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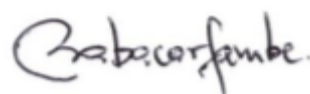
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Affidavit

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Liste de participation aux conférences

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To Mom, for your unconditional support
To Dad, in the hope that this thesis will make you proud

Résumé

Cette thèse propose d'analyser le cadre de gouvernance et la performance des investissements PPP en Afrique subsaharienne depuis les années 2000. Le premier chapitre mesure le rôle des investissements PPP multisectoriels dans l'efficience du PIB et dans le développement des infrastructures. A partir d'une méthode d'estimation des effets fixes et d'une approche stochastique des frontières, il a été analysé l'effet des investissements PPP multisectoriels dans le déplacement de la frontière de production ainsi que leur rôle en tant que déterminants de l'inefficience. Pour ce faire, il a été comparé, à l'aide d'un modèle à effets fixes, la frontière de production avec et sans PPP. Les résultats ont montré une contribution positive des PPP dans le PIB. Cette contribution est également positive lorsque les PPP sont combinés aux indicateurs de gouvernance. A partir d'une approche à deux étapes, les PPP ont aussi permis de réduire la distance inefficience lorsqu'ils sont considérés comme déterminant. En utilisant l'approche des frontières stochastiques et les critères EPIP comme déterminants, nous avons également noté une contribution positive des PPP au développement des infrastructures ainsi qu'une réduction de la distance inefficience. Toutefois, pour la majorité des pays, ces contributions positives ne compensent pas l'inefficience de 3,5% associée aux PPP.

Adoptant une démarche sectorielle, le second chapitre propose de mesurer le rôle des investissements PPP dans les secteurs des Ports et de l'électricité dans le déplacement de la frontière de production efficiente ainsi que leur rôle dans le secteur de l'électricité en tant que déterminants de l'inefficience grâce à une analyse stochastique des frontières. En adoptant la même approche que dans le premier chapitre, les résultats ont montré une contribution positive des PPP sectoriels dans le déplacement de la frontière efficiente. Toutefois, la contribution des PPP dans le secteur des ports (3%) est plus importante que celui du secteur de l'Electricité (1%).

Enfin, le troisième chapitre propose de mesurer la performance comparative des pays avec investissements PPP par rapport aux pays sans investissements PPP, et ce, dans trois différents secteurs : Tic, Eau et Routes, à partir de l'appariement sur score de propension (PSM) tout en contrôlant le cadre de gouvernance. Pour ce faire, les facteurs affectant la probabilité d'un pays à réaliser un PPP ont été identifiés avant de mesurer l'effet des investissements PPP sur les indicateurs de développement tout en contrôlant les facteurs de gouvernance liés à l'adoption d'une loi PPP et aux capacités PPP des Etats. Les résultats montrent que les investissements PPP ont permis d'améliorer le nombre d'abonnements à la téléphonie et à Internet ainsi que le taux d'accès à l'eau comparés aux indicateurs des pays sans investissements PPP. Pour les routes, les résultats obtenus par PSM ne sont pas significatifs alors que la méthode des moments généralisée (MMG) aboutit à un effet positif des PPP sur la qualité des routes. Pour les secteurs des routes et de l'Eau, l'adoption d'une loi PPP n'ont pas d'effet significatif sur la probabilité de réaliser un PPP contrairement au secteur des Tic où l'effet est négatif. Les capacités PPP n'ont pas d'effet significatif sur la probabilité de réaliser un PPP dans les secteurs de Tic. Alors que les capacités de préparation et de gestion des contrats PPP ont un effet négatif sur la probabilité de réaliser un PPP dans le secteur des routes. Pour le secteur de l'eau, les capacités de passation des marchés diminuent la probabilité de réaliser un PPP.

En résumé, les PPP aussi bien multisectoriels que sectoriels contribuent positivement aux indicateurs de développement des infrastructures et au PIB. De plus, ils sont efficaces dans les secteurs de l'Electricité et des Ports. Toutefois, les PPP multisectoriels ne sont pas efficaces pour la majorité des pays.

Mots clés : Partenariat Public-Privé, Infrastructure, efficacité, Afrique subsaharienne, EPIP, SFA, PSM, gouvernance

Abstract

This thesis proposes to analyze the governance framework and performance of PPP investments in sub-Saharan Africa since the 2000s. The first chapter measures the role of multi-sector PPP investments in GDP efficiency and infrastructure development. Using a fixed effects estimation method and a stochastic frontier approach, the effect of multi-sectoral PPP investments in shifting the production frontier and their role as determinants of inefficiency was analyzed. To do this, the production frontier with and without PPP was compared using a fixed-effects model. The results showed a positive contribution of PPPs to GDP. This contribution is also positive when PPPs are combined with governance indicators. Using a two-step approach, PPPs have also made it possible to reduce the inefficient distance when they are considered as determinants of inefficiency. Using the stochastic frontier approach and the CPIA criteria as determinants, we also noted a positive contribution of PPPs to infrastructure development as well as a reduction in inefficient distance. However, for most countries, these positive contributions do not compensate for the 3.5% inefficiency associated with PPPs

Adopting a sectoral approach, the second chapter proposes to measure the role of PPP investments in the ports and electricity sectors in shifting the efficient generation frontier as well as their role in the electricity sector as determinants of inefficiency through stochastic frontier analysis. Adopting the same approach as in the first chapter, the results showed a positive contribution of sectoral PPPs in the efficient frontier shift. However, the contribution of PPPs in the ports sector (3%) is greater than that of the electricity sector (1%).

Finally, the third chapter proposes to measure the comparative performance of countries with PPP investments versus countries without PPP investments, in three different sectors: ICT, Water and Roads, based on propensity score matching (PSM) while controlling the governance framework. To do this, the factors affecting the probability of a country carrying out a PPP were identified before measuring the effect of PPP investments on development indicators while controlling the governance factors related to the adoption of a PPP law and the PPP capacities of States. The results show that PPP investments improved the number of phone and internet subscriptions and the rate of access to water compared to indicators for countries without PPP investments. For roads, the results obtained by PSM are not significant, whereas the MMG approach leads to a positive effect of PPPs on road quality. For the roads and water sectors, the adoption of a PPP law does not have a significant effect on the probability of carrying out a PPP, unlike the ICT sector where the effect is negative. PPP capacities do not have a significant effect on the likelihood of a PPP in ICT sectors. While the capabilities of preparing and managing PPP contracts have a negative effect on the probability of carrying out a PPP in the roads sector. For the water sector, procurement capacity decreases the likelihood of a PPP.

In summary, both multi-sectoral and sectoral PPPs contribute positively to infrastructure development indicators and GDP. In addition, they are efficient in the Electricity and Ports sectors. However, multi-sectoral PPPs are not efficient for most countries.

Keywords: Public-Private Partnership; Infrastructure; Efficiency, Sub-Saharan Africa, CPIA, SFA, PSM, Governance

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General Introduction

Several reports from international institutions have focused on the infrastructure deficit as a major constraint to economic growth. In Sub-Saharan Africa (SSA), the infrastructure deficit is considerable compared with other regions of the world. To overcome this infrastructure deficit, SSA countries have considerably increased their public investment. However, this public investment has not been sufficient to meet the growing need for infrastructure. In addition to these infrastructure needs, which are mainly driven by population growth, public resources for infrastructure financing are becoming scarce. Indeed, with public debt rising to prescribed limits, governments have little room to use their fiscal space to finance their infrastructure needs. Added to this already difficult context is the stagnation or even decline in development aid. As a result, the only viable alternative for continuing to reduce the infrastructure deficit is to turn to innovative financing methods, particularly those involving greater participation by the private sector.

Over the past thirty years, the private sector has become increasingly involved in the provision of public infrastructure and services, through partnerships with the public sector known as Public-Private Partnerships (PPP). The notion of public-private partnership entered the vocabulary of development cooperation in the early 1990s. It enjoyed great success in the early 2000s, enabling contracting authorities to continue making investments (in infrastructure or services) while still in debt. Although there is no universal definition of a PPP, PPP knowledge Lab defines a PPP as a long-term contract between a private party and a government entity, for the provision of a public good or service, in which the private party assumes significant risk and management responsibility, and remuneration is linked to performance.

Despite an abundance of literature on the link between public infrastructure investment and economic aggregates, particularly economic growth, there is less on the effectiveness of infrastructure investment, particularly PPP investment. It is even less important when it comes to the effectiveness of PPP investments on the African continent. It is important to point out that much of this literature on the efficiency of infrastructure financing focuses on private sector participation in infrastructure and is not specific to public-private partnerships (Fabre and Straub, (2023)). This can be explained by the relatively low share of PPP investments in SSA compared with other regions of the world. Although its share in relation to the rest of the world remains low, according to the literature Fall and al. (2009), the first PPP investments in sub-Saharan Africa date back exceptionally to the 1960s, but mainly to the 1990s, with the semi-nationalization of private companies. In some countries, such as Côte d'Ivoire, the first PPP experience dates to 1959.

Inspired by the success of PPPs in several developed countries, SSA countries thought they had found an ideal way to finance the infrastructure deficit (MEF, (2016)). Apart from the few investments made in the 1990s, investments in Africa are relatively recent. However, the interest they hold in the eyes of leaders in SSA continues to grow. This interest can be justified by the advantages offered by this form of financing. In particular,

the financial aspect of this type of contract helps to alleviate the budgetary constraints faced by SSA states.

In view of the growing interest in PPPs on the African continent and the fact that since the first PPP experiments, the literature has not, to the best of our knowledge, addressed the efficiency of comprehensive and sectoral PPPs in SSA from a macro perspective other than case studies. This thesis aims to improve our knowledge of the efficiency of multisectoral and sectoral PPP investments and their effect on access to and quality of infrastructure. The primary motivation for this research is certainly empirical. It also has economic policy implications, contributing to the debate on the role of private sector participation in infrastructure. The remainder of the general introduction is as follows: first, we present a review of the different definitions of PPPs and their use across sectors, their role in reducing the financing gap, their financing structure and finally their sectoral determinants and performance. Secondly, for each chapter, we present the motivations, results, and contributions.

Definitions of PPPs and their use across sectors

In addition to its promotion by the World Bank in the early 1990s, PPP financing came to the fore with the launch of the United Nations Global Compact at the Davos Economic Forum in the late 1990s. The World Bank was the first multilateral institution to promote PPPs, particularly in the infrastructure sector, before bilateral development agencies and other multilateral development institutions followed suit. Before reviewing some PPP experiences around the world and in Africa in particular, it would be useful to review existing PPP definitions. From the outset, it is important to note that there is no universal definition of this concept. Indeed, definitions vary from one institution to another and from one author to another.

According to the Organization for Economic Co-operation and Development (2008), a PPP is an agreement between a state and one or more private partners (which may include operators and financiers), under which the private partners provide a service on terms that reconcile the state's performance goals with the private partners' profit objectives, with the effectiveness of the reconciliation depending on a sufficient transfer of risk to the private partners. The IMF defines a PPP as a partnership in which the private sector provides infrastructure and services that were previously provided by the state. In addition to financing public investment, the emphasis is on service delivery by the private partner and, above all, a significant transfer of risk from the state to the private sector. The European Investment Bank defines PPP as a generic term applied to relationships between public bodies and the private sector, often with the aim of drawing on the financial resources and/or expertise of the private sector for the purpose of delivering public assets and services. The World Bank defines PPPs as a long-term contractual arrangement between a public entity or authority and a private entity to provide a public good or service. Under this arrangement, the private entity assumes a significant share of the risk and management responsibilities. Finally, to take account of the disparities in the definition of a PPP that exist within its regional member countries (RMCs), the African Development Bank has opted for a broad definition, while retaining the key characteristics of a PPP. Thus, for the AfDB, a PPP is defined as: "A long-term contract between a public entity and a private company for the provision of public infrastructure and/or services, with risk allocation between the two parties based on their respective

capacities to manage each risk, and with the private party's investment exposed to performance risk". Although there is no universal definition of PPP, it is worth noting that the multiple definitions of PPP share certain common features. These include: a long-term contract, a transfer of risk to the most empowered party between the public and private sectors, remuneration based on private-sector performance, and a transfer of tasks from the public to the private sector. The various responsibilities to be transferred are design, construction, operation, maintenance, and financing.

In the literature, definitions of PPPs vary but revolve around key characteristics. According to Hall (2015), a PPP is a contract between a state and a private entity. In the contract, the private entity is required to finance, build, and operate certain elements of a public service. The private partner's remuneration is spread over several years, either through payments by users or through the payment of rent by the contracting authority, or through a mixed payment. Its definition is in line with that of Savas (2000), who define PPPs as long-term cooperation between the public and private sectors to provide public services while sharing risks for mutual benefit. In a similar vein, and with greater emphasis on the purpose of PPPs, Hodge and Greve (2005) conclude that PPPs aim to improve the efficiency, quality, and sustainability of public services through private-sector expertise. Emphasizing the different forms of PPP, Grimsey and Lewis (2007) state that the structure of PPPs depends on the objectives and needs of the contracting authority.

In practice, PPPs remain partnership mechanisms between the state and the private sector for the provision of public infrastructure and services. In addition to design, construction, operation and maintenance, this partnership may include financial resources to be mobilized by the private sector. It must also refer to risk-sharing between the parties, and stipulate that the private partner's remuneration is linked to its performance.

