (Osborne, 2000). This happens because confessing is the safest option for each one: by leaving aside what the other does, confessing protect them from the worst possible punishment. Nevertheless, this leads to a suboptimal outcome for both as they could be released from prison sooner if the two defect.

But if this situation takes place several times, "strategic possibilities are very much richer" (Axelrod, 2001). Since each prisoner has information of previous attempts and other's reactions as well as their possible consequences, cooperation will eventually occur: both will agree to defect to get low sentences. Thus, a successful strategy for each "prisoner" depends entirely on what the other decides to do. When both understand and recognise this, it leads to continuous interactions in which cooperation becomes mutually beneficial.

For instance, Axelrod demonstrated this through a series of computer-tournaments, in which participants were required to upload computer program that played the iterated Prisoner's Dilemma against other programs. The participants had to design strategy that chose whether to cooperate or betray the other player in order to get the highest scores possible. As a result, the most successful strategy was "Tit for Tat", which consisted of

cooperating on the first move and then doing the same that the other player did in the previous move. The reason behind the success of this strategy was due to “its being nice, provocable, and forgiving” (Axelrod, 2001): At the beginning, it was friendly as it was never the first one to defect. However, in the case that the other player decided to betray, Tit for Tat would defect him in the next round. Finally, if the adversary wanted to cooperate again, the player would forgive him and return to the cooperation. This pattern showed that reciprocity, that is, responding the others in the same way they treat you, is very important to maintain cooperation in repeated situations.

These concepts of trust and reciprocal behaviour, explained by Game Theory, are reflected in how India structures its investments in PPP projects across various sectors. The strategic collaboration between the public and the private sectors does not only influence the volume of investment, but it also affects to the durability of those investments. Sectors where there is an ongoing cooperation with shared common goals tend to attract more capital, as both parties can feel the long-term benefits of such partnership.

This can be observed in the Energy sector, which attracts the largest amount of investment in PPPs in India, about 160,000 million USD (see Figure 1), with a strong focus on renewable energy projects. For example, the National Solar Mission (NSM) during the first phase used a PPP with the objective of accelerating the use of solar energy. This partnership was a completely success because both partners complemented each other. The public sector fostered mutual trust by establishing a Public-Private Appraisal Committee (PPAC) to evaluate the projects, and mechanisms such as Viability Gap Funding and reverse auctions. These tools reduced uncertainty for private partners, which facilitated long-term relationships. In turn, the private partner brought knowledge, innovation and technology. As a result, India’s solar sector achieved a Compound Annual Growth Rate (CAGR) of approximately 59% from 2011 to 2021 (Swain and Trivedi, 2023).

3. ANALYSIS

The following part is divided in two subsections. Firstly, sample and method, where the dataset subject to study is examined and the methods used to carry out the analysis are explained. Secondly, variables, which presents and identifies the different variables consider throughout this analysis.

3.1. SAMPLE AND METHOD

The dataset under analysis consists of a sample of 1,180 PPPs conducted in India, comprising the period from 1990 to 2021.

As we can see in Figure 1, the evolution of PPPs projects shows a rising trend from the earlies 90s, reaching peak levels between 2010 and 2012. Nevertheless, from that point onward, it has been noted a sharply decline in the number of projects, with only 13 recorded in the last year of the study.

This pattern is closely connected to India's economic history and global trends. For instance, in 1991, India began its economic liberalisation (due to a severe balance of payment crisis) shifting from a closed and state-dominated economy to a more open and market-oriented one. Therefore, in the first decade, PPPs remained modest as institutions and legal system were adjusting to the new economic reality. This is evidenced by comparing figures between the beginning of 90s, having only 1 PPP project registered, and the end of the decade, achieving 22 projects in 1999.

Then, a moderate rise in PPPs was observed in the 2000s. During the half of the second decade, there was a sudden increase, from 27 projects in 2005 to 77 in 2006. The reason behind this change relies on the creation of entities such as "Infrastructure Development Authority (IDA)", to promote and facilitate PPP projects, and "Public-Private Partnership Appraisal Committee (PPPAC)" in order to foresee those projects at a central level.

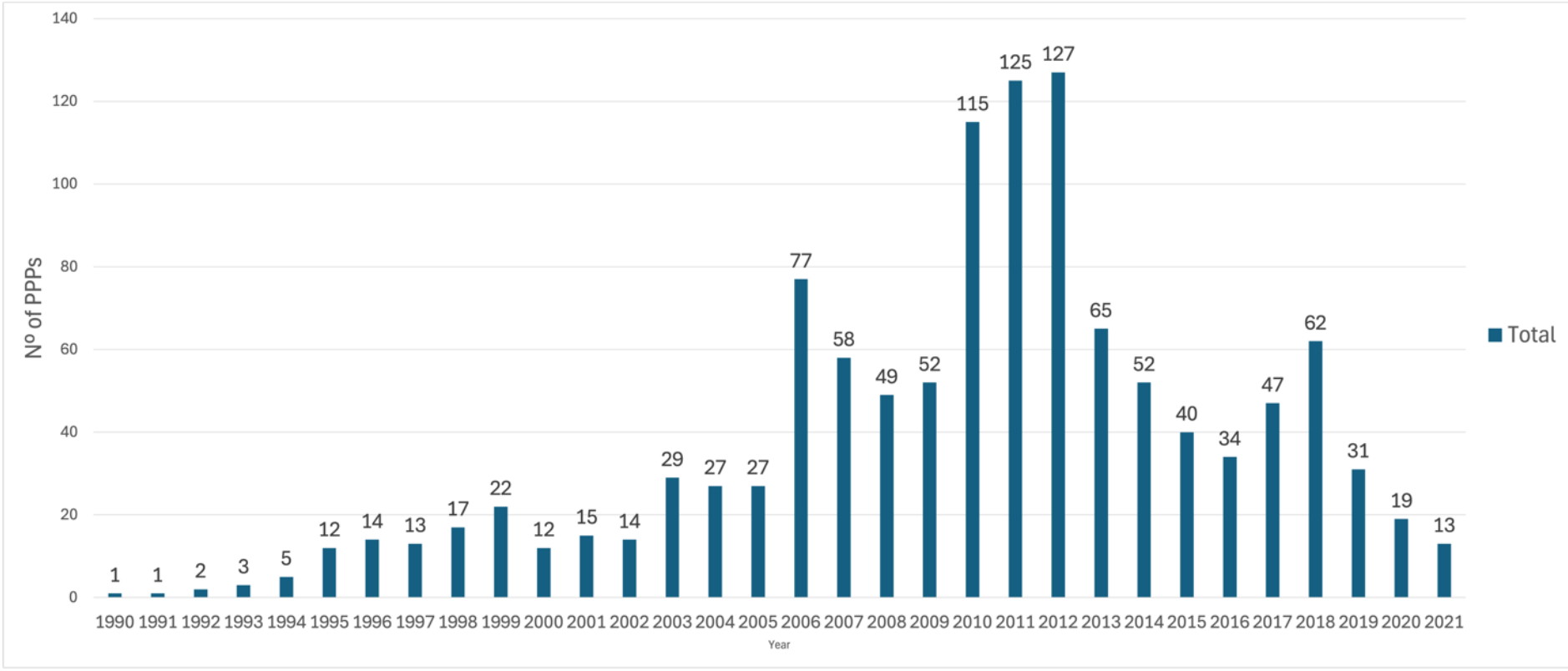

Figure 2: Evolution of PPPs in India (Source: Own elaboration based on the World Bank database)

Furthermore, India experienced a boom period in the number of PPPs projects, reaching tremendous figures in the years 2010 (115), 2011 (125) and 2012 (127). It is important to bear in mind that during this period, several policies have taken place. For example, the introduction of the "Draft of National PPP Policy", in 2011, was a key initiative to boost PPPs as it provided a framework for PPP projects across different sectors.