Although the definition may vary from one institution to another or from one author to another, PPPs are used in a wide range of sectors to provide public goods and services. However, some countries opt to exclude PPPs from certain sectors when defining their scope of application. These sectors may be related to strategic areas such as defense, or others where services are provided exclusively by the government and therefore cannot be delegated to a private partner as part of a PPP. Conversely, other countries limit the use of PPPs to certain key sectors. This approach may reflect a government's priorities to attract more private investment in a given sector, or to improve performance in the provision of public services in a given sector (Water, Electricity, etc.). For example, as part of the UK Conservative government's Private Finance Initiative in 1992, PPPs were particularly implemented in the health sector. In France, PPPs in the healthcare sector were used to build hospitals and provide ancillary services. Medical care services were excluded from PPP contracts (McKee, Edwards and Atun (2006)). Unlike in Lesotho, where a PPP project in the health sector was implemented, and health care services were transferred to the private partner (Lafitte (2006)). In addition to healthcare, several PPPs have also been implemented in the transport sector. In 2019, the World Bank's PPI database reported 1,182 projects with commitments totaling around \$350 million. In Europe, of the 227 road projects surveyed between 1990 and 2005, 65 were PPP projects (Blanc-Brude, Hugh and Timo (2007)). In emerging countries, too, the situation is similar. Singh (2018) carried out a study of 313 freeways in India over the period 1997 to 2015, a

third of which were financed by PPPs. The energy sector has also seen several PPPs around the world. Of the 4879 PPP projects listed, Latin America and Asia have the most projects, with 2108 and 1165 respectively. In the water sector, Grassner and al. (2009) found 141 water companies involving a private partner, mainly in Latin America and the Caribbean, Europe and Central Asia, and East Asia and the Pacific. Of these companies, around 90% were concessions. The ICT sector saw an increase in investment in PPP projects, especially in telecoms infrastructure, e-government platforms, and smart city initiatives. The World Bank's PPI report indicates an increase in investment commitments despite global economic challenges.

Infrastructure financing gap and PPP investment

Infrastructure is generally defined as physical facilities that are expected to provide services that form part of the consumption basket of residents and increase capital and labor as inputs into the production process Ayogu (2007). The infrastructure deficit represents an enormous social and economic cost for states. Indeed, infrastructure is a key driver of development, stimulating private investment and productivity growth. The literature on the relationship between infrastructure investment and development is quite extensive. However, there is no standard approach to measuring infrastructure investment. Several approaches have been used in the literature to try and estimate investment needs. There are generally two main approaches: "top-down" and "bottom-up". The latter approach is based on estimating the resources needed to achieve specific objectives, notably the Sustainable Development Goals (Hutton and al. (2016)). Whereas the first approach (Top down) which uses a variety of benchmarks such as historical cost trends or cost difference in comparison with developed countries (Ruiz-Núñez and Zichao Wei (2015). According to Rozenberg and al. (2019), the two main approaches mentioned above focus on providing a single quantified estimate, which is not very informative. According to the authors, estimating infrastructure investment needs based on these approaches does not provide a complete picture of the situation. In addition, there is a need to focus the debate on the efficiency and selection of spending.

However, there seems to be a consensus that the best approximation would be government GFCF data provided by the IMF, to which is added data on private sector participation in infrastructure financing provided by the World Bank (ADB, (2017); Fay and al. (2019)). On this basis, certain investments presenting infrastructure needs have been put forward. According to the World Bank, Africa should invest around 5% of its GDP in infrastructure and devote an additional 4% to infrastructure maintenance and operation activities to achieve a growth rate of 7%. According to the AfDB, Africa has a significant infrastructure deficit (energy, transport, water, sanitation, etc.), while its needs continue to grow and are estimated at between 130 and 170 billion dollars per year in 2025, with an investment deficit of between 68 and 108 billion dollars. This estimate does not consider the Sustainable Development Goals (SDGs) set by governments.

Based on recent data, infrastructure investment in SSA from 2015 to 2018 was mainly supported by governments (around 91% of financing), leaving only 9% to the private sector. Of this financing, 38% came from own resources and 53% from debt (concessional and commercial financing). Faced with the growing need for infrastructure, fiscal space is shrinking. The average public debt to GDP ratio is estimated at over 70% in 2021, up

from 43% in 2013, increasing debt servicing to the detriment of new infrastructure investment.

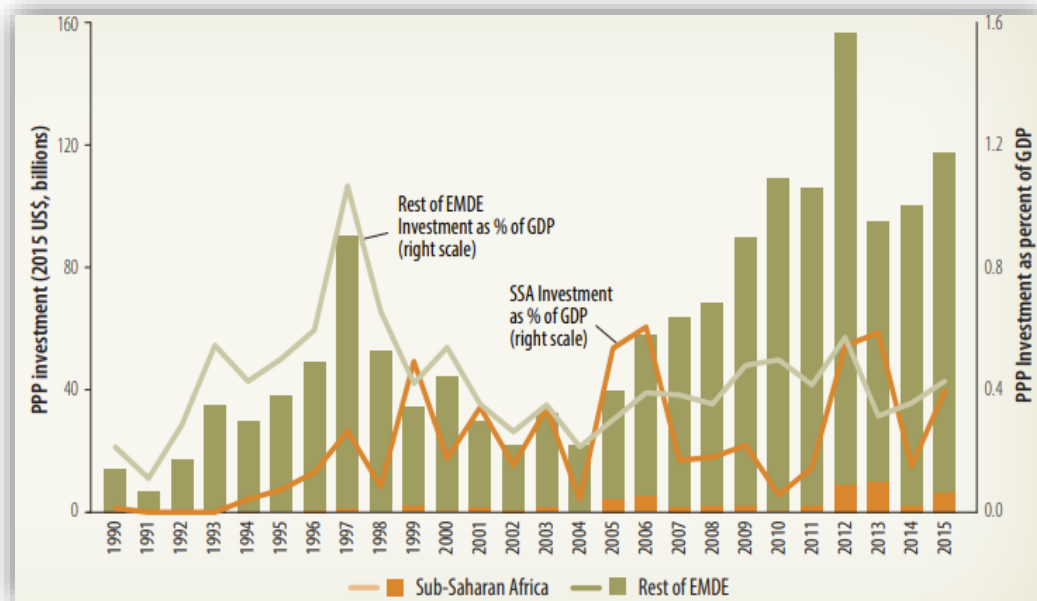
Faced with such a situation and in view of their limited fiscal space, governments alone cannot ensure the financing of infrastructure, hence the importance of calling on private financing. Countries' motivations for using PPPs as a financial mechanism fall into two categories APMG (2016): the first concerns the statistical and national accounting perspective. For example, in the context of a concessional PPP, where the financing is provided by the private partner in the form of equity or debt (not from the state budget) and a substantial part of the risks are also borne by the private partner, such a PPP may not impact public debt depending on the national accounting standards of the state concerned. In countries where fiscal regulations limit recourse to public debt, or where debt levels are close to prescribed limits (as is the case in several SSA countries), such a PPP investment scenario would enable the state to continue building infrastructure that could not otherwise be developed. This helps to reduce the infrastructure deficit without increasing debt. However, whatever the tax treatment, these long-term contracts involve substantial public resources, and certain guarantees offered by the State may have an impact on public finances. The second category is the financial flexibility that private financing can potentially offer, without any repercussions on debt levels. This second category is the main motivation for the majority of SSA countries to resort to PPPs. PPPs do not require the allocation of short- to medium-term resources (during the construction period) from the state budget. Nor is it necessary to include the funds required for the project in the state's budget strategy, or to negotiate specific or additional debt for the project. Some lenders who might extend credit to the PPP infrastructure project may not be willing to make direct loans to the government (APMG, (2016)).

While the main motivation for many SSA countries remains the financial aspect, private investors need an attractive and secure regulatory framework to commit to a long-term contract with the public authority. It is therefore essential for governments to strengthen the regulatory framework governing PPPs, to attract more private investment and improve their efficiency. Several studies have demonstrated the positive effect of the business environment on investment efficiency (Chinzara and al., (2023)). The desire to improve the business environment is evident in most SSA countries, with the adoption of new investment frameworks and PPP regulations. The latest survey carried out in 2023 by the African Legal Support Facility (ALSF) shows the growing evolution of PPP legal frameworks in Africa. Indeed, 42 out of 54 African countries have enacted PPP-related legislation. The rate of enactment was highest between 2015 and 2017: in three years, 16 African countries enacted PPP legislation. In view of the relatively high costs and risks faced by investors, several criteria must be met before a PPP contract is signed. For example, criteria such as quality of institutions, control of corruption, rule of law, country risk, good governance, etc. must be satisfactory to private investors. Chinzara and al. (2023) examined the determinants of private sector participation in infrastructure in 36 African countries. The authors found that the quality of institutions is the most important factor for private participation in infrastructure. In addition, the authors found that continuous improvement over a four (04) year period in regulatory framework reforms could generate the equivalent of 0.8% of GDP compared to countries with no reforms.

Despite efforts to improve the business climate and attract private investment, the PPP market remains very limited in SSA. According to the World Bank's Private Participation

in Infrastructure (PPI) database, 335 PPP projects have reached financial close over the past 25 years. Figure 0.1 shows that the number of PPP projects in the region remains relatively low compared with emerging markets and developing economies (EMDEs). PPP investments are unevenly distributed across the continent. Of the 335 projects completed since 2015, 48% have been carried out by just four (04) countries: South Africa, Nigeria, Kenya, and Uganda. However, looking at more recent data from the year 2023, the largest infrastructure investment involving the private sector remains South Africa with 30% of investments, followed by Senegal and Tanzania.

Figure 0.1: PPP investment in Sub-Saharan Africa versus the rest of the EMDEs¹



Source: World Bank PPI Database, 2017

Note: the figure shows PPP investments trends comparing SSA and the rest of the EMDEs

Infrastructure financing and PPPs

The low level of private-sector participation in infrastructure can be attributed to several factors, including the PPP legal and regulatory framework in the countries where private investment is to take place, the business environment, economic conditions, and country capacities. When these conditions are met, the private partner responsible for raising the funds to finance the infrastructure investment must ensure that its investment is profitable. Before signing a PPP contract, the contracting authority must also ascertain the added value of carrying out a given project in PPP mode and not in traditional mode. This section does not aim to analyze the profitability of a PPP from the point of view of either the government or the private partner. Rather, it focuses on the financing structure of a PPP project. A better understanding of the financing structure of a PPP will help to better grasp the very limited share of PPP investments on the continent. It is important to remember that beyond the financing aspect, a satisfactory realization of the above-mentioned factors is essential to increase the share of PPP investments for SSA countries.

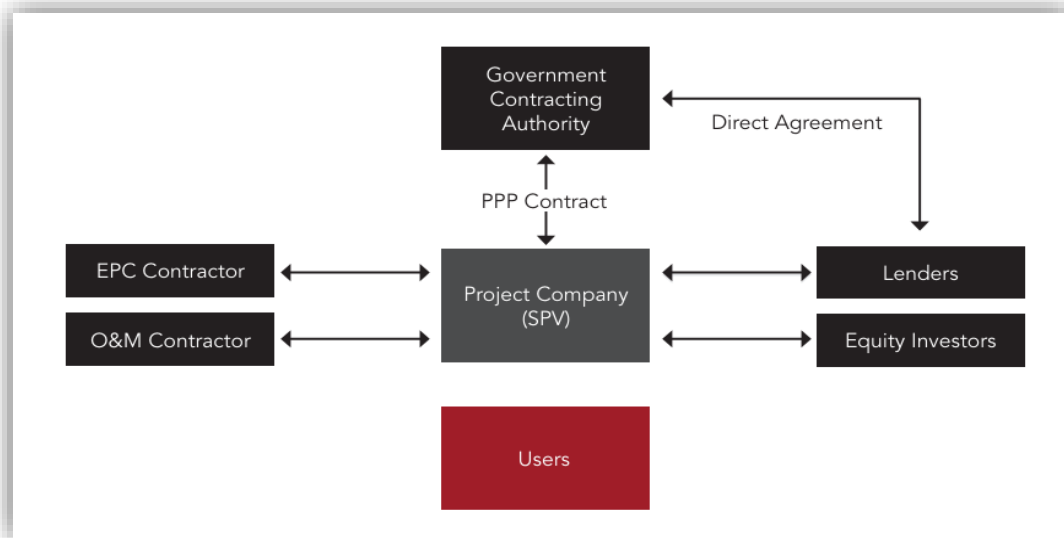
¹ Note: % of GDP for rest of EMDE uses GDP for all countries except SSA. Data exclude telecom.

The structure of PPP financing has been the subject of several studies. Indeed, Farquharson and al., (2011) in chapter 5 of his book gives an overview of PPP financing in emerging markets. Focusing on several types of PPP, Yescombe, (2013) presents a financing structure for each type of PPP. PPP project financing schemes are generally divided into two categories: corporate finance and project finance. In the former, investment is provided by an established company not dedicated to the project. Lenders assess the risk based on the balance sheet of the company's overall activities (assets and cash flows). In contrast, the second scheme uses a company specially created for the project, called a Special Purpose Vehicle (SPV). Lenders assess the risk based on the project's performance and financing structure. The reason for using this type of financing scheme is that the promoters want to share the risk and limit their investment in the project. SPVs make it possible to combine several types of financing.

Most PPP projects are structured around a project company (SPV). The SPV raises the necessary funds through a combination of equity, provided by its shareholders, and loans provided by banks or debt financed through bonds or other financial instruments.

Figure 0.2 shows a typical PPP financing structure. The government and the private partner, through the project company, are bound by a PPP contract. The project company is set up by the capital investors or shareholders. Project company shareholders are typically engineering or construction companies, private equity funds or infrastructure management companies. In some cases, notably in the case of institutional PPPs, governments may become shareholders in the SPV (Delmon, (2010)). In SSA countries, PPP lenders include commercial banks, institutional investors (deposit and consignment funds, pension funds) and Development Financial Institutions (DFIs). These DFIs can be multilateral (World Bank, African Development Bank, regional development banks) or bilateral (Agence Française de Développement, Japan International Cooperation Agency, etc.). The SPV, in turn, signs contracts with companies responsible for design, construction and operation and maintenance. Design and construction are referred to as EPC contracts (Engineering, Procurement and Construction).

Figure 0.2 : Typical PPP project structure



Source: world bank reference guide (2017)

Note: the figure shows the different interactions between the project company and the contracting authority related by the PPP contract; lenders and investors who finance by providing loans and equity respectively to receive a repayment of the principal plus interest and dividends; the EPC and OM contractors provide their services to the SPV against payment; Users use the service for a fee, possibly

Government contribution: To contribute to a PPP project, the government can mobilize several resources (Daube and al., (2007)): its own resources, financing from DFIs, commercial banks or local and international financial markets. More specifically, participation in the financing of a PPP through the SPV can take different forms:

- i) equity contribution alongside private developers as project shareholder.
- ii) investment subsidy under Viability Gap Funding (VGF).
- iii) commercial loan guarantee.
- iv) granting a loan to the SPV.

To provide the various forms of financing listed above, governments can call on DFIs (Delmon, (2009)). In addition to direct participation in the financing of PPP projects, governments can also contribute through investment funds (Nodalys, (2018)). On a continental level, these include the Africa50 fund, the African Infrastructure Investment Fund, the Emerging Africa Infrastructure Fund, the Alliance for Green Infrastructure in Africa, etc. At national level also, some countries have set up their own investment funds (Nigeria Infrastructure Fund, Kenya Infrastructure Fund, Fonds Souverain d'Investissement Stratégiques in Senegal, Ghana Infrastructure Investment Fund, etc.).

Equity contribution: This participation gives the government better access to project information, particularly information relating to the SPV's financial performance. This form of contribution also enables the government to play a role in strategic decisions within the SPV (World Bank, (2014)). It also ensures optimal use of the resources generated by the project. However, such public sector involvement can lead to a conflict of interest. Indeed, the state's role of providing a public service may be at odds with the private partner's profit-seeking motives (Harris and Kumar, (2008)).

Loan or grant to the company: under the PPP framework, governments can directly finance the SPV by providing loans or grants. These types of financing are designed to improve the project's viability (World Bank, (2014)). When financial projections show that the project is not financially viable, a government contribution is required to ensure viability. A government contribution in the form of a grant or loan can send a strong signal aimed at boosting the confidence of private partners (Ehrhardt and al. (2004)).

Government guarantee: in the absence of a direct loan, governments can provide a guarantee on the repayment of a loan granted by commercial banks in the event of default by the SPV. However, such a guarantee undermines the transfer of risk to the private sector, which is one of the reasons for resorting to PPPs (Burger and al., (2009)). For this reason, governments only partially provide such guarantees. On the other hand, these partial credit guarantees support the SPV or the state in mobilizing long-term commercial loans. In addition, partial risk guarantees can be used to support the establishment of a liquidity mechanism enabling the state to pay an infrastructure fee on time, if required.

Determinants and sectoral performance of PPPs

Given the growing use of PPPs in recent years in sub-Saharan Africa to address the infrastructure deficit, there is a need to assess the impact of this mode of financing on the economies of African countries, by carrying out studies to measure their impact. Indeed, although PPPs offer advantages such as cost reduction, risk transfer to the private sector, etc., there is a need for an overall assessment of the effectiveness of PPP investments. For some (Eberhardt and Gratwick (2010); Farquharson and al. (2011)) the growing use of PPP investments is due mainly to three reasons: insufficient public or private investment in the face of infrastructure needs, growing pressure on public finances, and the low quality of public services. This idea may be justified in the African context, given the decline in development aid. However, recourse to PPP financing should rather be a question of efficiency and effectiveness (Mazouz, (2009)). Indeed, PPPs are supposed to provide guarantees of efficiency, performance and quality of service delivered to the user (Iossa and Martimort, (2015)). However, they can also be seen as budget risk inducers (Sueur and Portelli, (2014)).

The literature distinguishes three types of efficiency: allocation efficiency, technical efficiency, and effectiveness. The first notion of efficiency refers to the investment decision: should the project or service be carried out? Efficiency, on the other hand, is measured by the output-to-input relationship. This relationship can be improved by producing more output with the same amount of input, or by producing the same output with less input. Several studies have demonstrated the efficiency gains associated with private participation in infrastructure or PPPs (Marin, (2009) IMF, (2015a)). However, these gains vary greatly depending on the context, the project's sector of activity, the country's regulatory framework and governance. In addition to these factors, efficiency gains are closely linked to the management of the project throughout its lifecycle. According to Wang and al. (2020), the government's ability to evaluate, delegate, collaborate and effectively manage private participation throughout the PPP lifecycle has a considerable impact on the success of PPP projects.

Assessing the efficiency of PPP investments is also linked to factors such as the structure of the PPP, hence the importance of a rigorous preliminary assessment of the

project to determine the most appropriate PPP structure technically, legally, and financially. Studies have highlighted the influence of PPP structures on efficiency levels, with some PPP models showing different efficiency indices depending on the PPP structure (Ortega-Díaz and al., (2020)). Focusing on the different stages of PPP investment implementation, research has identified the key determinants that can improve efficiency in the construction and operation stages of PPP infrastructure projects, providing valuable insights for practitioners seeking to improve efficiency in PPP implementation Xu and al., (2019).

In addition to the influence of determinants on efficiency, efficiency gains can vary from one sector to another. Depending on the sector, several indicators can be used to measure efficiency gains. In the transport sector, gains can be measured in terms of container traffic growth, reduced container dwell time, road quality, etc. In the energy sector, gains can be measured in terms of energy efficiency. Other indicators such as electricity generation capacity and coverage rate can be used to measure efficiency gains.

When it comes to infrastructure development in the transport sector, PPP investments have been recognized for their potential to improve the efficiency of project delivery compared with traditional public procurement methods (Wang and Zhao, (2018)). The ability of PPPs to transfer construction, financing and operating risks to the private sector while maintaining cost-effectiveness and reliability of service delivery has been highlighted as a key efficiency factor (Carbonara and Pellegrino, (2018)). The effectiveness of PPPs in the transport sector is also influenced by other factors such as payment mechanisms, the impact of transport costs and contractual arrangements (Gasilov and al., (2019)). In addition, the design and implementation of PPPs in the transport sector play a crucial role in promoting efficiency. Arata and al. (2016) present innovative approaches to the implementation of concessions in the roads sub-sector through PPPs, aimed at ensuring project reliability, sustainability, and profitability.

In the Water supply sector, PPPs have often been associated with substantial costs, although some costs are difficult to quantify (Marson and Maggi (2017)). However, several factors influence the effectiveness of PPP projects in the water sector. Risk allocation is a critical aspect that needs to be carefully managed in water supply PPP projects, particularly in developing countries such as those in the SSA region, due to the inherent risks associated with such investments (Chan and al., (2015) ; Ameyaw and Chan, (2015)). Surachman and al. (2020), concur. The authors state that PPP investments for the provision of water supply services, particularly in developing countries, require effective risk-sharing mechanisms between the government and the private partner.

Regarding the Energy sector, key factors have been identified in the literature aimed at attracting more private sector participation. For example, Debela (2021) considers that the private sector's ability to raise the necessary funds, the facilitation of innovative approaches to project structuring, time savings in project execution, and the speed of project development are important factors favoring the adoption of PPPs in the energy sector. In developing countries, including SSA, political incentives have been identified as a major factor in attracting the private sector into a contract with the government in the field of renewable energy (Kukah and al., (2022)). In addition, authors have identified other factors that influence private sector participation in PPPs: political incentives, cost-effectiveness and the synergy created by PPPs that enable efficient use of resources.

Several factors contribute to the success of PPPs in the ICT sector. The technological expertise of the private sector, particularly in the provision of innovative systems and solutions, makes the use of private partners a natural solution for developing PPPs in the ICT sector (Liu and al. (2020)). Political incentives, such as the promotion of PPPs in the sector, transparency, and the rule of law, play an important role in attracting the private sector into a partnership with the government (Bwalya, (2009)). The technological capacity of governments and the implementation of sectoral policies also influence the involvement of the private sector in the provision of ICT infrastructure and services.

While the determinants of PPPs in the various infrastructure sectors (Transport, ICT, Water and Energy) are supposed to justify the use of PPPs in these sectors, it must be said that the record of PPP projects in Africa is still poor compared with other regions. Despite this relatively weak record, the share of PPP projects has grown steadily over the past two decades. As a reminder, this section does not aim to draw up a global assessment of PPPs, which would be impossible given the subjectivity of such an approach. Rather, it is a succinct presentation of the mixed performance of PPPs.

Several studies have explored the success factors and outcomes of PPP projects in SSA, highlighting the effectiveness of PPPs. In general, the study by Kwak and al. (2009) provides a better understanding of PPPs for infrastructure development, highlighting the commercial aspects and dynamics of successful PPP projects. A study by Marson and Maggi (2017) on PPPs in the water sector in SSA highlighted the positive outcomes of management and service contracts. In addition, Nsasira and al. (2013) looked at the implications of PPPs in the energy sector in Uganda. In their study, they highlighted the role of PPPs in addressing deficiencies and improving service delivery in the energy sector. In the healthcare sector, too, some PPPs have been successful. We can cite the study by Hellowell (2019) who looked at a PPP project in Maseru (Lesotho) showing the role of PPP in improving hospital infrastructure as well as healthcare services.

Despite the gains they can bring in terms of efficiency, studies have shown that PPPs do not always outperform traditional public financing methods in terms of productivity changes (Ortega-Díaz and al., (2020)). This suggests that while PPPs may excel in some measures of efficiency, there are areas where traditional public institutions may still have advantages. In a review of PPP experiences in Africa, Mashwama and al. (2018) present the challenges faced by PPPs in the provision of public services. The study revealed several problems, not least the rigidity of PPP contracts. Indeed, PPPs are by essence long-term contracts whose openness to renegotiation, albeit framed, remains difficult. In addition, the study highlights limited trust between public and private sector professionals, lack of time for implementation, reduced control over public assets, conflicts of interest, lack of public acceptability, inadequate integration of PPPs into sector planning, resource constraints to encourage PPPs, political prejudice against PPPs, and changes in PPP policies with changes in political leadership. These challenges collectively contribute to the underperformance and shortcomings of PPPs in improving service delivery in Africa. These challenges partly explain the failure of PPP projects carried out in health sector in South Africa with the Uitenhage project (Hellowell, (2019)). The study by Mutiganda and al. (2020) on the challenges of PPPs in the water sector reveals shortcomings in accountability and the importance of careful planning, transparency, and sound legal frameworks for successful PPP projects. In summary, these challenges

demonstrate the complexity and risks associated with PPPs, which have an impact on the effectiveness and sustainability of PPP initiatives in Africa.

Outline of the Thesis

This thesis comprises three chapters that can be read independently. However, they do have one thing in common: the performance of PPP investments in infrastructure financing. Each chapter includes its own literature review that complements the one in this introduction. In addition, there is a particularity to the chapters. The first chapter deals with the evaluation of multi-sector PPP investments, while the other two chapters focus on sector-specific investments.

Traditionally, studies have focused on the relationship between public investment and economic growth (Barro, 1990). For those that have looked at the effectiveness of public investment, they have very often done so for a very specific sector of activity: roads, ports, water, education, health, etc. (Maatala and al. 2019; Tongzon and al. 2005 ; Wanke and Barros, 2015 ; Albouchi and al., 2007). As far as Africa is concerned, apart from a few studies carried out by the IMF or the World Bank aimed solely at the continent, the rare studies on the effectiveness of investments concerning it are carried out on a global scale, considering only part of the countries of Sub-Saharan Africa (SSA) (Murray and Lauer, 2000; Herrera and Pang, 2005; Gupta and al.; 2007). When studies are carried out on the continent, they are often done on a national scale (Miningou, 2012; Diagne and al. 2014; Naoussi and al. 2019). Furthermore, the question of the determinants of public investment efficiency is rarely addressed in the literature (Barhoumi and al. 2018). When it is addressed, the determinants generally used are institutional and governance factors (Grigoli and Mills, 2013; Soumaila, 2017; Albino-War and al. 2014). Faced with such a context our three chapters aim to fill the gap in the literature. The first looks at multi-sector PPP investments, while the remaining two articles adopt a sectoral approach.

How governance influences the efficiency of PPPs' contribution to economic growth and infrastructure development?

This chapter 1 aims to fill part of the gap in the literature on i) the efficiency of public infrastructure investments in SSA measured with a new indicator, ii) the determinants of inefficiency in public infrastructure investments, and iii) the relationship between multi-sector PPP investments and this inefficiency. In other words, the chapter aims to take a new approach to measuring the determinants of inefficiency by including Public-Private Partnership (PPP) investments, to gain a better understanding of their contribution since their widespread implementation across the African continent in the early 2000s. This analysis of the contribution of multisector PPP investments to infrastructure development is much needed, especially as most empirical studies on PPPs consist of anecdotal evidence and case studies, comparing results before and after implementation of a PPP investment (Fabre and Straub, (2023)).

in addition to measuring for the first time the efficiency of infrastructure investments through the composite African Infrastructure Development Index (AIDI) developed by the AfDB, the paper aims to analyze the effects of total PPP investments on infrastructure development and Economic Growth. The study covers 19 SSA countries over the period

from 2000 to 2019. Our modelling strategy is as follows. Once the PPP capital stock had been estimated, the determinants of PPP investments were captured by the CPIA criteria. The CPIA categories selected depend on their causality in the Granger sense. Next, we analyzed the effect of multisectoral PPP capital stock on the shift in the production frontier. Two approaches were used.

The first approach is carried out by an estimation of fixed effects. First, the effect of PPPs, combined with KKK's governance indicators and added one by one, on the shift of the frontier as measured by economic growth was analyzed. Secondly, the effect of PPPs alongside KKZ governance indicators considered as exogenous variables in reducing or increasing technical inefficiency. The second approach consisted of using the SFA method where the output, this time, is the African Infrastructure Development Indicator (AIDI) with the same inputs as in the first approach. However, instead of governance indicators, CPIA criteria were used that are equivalent to the determinants of PPPs and selected based on the results of the Granger causality test.

The results obtained show the important role of PPPs and CPIA criteria in infrastructure development. They also showed the positive relation between PPPs, GDP and KKZ governance indicator. However, despite the positive contribution of PPPs to infrastructure development and GDP, their level of efficiency needs to be improved. Indeed, for most countries, PPPs have failed to improve efficiency in terms of both infrastructure development and economic growth. This level of inefficiency can be explained by the relatively low and large disparity encountered in governance indicators and CPIA criteria. In view of the positive impact of these indicators when combined with the PPP, it would be useful to strengthen them to better benefit from the efficiency of PPPs.

Finally, a robustness analysis was carried out using a fixed effects estimation method as an alternative approach to analyze the effect of PPPs and CPIAs on infrastructure development instead of the SFA approach, the results obtained confirmed the robustness of our results. Indeed, we note that PPPs have a positive and significant effect on infrastructure development and even when combined with CPIA criteria. And when they are used as determinants of inefficiency, they help to reduce the inefficient distance as well as the other CPIA criteria used. Apart from the debt policy criterion, which has become significant and positive in our alternative approach.