However, since 2013, India has been characterised by a clear declining phase. In addition, Covid-19 pandemic has had a significant impact on the number of PPPs projects, reducing them up to 13 in the 2021.

Regarding the methods, this analysis is compounded by two phases:

1) The first phase comprehends a chi-square test of independence:
   This is a statistical method which allows us to determine whether there is a significant relationship between two categorical variables (Whatley, 2022).
   It is based on a hypothesis testing where, as a general rule, the null hypothesis (H0) assumes that the variables under analysis are independent from each other, while the alternative hypothesis (H1) exhibits a dependency between the two variables. This test will be conducted at a 5% significance level.
   Moreover, the "Results" section below will present a summary of the contingency table, including the observed frequencies of the two variable combinations and comparisons to their corresponding expected values.
2) The second phase involves an ANOVA test, also known as Analysis of Variance:
   This is a statistical method used to compare differences in means across multiple independent groups. The objective is to detect statistically significant differences between these group means (Whatley, 2022).
   In this analysis, the test initially chosen was a One-Way ANOVA, which compares these group means based on a categorical independent variable (factor) and a continuous dependent variable (response). The hypotheses for this test are the following ones: the null hypothesis (H0) states that all group means are equal, whereas the alternative hypothesis (H1) suggests that at least one mean is different from one other mean. The significance level for this test is also set at 5%.
   However, after testing the data, it was found that the sample means from each group were not normally distributed (see Annex, Table 5). Given that this assumption of normality is essential to validate a parametric ANOVA, it was

finally decided to perform a non-parametric alternative instead. Therefore, a Kruskal-Wallis ANOVA test has been conducted. This method allows us to compare multiple groups without needing a normal distribution of the data (Ostertagova et al., 2014).

Nonetheless, as this study compares more than two groups, in the case of significant ANOVA results, a post hoc test will also be performed in order to determine which specific groups differ from each other.

3.2. VARIABLES

The variables under analysis are based on Table 1, which also includes a main description of their statistics. Besides, these two variables have been individually transformed or adjusted to meet the requirements of the statistical tests applied (chi-square and ANOVA tests). These modifications have been carried out to ensure the validity and reliability of the results provided afterwards and are typical in the academic literature.

Variables	***Obs.***	***Mean***	***St. dev.***	***Min.***	***Max.***
Total investment	1,180	225	395	1.02	4,200
Total investment (log10)	1,180	1.94	0.647	0.00860	3.62
Type of primary sector	1,180	1.71	0.827	1	5

Table 1: Descriptive statistics of variables (Source: Own elaboration based on the World Bank database)

1. Total investment:

   This variable represents the aggregate value of physical assets. It is measured in millions of dollars. To reduce sharp fluctuations and improve interpretability, the variable has been transformed using a base-10 logarithm (see in Figure 5). This adjustment helps normalise the values by compressing the scale, so the data becomes more consistent and easier to work with.

In addition, this variable has also been modified in order to be able to perform a chi-square test of independence. The initial figures derived from the World Bank dataset were given in continuous format. However, a chi-square test of independence requires categorical variables. Thus, "Total investment" variable has been converted then into 3 categories: Low, Medium and High.

Variables	***Obs.***	***Mean***	***St. dev.***	***Min.***	***Max.***
Total investment	1,180	225	395	1.02	4,200
Total investment (log10)	1,180	1.94	0.647	0.00860	3.62

Table 2: Descriptive statistics of total investment (Source: Own elaboration)

The table 2 exhibits a summary of the main statistics for this variable. The dataset used considers 1,180 projects, with an average investment of 225 million of dollars per project. Nevertheless, it can be highlighted a very high standard deviation of 395 million of dollars. This means that the investment amount varies significantly among the projects, that is, some of projects require significantly lower or higher funding than the average. This can be appreciated also by looking to the minimum and maximum values, being 1.02 and 4,200 million of dollars respectively.

2. Type of primary sector:

   This variable considers five types of primary sectors: Energy, Information and Communication Technology (ICT), Municipal Solid Waste (MSW), Transport and Water.