Measuring PPP Efficiency: a sectoral analysis of Electricity and Ports

As for Chapter 2, it aims to fill in the literature by looking specifically at: i) the efficiency of PPP infrastructure investments in the electricity and ports sectors in SSA and ii) the determinants of inefficiency of sectoral investments (Electricity and Ports) captured by CPIA criteria alongside some classic determinants.

To do this, it was first necessary to estimate the PPP capital stock for each sub-sector (Ports and Electricity) based on PPP investments drawn from the World Bank's PPI database, in accordance with the PPP knowledge Lab's definition of a PPP. The perpetual inventory method was used to calculate PPP capital stocks for each sub-sector. The initial capital stock was assumed to be zero prior to the first PPP investment in each sector. The rate of depreciation is based on the country's income level, as estimated by the World Bank.

Once the sectoral PPP capital stocks had been estimated, the determinants of PPP investments were captured by the CPIA criteria. The CPIA criteria selected depend on their causality in the Granger sense with both sector output and sector PPP capital stock. Next, we analyzed the effect of each sectoral PPP capital stock on the displacement of its efficient production frontier. The analysis was carried out using a Cobb-Douglas production function with the public capital stock, the non-PPP private capital stock and the sectoral PPP capital stock, used as inputs. The residuals are defined as the sum of the idiosyncratic error term and an additional term measuring the shortfall (technical inefficiency) in relation to the maximum output used. Next, we compared the frontiers obtained with and without the total PPP capital stock.

We then analyzed the effect of CPIA criteria and some classic variables as determinants of inefficiency on the level of production measured by the various sectoral outputs. Indeed, for the Electricity sub-sector, we explore the relative importance of the sectoral PPP capital stock alongside CPIA criteria considered as exogenous variables in reducing or increasing technical inefficiency. For the Ports sub-sector, only the effect of CPIA criteria and other classic determinants on the variation in technical inefficiency is analyzed.

The results obtained made it possible to identify the various CPIA criteria that could be used as proxies for the determinants of PPP investments. For the electricity sub-sector, two CPIA criteria: Financial Sector (c.5) and Quality of Budgetary and Financial Management (c.13), both of which have a non-causal relationship in the Granger sense, with both sector output and sector PPP investments. We also analyzed the role of Exchange rate and credit to private sector as determinants. Furthermore, despite the positive and significant contribution of PPP investments to access to electricity, the shifting of the frontiers remains very limited without or with PPP investments. When sector PPP investments are used as determinants of inefficiency, we note their contribution to reducing inefficiency distance to the frontier, as does the Financial Sector criteria (c.5) and the variable credit to private sector. However, the Budget and Financial Quality criterion (c.13) does not contribute to improving access to electricity.

For the Ports sub-sector, Exchange rate, Trade Openness and three CPIA criteria were selected: Monetary Policy (c.1), Debt Policy (c.3) and Quality of Public Administration (c.15), all of which have a non-causal relationship in the Granger sense with the sector's output and PPP investments. The results showed a significant and positive contribution of PPP investments to container traffic. In addition, sectoral PPP investments improved the efficient production frontier by an average of around 3% compared to the situation without PPP investments. Used as determinants of inefficiency, the Debt Policy (c.3), Quality of Public Administration (c.15) criteria, trade openness and exchange rate contribute to improving the level of container traffic, while the Monetary Policy (c.1) criteria contributes negatively to container traffic. The estimation using an alternative approach confirmed the robustness of our results, except for monetary policy and the quality of administration, which became non-significant as determinants of inefficiency.

Finally, to test the robustness of our results, alternative approaches were used to estimate our models. The results obtained through the estimation of models using fixed effects methods and generalized least squares confirmed the findings in both sectors.

However, for the port sector, when monetary policy (c.1) and the quality of administration (c.15) are used as determinants of inefficiency, their effect is not significant.

PPPs Performance in ICT, Water and Road sectors: Does Governance really matter?

Several studies have been carried out on the performance of infrastructure projects involving the private sector. However, in many cases, these studies have been limited to case studies evaluating the pre- and post-project situations. Other studies have assessed the performance of projects in specific sectors, such as ports, roads, electricity and so on. These studies generally evaluate the performance of a set of projects from one or more countries in a given sector. Performance is assessed in terms of indicators such as cost overruns, completion times, quality of service or number of subscriptions, etc. What's more, these projects generally involve private-sector participation in infrastructure, rather than PPPs. In view of the current state of private-sector involvement in infrastructure, we wanted to break new ground by assessing the performance of PPPs in certain sectors (water, ICT, and roads). In the absence of a before-and-after analysis, Chapter 3. provides a comparative assessment between countries. Instead of project-specific indicators, we have used development indicators related to each sector.

The difficulty with this innovative approach to PPP performance benchmarking lies in the lack of randomization of PPP investments across countries. To overcome this difficulty, we have used a quasi-experimental approach. Two groups of countries are created: i) a first group of countries, called the treated group, with PPP investment in one sector (Water, ICT or Roads) and ii) a second group of countries with no PPP investment in these sectors (one sector at a time), called the control group. For the Water and ICT sectors, the result is the level of coverage or rate of access to water and the number of fixed-line telephone and Internet subscriptions. For the roads sub-sector, the outcome is the quality of road infrastructure. The evaluation involved analyzing the effect of PPP investments on these outcomes, for each sector.

Our approach is based on a three-stage process: the first stage consists in determining the factors explaining the assignment to the model under study. The characteristics are chosen based on their potential to influence the probability of a country belonging to the treated group and on the outcomes (coverage rate (Water and ICT) and road quality level). To analyze the real effect of PPPs on the 2 outcomes (coverage and/or quality²), the factors retained are exogenous variables, notably investment determinants. In addition to these characteristics, the following factors were considered: the adoption of a specific PPP law and the PPP capabilities of the public authority: PPP project preparation, procurement, and PPP contract management. The second step in our approach was to estimate propensity scores corresponding to the probability of a country benefiting from a PPP investment in each sector (Water, ICT and Roads). These propensity scores were estimated using a Logit-type model containing the explanatory variables for a country's probability of benefiting from a sectoral PPP. Having estimated the propensity scores, we then proceeded to analyze the results (output) for each sector: the coverage rate (Water, ICT) and quality level (Roads) in the treatment group versus the matched control group, to measure the effect of PPP investments in each sector.

² Depending on data availability

The data used in this chapter comes mainly from the World Bank's Private Participation in Infrastructure (PPI) database. These include PPP investments in the various sectors selected: water, ICT, and road transport. As a reminder, the World Bank's PPI database lists all projects involving private sector participation.

The results obtained in the ICT sector show that the probability of making a PPP is linked to market conditions dictated by the size of the population. The business environment is not significant enough to influence the probability of countries making a PPP investment, which can be explained by the high profitability in the sector offsetting policy-induced distortions. In other words, regulation in this sector is either insignificant or significant and negative. As is the case for the "PPP law" variable, which is negative and significant. As for the state's PPP capabilities, they have no significant effect on the probability of implementing a PPP. It is important to point out that these factors may not be significant or negative in relation to the probability of implementing a PPP but may have an indirect effect on the execution and management of PPP projects. Apart from these investment determinants, the results show that countries with PPPs had a higher ICT infrastructure coverage rate than countries without PPP investments in this sector. In other words, PPP investments led to an increase in the number of telephone and Internet subscriptions. This coverage rate increases further if we consider the adoption of a PPP law in the country, and improve government capacities in the evaluation, procurement, and management of PPP contracts.

The probability of implementing a PPP in the water sector increases with market conditions. Indeed, real GDP and population size are determining factors in the likelihood of a PPP in the water sector. The rule of law is also an essential factor in the likelihood of achieving a PPP in the sector. However, the quality of regulation reduces the likelihood of PPPs in the water sector. According to the literature, regulating quality is a challenge in public services, particularly water, because quality is multidimensional, not objectively measurable, and difficult to measure. The adoption of a PPP law has had no significant effect on the likelihood of PPP investment in the sector. This can be explained by the fact that almost all countries had already implemented PPPs long before the adoption of a specific PPP law. Regarding countries' PPP capabilities, the level of preparation decreases the probability of implementing PPPs in the sector. This negative sign can be explained by the fact that projects prepared by the public sector are not sufficiently attractive to private partners (long lead times, quality of studies, poor market sounding, inadequate risk identification or allocation). As for the effect of PPPs on the rate of access to water, the results show that countries with PPPs have a better coverage rate than countries without PPP investments. However, neither the adoption of a specific PPP law, nor the improvement of PPP player capabilities had a significant effect on the coverage rate.

In the road sector, market conditions, as measured by GDP, greatly increase the likelihood of a PPP in the road sector. Limited natural resources and controlled inflation are positively linked to the likelihood of a PPP in the roads sector. The adoption of a PPP law had no significant effect on the likelihood of PPP investment in the road sector. This can be explained by the fact that the countries that invested most in PPP roads did so before the adoption of a specific PPP law (Côte d'Ivoire, Senegal, and South Africa). In terms of countries' PPP capabilities, the level of preparation and contract management decrease the probability of implementing PPPs in the sector. However, capabilities related to procurement increases the probability of implementing PPPs. This can be explained by

the fact that projects prepared by the public sector are not sufficiently attractive to the private sector (long lead times, low quality of studies, poor market sounding, inadequate identification, or allocation of risks, etc.) and unbalanced contract drafting during preparation has a direct negative impact on contract management. As for the effect of PPPs on road quality, the results are not significant. This could be due to the limited number of PPP contracts in the road sector compared to traditional financing. However, the adoption of a PPP-specific law and improvement of PPP player capabilities indirectly improved road quality.

The various robustness tests conducted using alternative approaches such as IPW and GMM confirm the results obtained in the two sectors: Water and ICT. However, for the road sector, the GMM approach concluded that PPPs had a positive and significant contribution to quality of roads. Additionally, the placebo effect estimation confirms that the effect of PPPs was not due to mere coincidence

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1. PPPs contribution to economic growth and Infrastructure development: the role of governance

Abstract: This paper proposes a new approach to measuring the role of multi-sector PPP investments in GDP efficiency and infrastructure development. Using a fixed effects estimation method and a stochastic frontier approach, the effect of multi-sectoral PPP investments in shifting the production frontier and their role as determinants of inefficiency was analyzed. To do this, the production frontier with and without PPP was compared using a fixed-effects model. The results showed a positive contribution of PPPs to GDP. This contribution is also positive when PPPs are combined with KKZ governance indicators. Using a two-step approach, PPPs have also made it possible to reduce the inefficient distance when they are considered as determinants. Using the stochastic frontier approach and the CPIA criteria as determinants, we also noted a positive contribution of PPPs to infrastructure development as well as a reduction in inefficient distance. However, for most countries, these positive contributions do not compensate for the 3.5% inefficiency associated with PPPs.

Keywords: Public-Private Partnership, efficiency, Stochastic frontier, Fixed-effects, Governance, CPIA,

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1.1. Introduction

Over the past two decades, several studies have highlighted the lack of public investment and the relatively low level of private investment (World Bank, 2011; OECD, 2014; IMF, 2014) as major constraints on growth. Indeed, Africa has a significant infrastructure investment deficit. Foster and Briceño-Garmendia (2010) have estimated infrastructure needs at 93.3 billion US dollars per year. To remedy this sizeable infrastructure deficit, the countries of Sub-Saharan Africa (SSA) have substantially increased their public investment over the medium term. Indeed, in 2018, the Infrastructure Consortium for Africa (ICA) report on infrastructure financing trends revealed that funding reached a new record of 100.8 billion US dollars. A 24% increase on 2017 and a 38% increase on the 2015-2017 average. To achieve this record level of investment, the private sector was called upon. Indeed, several initiatives have been taken by SSA countries to improve the business climate and thus encourage private investment. For example, in June 2012, the Conference of Heads of State and Government of the West African Economic and Monetary Union (UEMOA) called on member states and institutions to adopt a mode of governance based on PPPs. Several African states have adopted new PPP laws and set up PPP Units. Regional and continental institutions have adopted PPP strategic frameworks. For example, BOAD has set up a Regional PPP Development Unit, and the AfDB recently adopted a 2021-2031 PPP strategic framework. According to the World Bank's doing-business report (2017), 37 of the 47 SSA economies have implemented at least one reform to improve the business climate over the past year, with 80 reforms in total - an increase of 14% on the number of reforms recorded the previous year. These initiatives are likely to have contributed to a total of US\$8.5 billion, including US\$7.4 billion in private capital for infrastructure financing, according to the World Bank's Private Participation in Infrastructure (PPI) database.

Despite the considerable increase in investment in infrastructure and the significant involvement of the private sector, particularly through PPP investments, infrastructure needs continue to grow and are estimated at between 130 and 170 billion dollars per year (African Economic Outlook, 2018). Given this situation, we cannot help but wonder about the effectiveness of public investment in infrastructure in Africa. Indeed, according to Foster and Briceño-Garmendia (2010), out of the 93.3 billion US dollars needed annually to spend on infrastructure, up to 17 billion dollars could be found simply by using existing resources more efficiently. Questioning the efficiency of investments involves, among other things, defining the output measurement indicator and the determinants of this efficiency.

Traditionally, studies have focused on the relationship between public investment and economic growth (Barro, 1990; Alogoskoufis and Kalyvitis, 1996; Lachler and Aschauer, 1998; Milbourne, 2003; Kondogo and Ojah, 2016). For those that have looked at the effectiveness of public investment, they have very often done so for a very specific sector of activity: roads, ports, water, education, health, etc. (Maatala and al. 2019; Tongzon and al. 2005; Wanke and Barros, 2015; Albouchi and al., 2007). As far as Africa is concerned, apart from a few studies carried out by the IMF or the World Bank aimed solely at the continent, the rare studies on the effectiveness of investments concerning it are carried out on a global scale, considering only part of the countries of Sub-Saharan Africa (SSA) (Murray and Lauer, 2000; Herrera and Pang, 2005; Gupta and al.; 2007). When studies are carried out on the continent, they are often done on a national scale (Miningou, 2012;

Diagne and al. 2014; Naoussi and al. 2019). Furthermore, the question of the determinants of the effectiveness of public investment is rarely addressed in the literature (Barhoumi and al. 2018). When it is addressed, the determinants generally used are institutional and governance factors (Grigoli and Mills, 2013; Soumaila, 2017 and Albino-War and al. 2014).