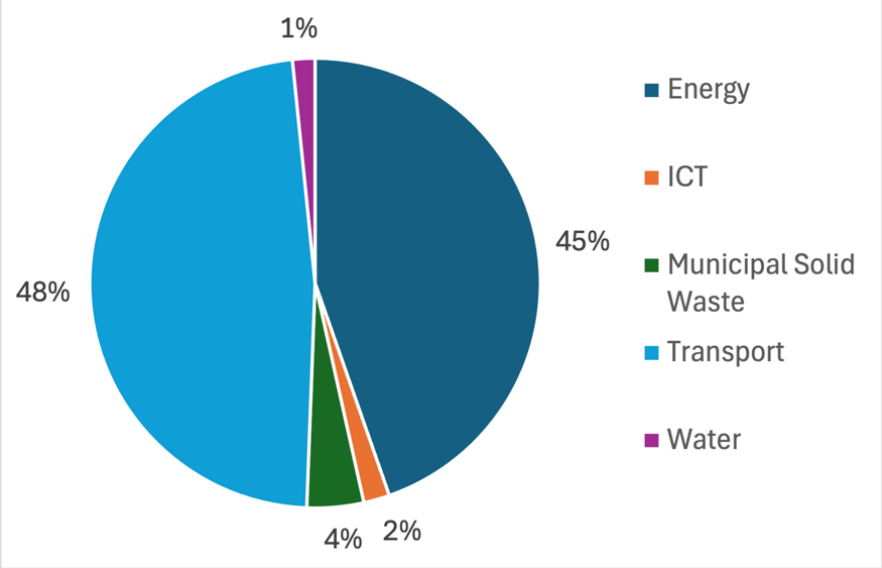

Figure 3: PPPs by Primary sectors (Source: Own elaboration based on the World Bank database)

Figure 2 shows a graphical representation of PPPs distributed across the main primary sectors. The World Bank database reveals that the majority of PPP projects are concentrated around the sectors of Energy (45%) and Transport (48%). These two sectors account for more than the 90% of the total of the PPP projects (see table 3). The remaining share is allocated to the sectors of Municipal Solid Waste (4%), ICT (2%) and Water (1%).

Type of Primary sector	***Obs.***	***% of Total (approx.)***	***% Accumulated***
Energy	527	45%	45%
Transport	564	48%	93%
Municipal Solid Waste	48	4%	97%
ICT	22	2%	99%
Water	19	1%	100%

Table 3: Type of Primary sector (Source: Own elaboration)

Furthermore, each type of sector has been coded numerically to extract the descriptive statistics observed in Table 4. Consequently: Energy = 1, Transport =

2, ICT = 3, Municipal Solid Waste = 4, and Water = 5. The mean obtained implies that the sectors most frequently involve in PPP projects in India are Energy and Transport. This is supported by a moderate standard deviation of 0.827.

Variables	*Obs.*	*Mean*	*St. dev.*	*Min.*	*Max.*
Type of Primary sector	1,180	1.71	0.827	1	5

Table 4: Descriptive statistics of type of primary sector (Source: Own elaboration)

The boxplot below, in Figure 3, illustrates the distribution of total investment across the five primary sectors. It reveals that the ICT and Transport sectors receive the highest median investments, compared to the Municipal Solid Waste sector which has the lowest median among all sectors. Additionally, the Energy and Transport sectors are characterised by a high variability in the total investment amount. This can be appreciated in their longer whiskers. Nonetheless, the Transport sector also shows several outliers at the end of the boxplot, which could distort the interpretation of results explained in the later section.