In this context, it would be useful to fill the gap in the literature on i) the effectiveness of public infrastructure investments in SSA measured with a new indicator, ii) the determinants of ineffectiveness of public infrastructure investments and iii) the relationship between PPP investments and inefficiency. In other words, it would be interesting to measure the determinants of inefficiency differently by including Public-Private Partnership (PPP) investments to better identify their contribution since their widespread implementation across the African continent in the early 2000s. This analysis of the contribution of PPP investments to infrastructure development is much needed, especially as most empirical studies on PPPs consist of anecdotal evidence and case studies, comparing results before and after the implementation of a PPP investment (Fabre and Straub, 2019).

In summary, this paper, in addition to measuring for the first time the efficiency of infrastructure investments through the composite African Infrastructure Development Index (AIDI) developed by the AfDB, aims to analyze the effects of total PPP investments on infrastructure development and Economic Growth. The study covers 19 SSA countries over the period from 2000 to 2019. Our modelling strategy is as follows:

Once the PPP capital stock had been estimated, the determinants of PPP investments were captured by the CPIA criteria. The CPIA categories selected depend on their causality in the Granger sense. Next, we analyzed the effect of multisectoral PPP capital stock on the shift in the production frontier. Two approaches were used.

The first approach is carried out by an estimation of fixed effects. First, the effect of PPPs, combined with KKZ's governance indicators and added one by one, on the shift of the frontier as measured by economic growth was analyzed. Secondly, the effect of PPPs alongside these governance indicators (KKZ) in the variation of the inefficient distance was analyzed. We explore the relative importance of the PPP capital stock alongside KKZ governance indicators considered as exogenous variables in reducing or increasing technical inefficiency.

The second approach consisted of using SFA method where the output, this time, is the African Infrastructure Development Indicator (AIDI) with the same inputs as in the first approach. However, instead of governance indicators, CPIA criteria were used that are equivalent to the determinants of PPPs and selected based on the results of the Granger causality test.

The results show that despite a positive and significant contribution of PPP investments to the infrastructure development index, PPPs did not promote a positive shift in efficient frontiers for most of the countries studied, regardless of the output chosen. The results showed a positive contribution of PPPs to economic growth and infrastructure development even when combined with governance indicator or CPIA criteria. In addition, PPP investments help to reduce the inefficiency score for economic growth and infrastructure development.

Finally, a robustness analysis was performed using the fixed-effect approach to confirm the results of the SFA approach.

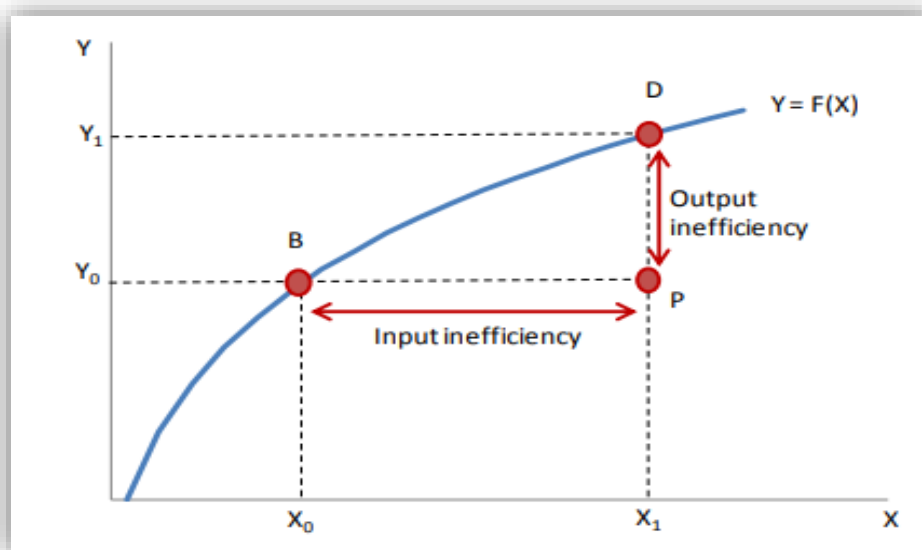
The remainder of the paper is organized as follows: Section 2 presents the literature review. Section 3 presents data description. Section 4 and 5 analyze the relation between PPP, Economic growth and Infrastructure development. Section 6 and 7 contains respectively the robustness analysis and a summary of the results. Finally, section 8 concludes the paper.

1.2. Literature review on key methods for assessing efficiency

In theoretical economic literature, several types of efficiency have been defined. However, two types of efficiency are generally used to define economic efficiency: technical efficiency and allocative efficiency (price efficiency). The latter refers to the capacity of a production unit to use the factors of production in optimal proportions given their price. The former defines the ability of a production unit to obtain maximum output from a given set of factors or, conversely, to use as few production factors as possible for a given level of output.

As illustrated below efficiency can be calculated based on minimizing the quantity of inputs to be used to achieve the same level of output (input orientation) or can be estimated based on maximizing the quantity of output to be produced for the same quantity of inputs (output orientation).

Figure 1.1 : inputs, outputs, and efficient frontier



Source: IMF, 2015a

Note: the figure illustrates the relationship between output and input of an efficient production function

The assessment of efficiency in infrastructure investments has gained significant attention in the literature, particularly through traditional econometric approaches and the application of two prominent methodologies: non-parametric and parametric

approaches. Each of these methodologies has its unique advantages and disadvantages, which are essential to consider when analyzing the efficiency of PPPs.

Regression analysis is one of the most used econometric methodologies for assessing Investments efficiency including PPPs. It allows to model the relationship between dependent and independent variables, providing insights into the factors that influence PPP performance. These regression techniques can be applied in various contexts, from evaluating the impact of PPPs on public service delivery to understanding the determinants of efficiency in these partnerships (Oksana and al., 2020). Although these methods are easy to apply, they do have their limitations. Indeed, regression models can suffer from issues such as omitted variable bias, multicollinearity, and endogeneity, which can compromise the validity of the results (Oksana and al., 2020). Moreover, the assumption of linearity may not hold in all cases, particularly in complex investments like PPPs where relationships can be non-linear.

Generalized Method of Moments (GMM) is also a statistical method used to estimate parameters in models with potentially endogenous variables. This technique is particularly useful in the context of PPPs, where the relationship between public and private sectors can be complex and interdependent. GMM allows for the control of unobserved heterogeneity and provides consistent estimates even in the presence of endogeneity (Ghorbany and al., 2022). This is particularly relevant in evaluating the impact of PPPs on service delivery, where the influence of external factors must be accounted for. However, its application in evaluating PPP projects is fraught with challenges that can compromise the reliability and validity of the performance assessments. For instance, the performance of PPP projects may be influenced by a myriad of factors, including economic, social, and environmental dimensions, which are not easily captured by traditional GMM specifications (Lei, 2023). The failure to adequately account for these factors can lead to misleading conclusions regarding project effectiveness and sustainability. Moreover, the GMM approach is sensitive to the choice of instruments used in the estimation process. The validity of the GMM estimator hinges on the assumption that the instruments are both relevant and exogenous. For PPP Investments, identifying appropriate instruments can be particularly challenging due to the intricate nature of the relationships involved. For instance, Xu and al., (2020) highlight that the evaluation of PPP project performance often relies on manually collected data, which may not comprehensively capture all relevant variables, thereby undermining the robustness of the GMM results. In addition to these limitations, the practical application of GMM in evaluating PPP performance is often hindered by the lack of comprehensive data. Many PPP projects, especially in SSA, do not maintain systematic records of performance metrics, which can lead to incomplete datasets that are unsuitable for GMM analysis (Luo and al., 2018).

Another widely used approach to assessing PPP performance is the non-parametric methods such as Data Envelopment Analysis (DEA). This method is used to evaluate the efficiency of DMUs by comparing their input-output ratios. It does not require the specification of a functional form, which allows for greater flexibility in analysis. The ability of DEA to handle multiple inputs and outputs simultaneously makes it particularly useful for assessing the multifaceted nature of PPPs, where various performance indicators must be considered. Despite its strengths, DEA has notable drawbacks. DEA assumes that all DMUs are operating under similar conditions, which may not hold true

in the context of PPPs. This is an important limitation when we consider the effect of the business environment on the level of PPP investment in Africa, and consequently its impact. The heterogeneity of PPP projects, influenced by varying regulatory environments, stakeholder interests, and project scopes, can complicate comparisons across different Projects and Countries. Naderi (2019)'s study illustrates how DEA can yield different efficiency scores based on the homogeneity of the evaluated units. Another significant limitation of DEA is its inability to handle stochastic variations in data. DEA operates under the assumption that the observed data are deterministic, which ignore measurement errors as well as any stochastic influence, considering any variation between units as inefficiency (Kumbhakar and Lovell, 2000; Kumbhakar and Lovell, 2003). As stated by Apeti, and al. (2023), such an assumption can led to major estimation biases, as public expenditure is impacted by exogenous shocks (e.g., commodity price shocks, environmental shocks, etc.), which in turn affect public sector performance, irrespective of the resulting efficiency (or inefficiency). Cheng and al. (2023) highlight that the performance of PPPs can be influenced by external factors such as economic fluctuations and policy changes, which may introduce randomness into the data. Most importantly, DEA does not provide insights into the causes of inefficiency. This lack of diagnostic capability can hinder the development of targeted strategies for performance improvement in PPPs. As noted by Tsolas (2010), understanding the underlying reasons for inefficiency is crucial for implementing effective interventions. Furthermore, the static nature of DEA is another limitation that affects its applicability to PPP performance assessment. DEA typically evaluates efficiency at a single point in time, which may not reflect the dynamic nature of PPP projects as stated by Fend and al. (2022). Indeed, PPP performance can change significantly over their lifecycle due to various factors, including changes in management practices, stakeholder engagement, and external economic conditions. Another non-parametric approach is Free Disposal Hull (FDH) that was first proposed by Deprins, Simar, and Tulkens (1984). Unlike the DEA approach, which assumes that the production frontier is convex, this can lead to an upward bias in efficiency estimates, as it does not consider the possibility of non-convex production technologies (Kim and An, 2015). Furthermore, the treatment of outliers and extreme values differs between the two methods. DEA is known to be sensitive to outliers while FDH is less affected by outliers due to its reliance on actual observed data points, making it potentially more robust in datasets with extreme values (Tauchmann, 2012). This is why FDH is used in multi-country comparative studies where outliers may be present. Afonso and al. (2003) use FDH to study the performance and the efficiency of the public sectors of 23 industrialized OECD countries. However, in their study, differences across countries are not statistically assessed, which can be considered as a limitation of such methodology.

In view of the limitations of traditional regression methods and non-parametric approaches and the objectives pursued in this chapter, a parametric approach may be more appropriate given the advantages it offers. Indeed, parametric techniques are often used in the literature of public investment efficiency (Apeti and al., 2023).

The two-step fixed effects method has often been used in the literature to estimate technical efficiency. Battese, G.E., and Coelli, T.J. (1995) used a two-stage approach to estimating technical inefficiency, where the first stage involves estimating the frontier production function and the second stage regresses the inefficiency estimates on environmental variables. Benlemlih and Bitar (2018) examine the relationship between

corporate social responsibility (CSR) and financial performance using a two-step approach. Simar and Wilson (2007) introduce a two-stage estimation method for productivity and efficiency measures, allowing for the incorporation of environmental factors in the second stage. The two-step method presents several advantages, including its ability to correct selection biases and control for unobserved differences between firms with varying levels of transparency. Additionally, it can be used in diverse contexts. It allows for consideration of the determinants of inefficiency and is applicable to large panel data sets. Despite the plethora of authors who have used this two-step parametric approach, it is not without its criticisms. According to Engida (2019), this approach attributes all deviations from optimal investment levels as investment inefficiency, and does not allow for noise, omitted variables which determine the optimal level of investment, nor misspecification of the relationship between past sales and current investment levels. These omissions most likely produce biased parameter estimates in the second stage regression. Moreover, this two-stage approach treats both positive and negative residuals in the same fashion. This two-stage approach has been shown to be illogical and inconsistent in Wang and Schmidt (2002), Schmidt (2011), Parmeter and Kumbhakar (2014) and Parmeter and al. (2017) when applied to a composed error term.

Furthermore, the Stochastic Frontier Analysis (SFA) approach is often used in estimating technical inefficiency. One of the primary advantages of SFA is its ability to incorporate random errors into the efficiency measurement process. Unlike DEA, which assumes that all deviations from the frontier are due to inefficiency, SFA recognizes that some of these deviations may arise from random noise or measurement errors. According to Lovell (1996), SFA enables the estimation of efficiency relative to a stochastic frontier, which can yield more reliable results especially in the context of PPPs where data may be subject to variability. The fact that the methodology can be applied to several sectors, particularly infrastructure, is crucial for accurately capturing the performance dynamics of PPPs. Kumbhakar and al. (2003) emphasize that SFA can adapt to different production technologies and structures, making it suitable for diverse sectors. Additionally, SFA can be employed to analyze the effects of specific factors on efficiency, such as ownership structure or management practices which allows to explore the relationships between various determinants of performance and efficiency outcomes. For example, Ortega-Diaz and al. (2020) utilized SFA to examine the relationship between ownership structure and technical efficiency in hospitals. Finally, SFA's ability to conduct panel data analysis enhances its applicability in assessing PPP performance over time. The capacity to track performance over time is particularly beneficial, which often spans multiple years and undergoes various phases of development and operation. As noted by Koop and al. (1999), SFA can effectively decompose output changes into technical, efficiency, and input changes, providing a comprehensive understanding of performance dynamic. However, SFA also has limitations. The need for a specific functional form to represent the production process can introduce bias if the chosen model does not accurately reflect reality. Additionally, SFA requires a substantial amount of data, which may not always be available, particularly in developing regions where PPPs are increasingly common (Yildiz and al., 2018).

1.3. Data description

The study sample comprises 19 countries in Sub-Saharan Africa (SSA) and covers the period from 2000 to 2019. The countries were selected based on the availability of PPP financing each year. In addition, only the SSA countries in the PPI database that meet the

definition of a PPP as indicated by the PPP Knowledge Lap are included in our database. Consequently, all privatization projects (partial or total), short-term lease and management contracts, and market projects in which a private promoter builds a new facility in a liberalized market and for which the government provides no guarantee of revenue or payment are excluded from this database.

In our analysis, the indicator used as an output to measure the effectiveness of infrastructure investment is the infrastructure development indicator. This output is a composite indicator measuring infrastructure development. It is the African Infrastructure Development Index (AIDI) developed by the African Development Bank (AfDB). The AIDI is based on four major components: (i) Transport; (ii) Electricity; (iii) ICT; and (iv) Water and sanitation. To the best of our knowledge, this is the first time that such an index has been used to measure the efficiency of infrastructure investment. In addition, given that the effect of multi-sector PPPs target several sectors of activity (transport, energy, water, etc.) that are key drivers to economic growth, GDP as an output will be analyzed. In this sense, GDP can capture the medium- and long-term effect of these investments on the economy. Thus, GDP will also be used as output.

Regarding the inputs, three inputs are therefore considered: public capital stock, private capital stock and PPP capital stock. These capital stocks derived respectively from public, private and PPP investments.

Inefficiency determinants

As announced above, the paper aims to analyze the effect of PPPs on economic growth and infrastructure development while controlling for governance framework. In the context of the analysis of the effect of PPPs on economic growth, we will focus on the classical determinants of Kaufmann, Kraay and Zoido-Lobaton (KKZ). The 6 KKZ governance indicators are: Voice and Accountability; Political Stability; Government Effectiveness; Regulatory Quality; Rule of Law and Control of Corruption.

As for the effect of PPPs on economic growth, we wanted to measure the influence of governance in a different way to further fuel reflection on this subject. To do this, the determinants of PPPs will be used based on the results of the study by Hammami and al. (2006). Once the PPP determinants are identified, they will be associated with their CPIA equivalent as a proxy to capture the governance indicator and business climate. Finally, the CPIAs to be included in our analysis will be selected based on the results of the Granger causality test below.

Table 1.1: Comparison of PPP drivers and selected CPIA criteria

Categories	PPP Determinants	
	Traditional Variables	CPIA criteria
Budget constraints	- Fiscal deficit - Public debt	- Fiscal Policy (c.2) - Debt Policy (c.3)
Macroeconomic stability	- Inflation - Money supply M2 - Foreign exchange reserves - Exchange rate	- Monetary Policy (c.1)
Market conditions	- Population - GDP per capita	- Efficiency of revenue mobilization (c.14)
Governance	- Country Risk - rule of law - Control of corruption - Regulatory Quality - Government effectiveness	- Property Rights and Rule-based Governance (c.12)) - Quality of Budgetary and Financial Management (c.13) - Quality of Public Administration (c.15) - Transparency, Accountability and Corruption in the Public Sector (c.16) - Business Regulatory Environment (c.6)
financial sector development	- Private sector credit	- Financial sector (c.5)

Note: The table presents the determinants of PPP in different categories measured by traditional variables and their equivalent in the CPIA criteria

Selecting the CPIA over classical indicators as PPP determinants

CPIA scores are designed to provide insights into the policy frameworks and institutional capacities that can influence economic performance and development outcomes. It evaluates countries based on 16 criteria grouped into four clusters: economic management, structural policies, policies for social inclusion and equality, and management and public sector institutions (Nabilah and al., 2022). This multidimensional approach allows for a nuanced understanding of how various aspects of governance interact to influence the effectiveness of PPPs.

In contrast, classical indicators such as the Kaufmann, Kraay and Zoido-Lobaton (KKZ) often focus on narrower dimensions of governance. According to Merry and al. (2015) The WGI, for example, assesses governance through six dimensions, including voice and accountability, political stability, and regulatory quality. While these indicators provide valuable insights into specific governance aspects, they may overlook critical factors that affect the overall effectiveness of PPPs. For example, the CPIA primarily measures perceived corruption levels without necessarily linking these perceptions to broader governance outcomes or the specific context of PPPs (Merry and al., 2015). This limitation can hinder the ability to fully understand the determinants of PPP success.

Moreover, the CPIA's participatory approach, which incorporates feedback from various stakeholders, enhances the credibility and relevance of its assessments. By engaging governments, civil society, and international organizations in the evaluation process, the CPIA reflects a broader consensus on governance issues (Ardiwinata and al., 2022). This participatory aspect is particularly important for PPPs, where stakeholder engagement is critical for success. In contrast, classical indicators may rely on limited data sources or expert opinions, which can introduce biases and affect the reliability of the results (Merry and al., 2015).

However, the application of CPIA as a proxy for determinants of PPPs is fraught with challenges. The CPIA framework primarily focuses on macroeconomic indicators and governance structures, which may not adequately reflect the specific dynamics and contextual factors that influence PPP effectiveness (Baliamoune-Lutz and McGillivray, 2011; Popa, 2018). One of the primary limitations of CPIA as a proxy for PPP determinants is its inability to account for the unique contextual factors that shape the success or failure of PPP initiatives. However, this limitation is also inherent in the World Development Indicators traditionally used. Furthermore, the World Bank (2004) created an indicator that most closely relates to CPIA D cluster (Governance) comparing it to the KKZ governance indicators. The results showed that the two indicators are quite strongly correlated.

Granger non-causality test

To analyze the effect of PPPs and the business environment, mainly captured by CPIA criteria, on the level of infrastructure development, it is important to determine whether there is a temporal precedence between the variables. Moreover, given our sample, which includes several Sub-Saharan African countries, we must expect regulatory, social, and economic disparities. This highlights the issue of heterogeneity among countries, which has been confirmed by group heteroscedasticity tests, yielding a p-value of zero, thus rejecting the hypothesis of homoscedasticity. Finally, understanding the relationship between infrastructure development indicators, PPPs, and institutional and governance variables is valuable in terms of the policy implications that may result. Indeed, the empirical evidence of such relationships provides greater consistency in interpreting the quantitative impact of the general institutional context on the economic performance of PPPs (Belaid and al., 2009). For these reasons, we will conduct a Granger causality test.

In the context of public sector efficiency and governance indicators, it is essential to determine whether changes in governance indicators precede changes in public sector outputs or vice versa. This temporal relationship can provide insights into the dynamics of governance and its impact on public sector performance Wu and Legoh  rel (2023). Also, due to the diversity of the countries in our panel database, the use of Granger causality tests that account for this heterogeneity allows us to identify whether the causal relationships differ across countries with varying governance structures or PPP framework characteristics

The table below shows the optimal lag, the z-bar tilde statistics, and the p-values of the Granger non-causality test between the AIDI output and the determinants of inefficiency on the one hand and those of the Granger non-causality test between the PPP capital stock and the determinants of inefficiency on the other hand, in a heterogeneous panel by Juodis, Karavias and Sarafidis (2021). To analyze the shift of the efficient frontier without or with PPP as well as the role of PPP in reducing the inefficiency, only CPIA criteria (or determinants) with a causal effect in the Granger sense ($CPIA \rightarrow AIDI$) or ($CPIA \rightarrow PPP$) will be retained. The results in Table 4 have identified the following CPIA: Debt Policy (c.3), Financial sector (c.5), Property Rights and Rule-based Governance (c.12), Quality of Public Administration (c.15) and Transparency, Accountability and Corruption in the Public Sector (c.16).

Table 1.2 : JKS (2021) Granger non-causality test results

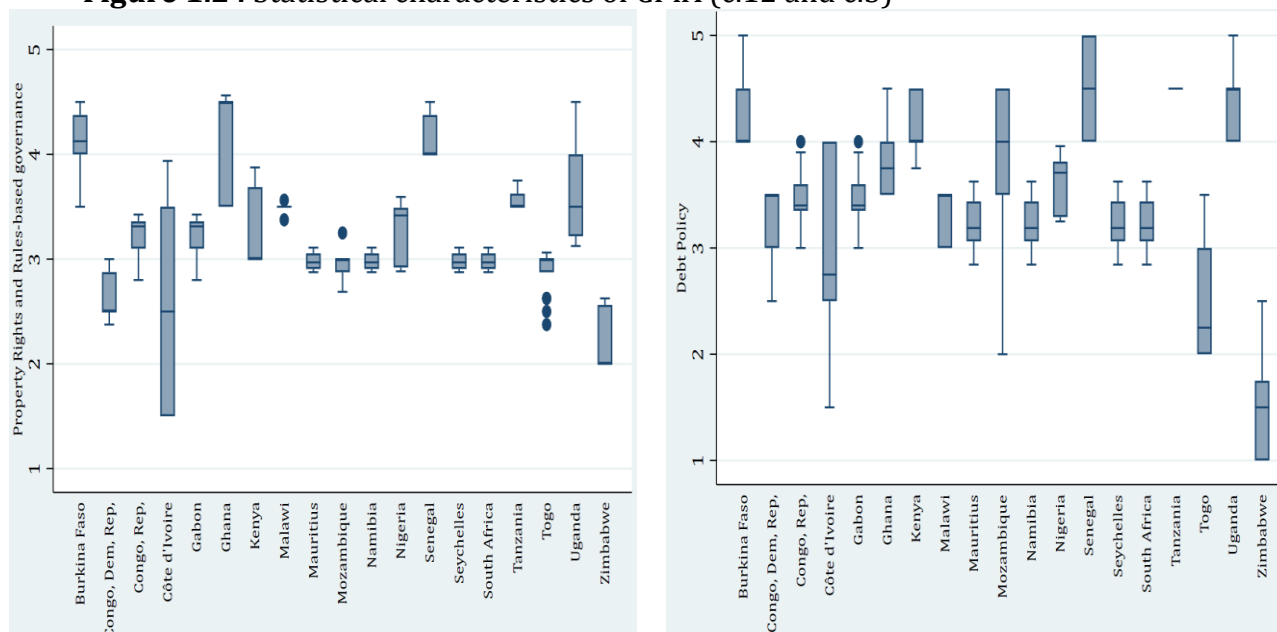
	(1)			(2)		
	H0: CPIA (Determinant) do not Granger cause AIDI			H0: CPIA (Determinants) do not Granger cause lnPPP		
CPIA (Determinants)	Optimal lag	z-bar tilde	p-value	Optimal lag	z-bar tilde	p-value
Monetary Policy (c.1)	1	9.46	0.00***	1	-1.18	0.24
Fiscal Policy (c.2)	1	1.30	0.19	1	1.35	0.17
Debt Policy (c.3)	1	5.89	0.00***	1	2.30	0.02*
Financial sector (c.5)	1	6.25	0.00***	1	2.84	0.00**
Business Regulatory Environment (c.6)	1	-2.71	0.00***	1	-1.57	0.11
Property Rights and Rule-based Governance (c.12)	1	4.23	0.00***	1	4.93	0.00***
Quality of Budgetary and Financial Management (c.13)	1	0.47	0.63	1	0.65	0.51
Efficiency of revenue mobilization (c.14)	1	8.48	0.00***	1	-0.69	0.48
Quality of Public Administration (c.15)	1	5.85	0.00***	1	-3.88	0.00***
Transparency, Accountability and Corruption in the Public Sector (c.16)	1	1.94	0.05*	1	-2.22	0.02*

Source: Author's estimation

Note: The table shows the results of the non-causal rates in the sense of granger as a function of the p-value. Column (1) analyzes the non-causal relationship of determinants (CPIA) to output (Aidi). The measure column (2) analyzes the non-causal relationship of determinants (CPIA) to input (PPP).

Thus, the following CPIA criteria will be used: Debt Policy (c.3); Financial Sector (c.5); Property Rights and Rule-based Governance (c.12); Quality of Public Administration (c.15) and Transparency, Accountability and Corruption in the Public Sector (c.16). The **figure 1.2** below shows the characteristics of these CPIA criteria for all countries to better anticipate their future interaction with the variables of interest in advance. We note that for criteria c.12 and c.3, the median values for most countries are between 2 and 3. Côte d'Ivoire has the largest dispersion and lowest values next to Zimbabwe.

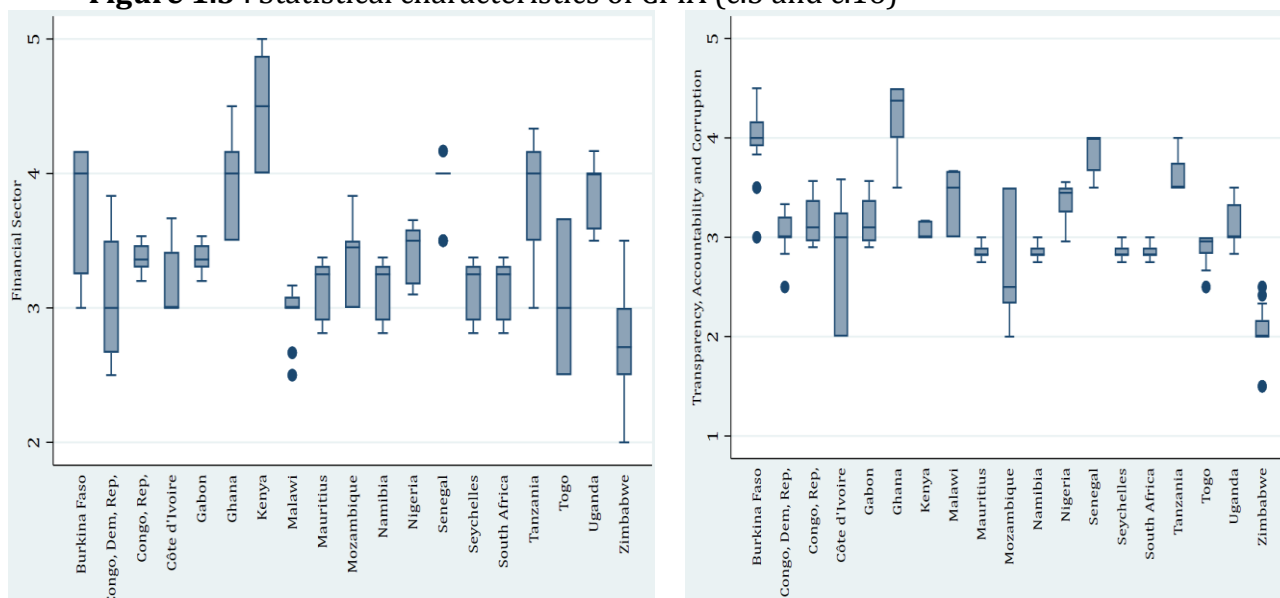
Figure 1.2 : Statistical characteristics of CPIA (c.12 and c.3)



Note: The figure shows the Tukey box diagram showing the characteristics of CPIA c.12 and c.3 including maximum, minimum, median and quartile values.