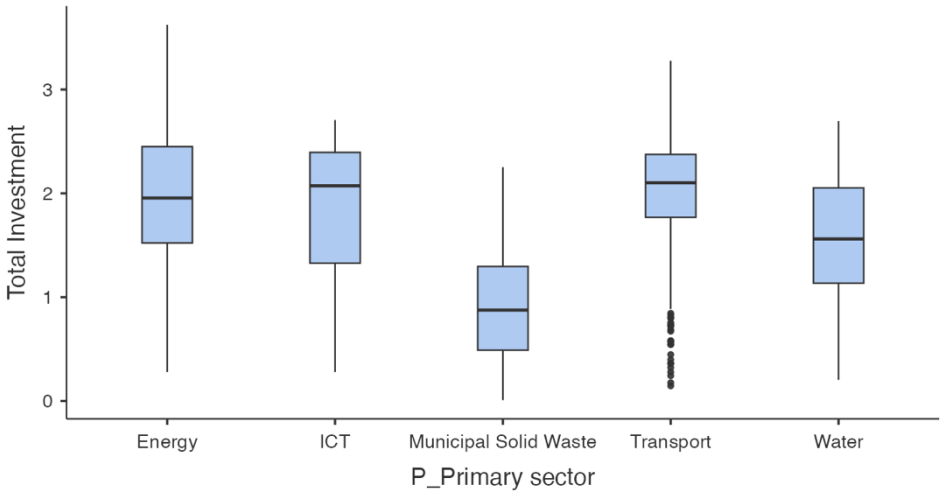

Figure 4: Boxplot of Total Investment and type of Primary Sector (Source: Own elaboration through JAMOVI)

4. RESULTS

This section presents the main results obtained from the analysis. As previously stated, two methods have been applied throughout this study: a chi-square test of independence and ANOVA.

Regarding the chi-square test of independence, it has been examined whether it exists a significant relationship between the type of primary sector and the total investment amount in PPP projects. For this purpose, the following hypothesis has been adopted:

- H0: The type of primary sector and the total investment are independent.
- H1: The type of primary sector and the total investment are not independent.

The null hypothesis is rejected as the p-value is 0.004 (see Figure 3), which is below the significance level set at 0.05. This indicates that there is statistically significance evidence of an association between the type of primary sector and the total investment variables, being both variables are not independent from each other.

Additionally, the null hypothesis can be rejected too when the chi-square value exceeds the critical value for the corresponding degrees of freedom. In this case, there are 8 degrees of freedom, which corresponds to a critical value of 15.507 (see Annex, Table 6) at a 5% significance level. Given that the $\chi^{2.}$ is 22.6, it is higher than the critical value, and we reject H0 and accept the dependency between these two variables.

χ² Tests

	Value	df	p
χ²	22.6	8	0.004
N	1180		

Figure 5: Chi-square test of independence resutl (Source: Own elaboration through JAMOVI software)

This association is further supported by a contingency table (see Figure 4), which shows the distribution of PPP projects across the different primary sectors and the levels of total investment, including differences between the observed frequencies of the two variable combinations and their expected values.

For example, there is a considerable deviation between the observed and expected values when looking at high-investment projects. The energy sector is the only one which has observations in this category, specifically, 5. However, the expected frequency is of 2.23 under the assumption of independence. This suggests that the energy sector is overrepresented. In contrast, the remaining sectors have non observations within the high-investment category, despite the fact that small frequencies were expected (0.0932 ICT, 0.2034 MSW, 2.3898 Transport and 0.0805 Water).

When it comes to low-investment projects, the gap between observed and expected values became closer, presenting small differences. For instance, the observed values of MSW and Water are 48 and 19, whereas the expected values accounts for 46.8 and 18.5 respectively. Also, the low-investment category is dominated by the energy and transport sectors, which constitutes 48.7% and 43.6% of all PPP projects.

Lastly, the medium-investment category is leaded again by the energy sector with 21 projects. This figure greatly exceeds the expectations which represents 11.165 (nearly half of the observed values). The opposite occurs to the transport sector, where only 4 projects are observed while there are expected 11.949. The other sectors such as ICT, MSW and Water show no activity.

Contingency Tables

		TOTAL INVESTMENT			
P_Primary sector		High	Low	Medium	Total
Energy	Observed	5	501	21	527
	Expected	2.2331	513.6	11.165	527.0
	% within column	100.0%	43.6%	84.0%	44.7%
ICT	Observed	0	22	0	22
	Expected	0.0932	21.4	0.466	22.0
	% within column	0.0%	1.9%	0.0%	1.9%
Municipal Solid Waste	Observed	0	48	0	48
	Expected	0.2034	46.8	1.017	48.0
	% within column	0.0%	4.2%	0.0%	4.1%
Transport	Observed	0	560	4	564
	Expected	2.3898	549.7	11.949	564.0
	% within column	0.0%	48.7%	16.0%	47.8%
Water	Observed	0	19	0	19
	Expected	0.0805	18.5	0.403	19.0
	% within column	0.0%	1.7%	0.0%	1.6%
Total	Observed	5	1150	25	1180
	Expected	5	1150	25	1180
	% within column	100.0%	100.0%	100.0%	100.0%

Figure 6: Contingency Tables (Source: Own elaboration through JAMOVI)

As illustrated previously in Figure 5, it is noticed already differences in the median values and the dispersion of investment among the sectors. To assess if those differences are statistically significant, a non-parametric ANOVA (Kruskal-Wallis) test has been performed.

The test has been carried out under the following hypothesis:

- H0: All group means are equal
- H1: All group means are not equal

Figure 7 exhibits the results of the Kruskal-Wallis test applied. It reveals a p-value of less than 0.001, which suggests statistically significant differences in investment amounts among the sectors. Thus, the null hypothesis is rejected as there is strong statistical evidence that at least one group mean is different from one other group mean.

Kruskal-Wallis

	χ^2	df	p
Total Investment	97.5	4	<.001

Figure 7: One-way ANOVA non-parametric (Source: Own elaboration through JAMOVI)

Nevertheless, since this non-parametric One-Way ANOVA test does not inform us, which group means differ from one another, a post hoc analysis has also been conducted using pairwise comparisons (see Figure 8).

Pairwise comparisons - Total Investment

		W	p
Energy	ICT	−0.910	0.968
Energy	Municipal Solid Waste	−12.666	<.001
Energy	Transport	2.428	0.424
Energy	Water	−3.513	0.094
ICT	Municipal Solid Waste	−5.958	<.001
ICT	Transport	0.995	0.956
ICT	Water	−2.218	0.518
Municipal Solid Waste	Transport	13.224	<.001
Municipal Solid Waste	Water	4.741	0.007
Transport	Water	−4.618	0.010

Figure 8: Dwass-Steel-Critchlow-Fligner Pairwise comparisons (Source: Own elaboration through JAMOVI)

The results of the Dwass-Steel-Critchlow-Flinger pairwise comparisons present significant differences in total investment amount across several sectors.

One of the key findings is that the Municipal Solid Waste (MSW) sector consistently shows significant differences. This can be seen in the Figure 9, when the p-value is less than 0.05. This occurs when the Municipal Solid Waste sector is compared to the Energy ("<0.001"), ICT ("<0.001"), Transport ("<0.001") and Water ("0.007") sectors.

These outcomes place the MSW sector in an unfavourable position, as investments made in this sector are significantly lower compared to that of the other sectors. This can also be noticed in Figure 5, where the median investment for the MSW sector is located below those of the other sectors.

Another significant difference is observed in the pair of Transport and Water sectors because the p-value, 0.010, is lower than the significance level set at 5%. This means that the Water sector receives an investment amount significantly lower to that of the Transport sector. This is further reflected in Figure 10, where the range of the Transport sector (3.13) is higher than the Water sector (2.49).

Descriptives

	P_Primary sector	Total Investment
Range	Energy	3.34
	ICT	2.43
	Municipal Solid Waste	2.24
	Transport	3.13
	Water	2.49

Figure 9: Range (Source: Own elaboration through JAMOVI)

5. CONCLUSIONS

Public-Private Partnerships (PPPs) have become a worldwide strategic mechanism for public asset and services delivering, especially in countries facing rapid economic growth and limited public infrastructure capacity. India is a clear example of this as it has increasingly adopted PPPs across multiple sectors to meet its demand of urbanisation and infrastructure development. Therefore, this paper has analysed how investment in PPP projects is distributed among primary sectors in this country, with the aim of identifying whether the type of sector significantly influences investment patterns.