For the Financial Sector criterion (c.5), the Democratic Republic of the Congo and Zimbabwe have the lowest minimum values. We also note that Zimbabwe, Kenya, and the Democratic Republic of Congo are the only countries whose median variables are outside the range 3 and 4. Malawi presents some outliers. As for the criterion Transparency, Accountability and Corruption in the Public Sector (c.16), Côte d'Ivoire, Mozambique and Zimbabwe have the lowest values, while Ghana and Burkina Faso have the highest values. Finally, Côte d'Ivoire and Mozambique have the largest dispersion of their CPIA, c.16.

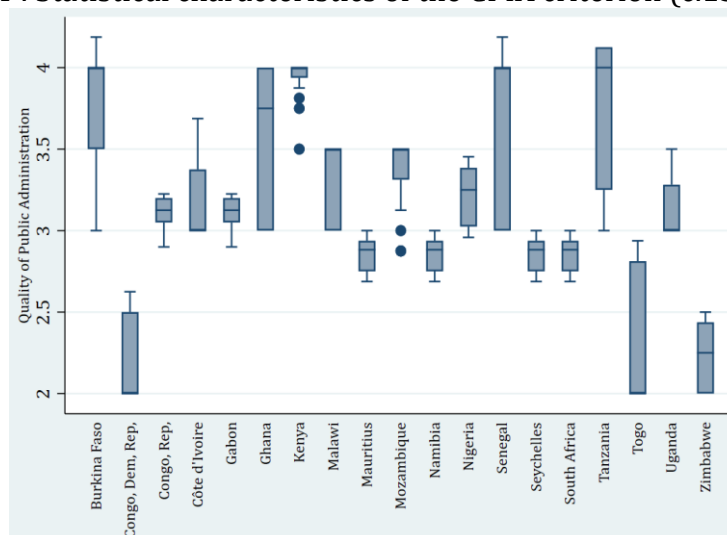
Figure 1.3 : Statistical characteristics of CPIA (c.5 and c.16)



Note: The figure shows the Tukey box diagram showing the characteristics of CPIA c.5 and c.16 including maximum, minimum, median and quartile values

Finally, for the Quality of Public Administration criterion (c.15), we note that three countries have the lowest minimum values: the Democratic Republic of Congo, Togo and Zimbabwe. In terms of maximum values, three countries stand out. They are Burkina Faso, Senegal and Tanzania.

Figure 1.4 : Statistical characteristics of the CPIA criterion (c.15)



Note: The figure shows the Tukey box diagram showing the characteristics of criterion c.5 including maximum, minimum, median and quartile values.

The Choice of PPP Capital Stock as Both an Input and a Determinant

The choice of PPPs as an input to estimate the inefficiency of public sector performance is a common practice in the literature (IMF, 2015; 2018). The primary motivation is their direct contribution to public investments. In our case, even though PPP investments appear economically negligible for many Sub-Saharan African (SSA) countries, they do have an impact on the infrastructure development indicator in Africa. This can be explained by the PPP projects carried out in sectors such as Water, Transport, Energy, and ICT. PPPs provide additional resources to finance infrastructure projects or public services without relying solely on public budgets. As an input, PPPs represent a source of capital and private expertise, which theoretically aims to improve project performance.

The use of PPPs as a determinant of inefficiency in a Stochastic Frontier Analysis model can be justified by several factors related to the very structure of PPPs, their management, and their impact on the efficiency of public services. PPPs are often seen as mechanisms designed to improve efficiency in the delivery of public services by combining the resources and expertise of both the public and private sectors. However, their implementation can also lead to inefficiencies, making their analysis crucial. According to Trebilcock and Rosenstock (2015), governments have used PPPs to address inefficiencies in infrastructure delivery, but these arrangements can also result in high coordination costs and poor resource allocation. This complexity can lead to inefficiency, where actual costs exceed projected costs due to suboptimal project management (Castillo and Salem, 2016). The choice of PPPs as a determinant can help better quantify these inefficiencies and identify the specific factors that contribute to suboptimal performance.

1.4. PPP and economic growth

PPPs play a key role in infrastructure development and the provision of public services, which can boost economic growth and influence a country's GDP. Capital expenditure on infrastructure construction (transport, energy, water and ICT) feeds GDP directly through increased production in the sectors concerned. PPPs often provide essential public services (electricity, water, transport), which increases private consumption and supports economic activity. As activity in the infrastructure sectors is stimulated, PPPs also create jobs and increase incomes, resulting in an increase in GDP. PPPs have a direct and indirect impact on GDP and economic growth.

To better understand the relationship between PPPs and economic growth, we will analyze the effect of PPPs through two different approaches. First, we will analyze the role of PPPs in shifting the production frontier. Second, we will study the role of PPPs in the variation of the efficient distance to the frontier. Furthermore, in view of the quality of governance on the level of development of countries and the importance of governance in the realization of infrastructure projects, particularly those in PPP, the interaction between PPP and governance indicators on economic growth will be analyzed.

1.4.1. Contribution of PPPs to GDP

To estimate the contribution of PPPs to GDP with Panel data, we start our modelling strategy by drawing on the work of Schmidt and Sickles (1984).

$$y_{it} = \beta_0 + X_{it} \beta + v_{it} - u_i \quad (1)$$

$$y_{it} = (\beta_0 - u_i) + X_{it} \beta + v_{it} \quad (2)$$

$$y_{it} = \alpha_i + X_{it} \beta + v_{it} , \quad (3)$$

y_{it} is taken as the logarithm of GDP in the i^{th} country in year t . X_{it} is a vector of the i^{th} country's input quantities in year t , measured by the logarithm of the public investment capital stock, the logarithm of the private capital stock and the logarithm of the PPP capital stock in the electricity sector. The PPP capital stock is combined with KKZ governance indicators added one by one. β is the vector of associated parameters to be estimated; v_{it} is the idiosyncratic error term. α_i are assumed to be the fixed parameters that are to be estimated along with the parameter vector β

To estimate our model, several tests will be carried out beforehand to determine the best estimation method. First, it will be necessary to proceed with the Fisher specification test to distinguish between a specific effect and a common effect. Then, the Hausman test will be conducted to choose the most appropriate model between the fixed effects model and the random effects model. A test will also be carried out to ensure that the error terms are homoscedastic and not autocorrelated. A unit root test will be conducted to ensure that our estimates meet standard statistical properties. Finally, we will conduct a cointegration test between the variables.

Interpretation of Results

The result of the Fisher individual effects specification test, presented in the table below, rejects the null hypothesis of no individual effects at the 5% level. So, there are specific individual effects in the model.

Table 1.3 : Fisher test results

	Statistic	p-value
F (3; 380)	423,6	0,0000

Using panel data is thus well-suited to the situation we describe. However, this specific effect can either be individual or random. Therefore, we performed the Hausman specification test to check whether the specific effects are random or not. The chi-squared statistic calculated has a p-value below the 5% threshold. Therefore, we reject the null hypothesis. This means that the specific effects of the entities are correlated with the explanatory variables. Consequently, the fixed effects model should be preferred.

Table 1.4: Hausman test results

	Statistic	p-value
Chi2(3; 380)	18.34	0,0003

The Fisher statistic obtained after regression according to the estimation of a fixed effects model confirms the heterogeneity of individuals in the form of a fixed effect. Now we will test that the errors are homoscedastic and non-autocorrelated. Therefore, it is important to perform heteroscedasticity tests to ensure the validity of these estimators. A modified Wald test is performed to test the specific hypothesis of homoscedasticity between the countries in the sample. Thus, we reject the null hypothesis, indicating the presence of heteroscedasticity.

Table 1.5 : Modified Wald Homoscedastic test results

	Statistic (W)	p-value
Chi2(19)	11290.08	0,0000

With the Wooldridge test, we checked for autocorrelation in the panel. The following hypotheses were tested: Null hypothesis (H0): There is no autocorrelation in the errors. Alternative hypothesis (H1): There is autocorrelation in the residual errors. Since the p-value is less than 0.05, we reject the null hypothesis. Consequently, there is autocorrelation in the residual errors.

Table 1.6: Wooldridge autocorrelation test results

	Statistic	p-value
F (1; 18)	288.912	0,0000

The Levin, Lin, and Chu (2002) unit root test was conducted to ensure that our estimates meet standard statistical properties. Given that some variables were not stationary at their level, we performed a first-difference transformation before conducting the test again. The following table shows the test results for the various variables used in this section.

Table 1.7: Levin, Lin and Chu unit root test results

Variables	Statistic (P-value)
Real GDP	-2.1209* (0.0170)
Private capital Stock	-5.1999*** (0.0000)
Public capital Stock	-4.2322*** (0.0000)
Control of Corruption	-1.0865 (0.1386)
d(Control of Corruption)	-8.8271*** (0.0000)
Rule of Law	-1.0585 (0.1449)
d(Rule of Law)	-1.5158 (0.0648)
Regulatory Quality	-0.3146 (0.3765)
d(Regulatory Quality)	-8.6322*** (0.0000)
Government effectiveness	-1.5807 0.0570
d(Government effectiveness)	-9.1380*** (0.0000)
Voice Accountability	-1.8514* (0.0321)
Political Stability	-1.9860* (0.0235)

t statistics in paratheses *p<0.05, **p<0.01, ***p<0.001

Source: Author's estimation

Note: Table show Results of Levin, Lin and Chu unit root test show that all variables are stationary in first differences or stationary at level. PPP variable is stationary in first difference with IPS test. The asterisks indicate the level of significance of the estimators.

To avoid “spurious” results issue, we performed a cointegration test to verify whether the variables are cointegrated. Indeed, a necessary condition for cointegration is that the series must be integrated of the same order; otherwise, they cannot be cointegrated. We performed Kao (1999) cointegration test applicable to panel data. The results indicate mixed evidence regarding the presence of cointegration among the variables being tested. While 3 tests suggest that a long-run relationship exists, 2 tests do not find sufficient evidence to reject the null hypothesis.

Table 1.8: Results of Kao Cointegration Test

Test	Stat	P-Value
Kao	Modified Dickey-Fuller	
	2.2950*	0.0109
	Dickey-Fuller	
	2.5023**	0.0062
	Augmented Dickey-Fuller	
	2.6543**	0.0040
	Unadjusted Modified Dickey-Fuller	
	1.0324	0.1509
	Augmented Dickey-Fuller	
	1.0664	0.1431

Source: Author's estimation

Note: The table shows the results of Kao cointegration tests: Westerlund, Pedroni, and Kao. Out of the 5 tests conducted, 2 reject cointegration. The asterisks indicate the level of significance of the estimators. The asterisks indicate the level of significance of the t statistics based on the following * p<0.05, ** p<0.01, *** p<0.001

Based on the tests conducted, we can conclude that the errors are heteroskedastic and autocorrelated. Moreover, given that we are interested on variations within entities (intra-individual) rather than differences between entities. The most suitable estimator for these kinds of issues remains the Fixed effects estimator. The results of the estimation of the different models are presented in the table below. Unsurprisingly, we find that all variables measuring public and private capital stocks have a positive and significant effect GDP. In addition, our variable of interest the PPP capital stock has a positive and very significant contribution to GDP. When the capital stock is combined with the various governance indicators of KKZ, we notice that its contribution to GDP remains positive and significant. Finally, we also note the positive and significant contribution to GDP of KKZ governance indicators when analyzed in combination with PPPs.

Table 1.9: Estimation results using Fixed Effects

Variables	No Governance Factors		Control of Corruption		Rule of Law		Regulatory Quality	
	No PPP	PPP	No PPP	PPP	No PPP	PPP	No PPP	PPP
Public	0.276*** (8.78)	0.273*** (9.08)	0.289*** (0.0302)	0.286*** (0.0289)	0.253*** (0.0296)	0.254*** (0.0288)	0.275*** (0.0302)	0.272*** (0.0284)
Private	0.549*** (16.15)	0.442*** (11.87)	0.546*** (0.0326)	0.443*** (0.0357)	0.551*** (0.0318)	0.469*** (0.0357)	0.565*** (0.0327)	0.449*** (0.0352)
PPP		0.0684*** (5.96)		0.0657*** (0.0110)		0.0513*** (0.0113)		0.0747*** (0.0109)
KKZ governance indicators								
Cont. of Corrupt.			0.265*** (0.0465)	0.254*** (0.0444)				
Rule of Law					0.336*** (0.0462)	0.284*** (0.0464)		
Regula. Quality							0.237*** (0.0415)	0.260*** (0.0392)
Constant	1.784*** (7.17)	2.609*** (9.49)	1.829*** (0.239)	2.619*** (0.264)	2.181*** (0.239)	2.738*** (0.263)	1.734*** (0.239)	2.630*** (0.260)
Observations	380	380	380	380	380	380	380	380
R-squared		0.797	0.796	0.814	0.806	0.817	0.796	0.820
Numb. countries	19	19	19	19	19	19	19	19

Variables	Govern. Effectiveness		Voice Accountability		Political Stability	
	No PPP	PPP	No PPP	PPP	No PPP	PPP
Public	0.276*** (0.0311)	0.272*** (0.0294)	0.280*** (0.0286)	0.277*** (0.0278)	0.254*** (0.0302)	0.253*** (0.0291)
Private	0.553*** (0.0336)	0.436*** (0.0364)	0.483*** (0.0319)	0.407*** (0.0347)	0.584*** (0.0329)	0.485*** (0.0366)
PPP		0.0753*** (0.0114)		0.0527*** (0.0108)		0.0605*** (0.0111)
KKZ governance indicators						
Gov. Effectiveness	0.158*** (0.0516)	0.206*** (0.0493)				
Voice Accountability			0.366*** (0.0423)	0.329*** (0.0417)		
Political Stability					0.158*** (0.0262)	0.141*** (0.0254)
Constant	1.830*** (0.246)	2.751*** (0.271)	2.590*** (0.245)	3.142*** (0.263)	1.711*** (0.238)	2.449*** (0.266)
Observations	380	380	380	380	380	380
R-squared	0.783	0.807	0.816	0.827	0.798	0.813
Numb. countries	19	19	19	19	19	19

Source: Author's Estimation

Note: The table presents comparative results between models with PPP and without PPP estimated by GLS, while accounting for the interactions between PPP and KKZ governance indicators. The asterisks indicate the level of significance of the results. The asterisks indicate the level of significance of the t statistics based on the following * p<0.05, ** p<0.01, *** p<0.001

Once the contribution of PPPs to GDP is analyzed, we will now look at the efficiency of PPP investments in relation to the shift of the production frontier. In other words, we will compare the production frontier of countries with and without PPPs. Thus, we will estimate equation (3) with and without PPP, then estimate the technical efficiency and compare the results obtained. To do this, the following transformation is performed to obtain $\hat{u}_i$:

$$\hat{u}_i = \max_i \{\hat{\alpha}_i\} - \hat{\alpha}_i \geq 0 \quad i = \hat{\alpha}_i \quad (4)$$

$$TE_i = \exp (- \hat{u}_i) \quad (5)$$

The results obtained show a negative shift in the efficient frontier of 3.5%. Indeed, the average efficiency when PPPs are not considered is 46% compared to 42.5% when PPPs are considered. Thus, despite the positive contribution of PPPs to GDP, PPPs have not allowed for a positive shift in the production frontier as measured by GDP. This result is very plausible when we consider the budgetary risks associated with PPPs and the lack of control over this method of financing by the States, as highlighted by several authors in the literature (Richet and Durand, 2009; Garrec and Touzé, 2022). Indeed, PPPs can contribute positively to GDP by stimulating infrastructure investment and increasing economic output. However, in some cases, efficiency as measured by the production frontier may be lower in PPP countries than in non-PPP countries, due to poor project management, high costs to the government, or misallocation of resources. Indeed, many PPPs impose excessive costs on the government because poorly prepared or poorly negotiated (annual payments and guarantees that are too high), these costs can limit future public spending in other essential sectors, such as health or education.