The results obtained in chi-square test of independence indicate that there is a statistically significant relationship between the type of primary sector and the amount of investment, so that the distribution of capital in PPPs in India is not merely random. In addition, the non-parametric ANOVA test has further confirmed that investment levels also differ significantly across sectors, showing that some sectors attract more funding than others.

For instance, most of the PPPs are highly concentrated in the sectors of Energy and Transport, which accounts for more than 90% of all projects in India (Table 3) and exceeds 260 million US dollars (Figure 1). Moreover, the contingency table, in Figure 7, reveals that the Energy sector is the only one with high-investment projects. The predominance for these sectors could be because they usually often stable cash flows during long periods of time (between 20 and 30 years) and have well-defined regulation, which foster trust and reassure investors.

Nevertheless, this concentration has led to an unequal distribution of capital in other sectors. The pairwise comparisons test (Figure 9) exhibits that the Municipal Solid Waste (MSW) sector differs significantly from all the other sectors. This result is not surprising as it can be directly observed in Figure 5, where MSW sector has the lowest amount of investment relative to the rest. Also, the Water sector is underfunded compared to Transport. This is likely due to the fact that these kinds of projects generally generate less revenues (they rely on municipal budgets). Furthermore, another reason could be that, although these projects are smaller in scale than those in the Energy and Transport sectors, they present higher operational complexity as it requires a daily service delivery and multiple agents might be involved during the process. These factors might increase uncertainty and risk among investors, which reduces the sector's overall appeal.

In conclusion, the findings gathered from the analysis show a correlation between investment and type of primary sector. In addition, there are also statistically significant differences in investment amounts among such sectors (like for example, the Municipal Solid Waste sector). This can be due to the fact that certain sectors are able to provide more attractive condition for investors in terms of monetary incentives and regulatory stability.

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7. ANNEXES

Normality Test (Shapiro-Wilk)

	W	p
Total Investment	0.993	<.001

Note. A low p-value suggests a violation of the assumption of normality

Homogeneity of Variances Test (Levene's)

	F	df1	df2	p
Total Investment	8.12	4	1175	<.001

Table 5: Parametric ANOVA assumptions results (Source: Own elaboration through JAMOVI)

	Probability less than the critical value				
ν	0.90	0.95	0.975	0.99	0.999
1	2.706	3.841	5.024	6.635	10.828
2	4.605	5.991	7.378	9.210	13.816
3	6.251	7.815	9.348	11.345	16.266
4	7.779	9.488	11.143	13.277	18.467
5	9.236	11.070	12.833	15.086	20.515
6	10.645	12.592	14.449	16.812	22.458
7	12.017	14.067	16.013	18.475	24.322
8	13.362	15.507	17.535	20.090	26.125
9	14.684	16.919	19.023	21.666	27.877
10	15.987	18.307	20.483	23.209	29.588
11	17.275	19.675	21.920	24.725	31.264
12	18.549	21.026	23.337	26.217	32.910
13	19.812	22.362	24.736	27.688	34.528
14	21.064	23.685	26.119	29.141	36.123
15	22.307	24.996	27.488	30.578	37.697
16	23.542	26.296	28.845	32.000	39.252
17	24.769	27.587	30.191	33.409	40.790
18	25.989	28.869	31.526	34.805	42.312
19	27.204	30.144	32.852	36.191	43.820
20	28.412	31.410	34.170	37.566	45.315
21	29.615	32.671	35.479	38.932	46.797
22	30.813	33.924	36.781	40.289	48.268
23	32.007	35.172	38.076	41.638	49.728
24	33.196	36.415	39.364	42.980	51.179

Table 6: Critical values of chi-square distribution table (Source: National Institute of Standards and Technology)