Table 1.10: Efficiency Estimation with and without PPP

Variable	Obs	Mean	Std. Dev.	Min	Max
No PPP Efficiency	380	0.460	0.198	0.144	1
PPP Efficiency	380	0.425	0.208	0.113	1

Note: the table shows the average efficiency of countries with and without PPP investments. The table also presents the minimum, average and maximum efficiency values.

According to Kumbakhar and al. (2015), it is important to note that, by construction, efficiency estimates are sensitive to adding/dropping “outlier” countries (i.e., countries with either very high or very low values of α_i). So, we decided to remove the outliers to see the result on efficiency. The results show an improvement in average efficiency without and with PPP from 46% to 60% and from 43% to 52% respectively.

Table 1.11: Efficiency Estimation with and without PPP and outliers

Variable	Obs	Mean	Std. Dev.	Min	Max
No PPP Efficiency	340	0.604	0.209	0.201	1
PPP Efficiency	340	0.523	0.202	0.158	1

Note: the table shows the average efficiency of countries with and without PPP investments and does not consider countries with outliers. The table also presents the minimum, average and maximum efficiency values.

1.4.2. PPP as determinant of inefficiency

In this section, we will analyze the role of PPPs as a determinant of the inefficiency of the output measured by GDP. As a reminder, PPPs are used to achieve efficiency gains, which is why they are considered here as determinants of inefficiency. In addition to PPPs, the study will also focus on KKZ governance indicators as inefficiency determinants. To analyze the effect of the determinants on efficiency, as measured by GDP, we will adopt a two-step approach. Generally, the strategy for estimating investment inefficiency while incorporating determinants into the analysis involves first estimating deviations from the expected optimal investment, which is reflected in the residuals of the selected model. In the second step, these residuals are regressed on the determinants. For this, we will draw inspiration from the work of Benlemlih and Bitar (2018).

In the first stage, the model is estimated based on the public, private and PPP investments of countries, which are expected to influence the GDP level. The residuals (the differences between the actual GDP and the GDP predicted by the model) represent the deviations from the expected optimal PPP level. These residuals are considered an approximation of the investment inefficiency measured by the GDP. The empirical specification of the model is as follows:

$$\ln \text{GDP}_{it} = \beta_0 + \beta_1 \ln \text{public}_{it} + \beta_2 \ln \text{private}_{it} + (v_{it} - u_{it}) \quad (6)$$

In the second step, the residuals obtained from equation (6) are regressed on the KKZ governance indicators as determinants of inefficiency. This step allows for the identification of factors that contribute to GDP inefficiency. The empirical specification of the equation is as follows:

$$\hat{u}_{it} = \delta_0 + \delta_1 \ln \text{ppp} + \delta_2 \text{control of corruption} + \delta_3 \text{rule of law} + \delta_4 \text{regulatory quality} + \delta_5 \text{government effectiveness} + \delta_6 \text{voice and accountability} + \delta_7 \text{political stability} \quad (7)$$

Presentation and Interpretation of Results

As in the previous section concerning the contribution of PPPs to GDP, several tests were conducted to determine the estimation method for our equations. The Fisher specification test rejected the null hypothesis of no individual effects (p-value = 0,000). We performed the Hausman specification test, the chi-squared statistic calculated had a p-value of 0,003 indicating a preference for the fixed effects model. A modified Wald test is performed to check the specific hypothesis of homoscedasticity between the countries in the sample. Thus, we reject the null hypothesis, indicating the presence of heteroscedasticity. With the Wooldridge test, we checked for autocorrelation in the panel. Since the p-value (0,000) is less than 0.05, we reject the null hypothesis. Consequently, there is autocorrelation in the residual errors. A Breusch-Pagan correlation test between individuals yielded a p-value = 0.001, which allows us to reject the null hypothesis and conclude that there is a contemporary correlation.

The results obtained indicate that the errors are heteroscedastic, and that there is correlation between individuals. Therefore, we opted for estimation using the generalized least squares (GLS) method.

The table below presents the results of our estimation. Unsurprisingly, the effect of public and private investment on GDP remains positive and significant. As for our variable of interest, the PPP capital stock, we note that it contributes significantly to reducing the inefficient distance. As well as the other governance indicators: control of corruption, government effectiveness, Voice Accountability and Regulatory Quality. The variable Political stability is not significant despite its negative sign. Only the rule of law indicator shows a significant sign that is not expected. This result can be explained by several factors such as challenges, weak institutions, administrative burden, the gap between the formal and informal economy, and the capture of public resources. These factors may limit the positive impact of the rule of law variable on GDP efficiency. This result confirms several authors (Alharti, 2019; Haini, 2022; Rawashdeh, 2022). Alharti (2019) suggests that in some contexts, an improvement in the rule of law may not translate into a proportional increase in GDP.

Table 1.12: Estimation results of PPP as a determinant of inefficiency

VARIABLES	expected sign	Model
Public	+	0.399*** (0.0303)
Private	+	0.656*** (0.0261)
Inefficiency		
PPP	-	-0.317*** (0.0228)
Control of Corruption	-	-0.430*** (0.0964)
Rule of Law	-	2.166*** (0.223)
Regulatory Quality	-	-0.637*** (0.171)
Government Effectiveness	-	-0.769*** (0.247)
Voice Accountability	-	-0.824*** (0.217)
Political Stability	-	-0.130 (0.239)
Constant		-7.344*** (0.330)
Observations		380

Source: Author's estimation

Note: The table shows the results of the estimation of equations 6 and 7 in two steps using the GLS method considering the PPP and KKZ indicators as determinants of inefficiency. The asterisks indicate the level of significance of the estimators. The asterisks indicate the level of significance of the t statistics based on the following * p<0.05, ** p<0.01, *** p<0.001

1.5. PPP and infrastructure development

In this section, we will look at the relationship between multi-sector PPPs and an alternative and more specific output than GDP. Indeed, the economic relationship between PPPs and GDP can be difficult to analyze for several reasons. PPPs are partly aimed at improving the quality of infrastructure and public services. However, GDP measures production and does not consider the quality of investments. In addition, PPPs can have long-term effects while the measurement of GDP is annual. Finally, the contribution of PPPs to GDP can be indirect and gradual. Indeed, PPPs often aim at specific objectives (efficiency of public services) that do not directly translate into an increase in GDP. For all these reasons, this section will focus on the relationship between PPP and the African Infrastructure Development Indicator (AIDI).

1.5.1. The role of PPPs in shifting the frontier

In this section, we will analyze the role of multisectoral PPP investments in moving the frontier in terms of infrastructure development. Multisectoral PPP investments are defined as all the PPP projects carried out by a given country, regardless of sector, during the analysis period.

Drawing on the work of Greene (2005a, b), the models below will be estimated using the Maximum Likelihood Method (MLE). This section of the paper analyses the role of PPP investment, combined with its determinants as measured by the CPIA criteria, in shifting the efficient frontier.

$$y_{it} = \alpha_i + X_{it}\beta + Y_{it}\gamma + (v_{it} - u_{it}) \quad (8)$$

$$y_{it} = \alpha_i + X_{it}\beta + Y_{it}\gamma + Z_{it}\delta + (v_{it} - u_{it}) \quad (9)$$

$$v_{it} \sim N(0, \sigma^2_v),$$

$$u_{it} \sim N^+(0, \sigma^2_u), i = 1, \dots, N, t = 1, \dots, T$$

y_{it} is taken to be the logarithm of the output of the i^{th} country in year t . This output is measured by the African Infrastructure Development Index (AIDI). v_{it} represent the random error terms, independently distributed according to the normal distribution; u_{it} are the non-negative random error terms, which are supposed to take account of the technical inefficiency in production and are iid according to the semi-normal distribution.

X_{it} , Y_{it} and Z_{it} are the vectors of the quantities of inputs of the i^{th} country during year t which are measured respectively by the logarithm of the public investment capital stock, the logarithm of the private capital stock and the logarithm of the PPP capital stock combined with the CPIA criteria added one by one. The sequential inclusion of determinants enhances the interpretability of the results. In infrastructure investment efficiency analysis, it is crucial to understand the specific factors that influence performance. When determinants are included one at a time, it becomes easier to communicate the effects of each CPIA variable. As stated by Farantos (2023), this clarity is essential for informing decision-making processes and for the effective implementation of reforms aimed at improving efficiency in public services. The role of the CPIA criteria without combination with the PPP capital stock will also be analyzed to compare the effects.

In equation (8), the maximum level of infrastructure development depends on the stock of public capital (X) and the stock of private capital (Y). In equation (9), the frontier shifts when, in addition to X and Y , the PPP capital stock variable associated with the CPIA criteria is added to the list of explanatory variables based on the results of the Granger non-causality test. These are Debt policy (c.3), Financial sector (c.5), Property rights and rules-based governance (c.12), Quality of public administration (c.15) and Transparency, accountability, and corruption in the public sector (c.16).

Results and interpretation

Regarding the statistical relevance of inefficiency, the results of the Likelihood Ratio (LR) tests show that technical inefficiency plays a non-negligible role in explaining the distance to the production frontier. This allows us to justify the interest of having considered a stochastic frontier rather than a deterministic one.

After analyzing the statistical relevance of inefficiency, in a second step we tested the most appropriate form of production function between Translog and Cobb-Douglas. To do this, we tested for both models, i.e., the one including the PPP capital stock ($\delta \neq 0$) and the one not including the PPP capital stock ($\delta = 0$) with the null hypothesis $H_0: \beta_4 = \beta_5 = \beta_6 = \beta_7 = \beta_8 = \beta_9 = 0$ or $\beta_3 = \beta_4 = \beta_5 = 0$ respectively. If the null hypothesis is accepted, then the Cobb-Douglas specification will be the most suitable. With the LR test based on the following statistic: $LR = -2\{\ln[L(H_0)/L(H_1)]\}$ where $L(H_0)$ and $L(H_1)$ correspond to the Cobb-Douglas form and Translog form likelihood functions respectively, we accept the null hypothesis in both models. We find when there is no PPP capital stock ($\delta = 0$) a LR test = -1.385 which is lower than $\chi^2(3; 0.01) = 10.501$ (according to the Kodde and Palm table) and when the PPP capital stock is in the model ($\delta \neq 0$), a LR test = -1.909 which is lower than $\chi^2(6; 0.01) = 16.704$ (according to the Kodde and Palm table). In both models we cannot reject the null hypothesis. Consequently, the Cobb-Douglas form is more appropriate.

Unsurprisingly, the results show the positive and significant contribution of public and private capital stocks to infrastructure development both with and without the presence of the PPP capital stock in the equation. For our variable of interest, we find that PPP investment (PPP capital stock) is significant and contributes positively to infrastructure development. More importantly, we find that when PPP capital stock is combined with a CPIA criteria, its contribution to infrastructure development becomes more significant and important compared to the situation where the contribution of PPP capital stock is assessed without an CPIA criteria. However, for the quality of administration criterion (c.15), the results do not really show any variation (3%). The reason could be since CPIA measuring public administration might not directly affect the efficiency of infrastructure development for several reasons, despite expectations. The CPIA criteria for quality of public administration focuses on broader governance and administrative efficiency, which may not directly translate into infrastructure-specific outcomes.

Infrastructure development often requires specialized agencies or ministries that operate outside the core public administration system. Therefore, the quality of public administration might not directly influence the ability of these specialized entities to efficiently manage infrastructure projects (Wang and Ma; 2020). In many countries, the responsibilities for infrastructure development are spread across multiple agencies. For example, several countries have set up specialized agencies outside central government to manage infrastructure projects (in Senegal, for example, there is APIX, AGEROUTE, CETUD, etc.). Improvements in central public administration might not trickle down to all these layers, especially if there is institutional fragmentation.

Infrastructure projects are often large-scale and vulnerable to corruption, mismanagement, and inefficiency. While the CPIA rating for public administration may reflect improvements in administrative procedures, it may not sufficiently address

inefficiency specific to large-scale infrastructure project. According to Smets and Knack (2018), while the CPIA can provide a useful assessment of public governance, it does not always capture the nuances necessary to understand how these factors directly influence the efficiency of infrastructure projects.

Table 1.13: Estimation results for equations 8 and 9 using SFA approach

	no CPIA		CPIA									
			c.12		c.15		c.16		c.3		c.5	
	no PPP	PPP	no PPP	PPP	no PPP	PPP	no PPP	PPP	no PPP	PPP	no PPP	PPP
Frontier												
Public capital stock	0.139** (3.14)	0.198*** (5.01)	0.227*** (6.42)	0.190*** (29849.55)	0.102* (2.30)	0.228*** (163328.06)	0.214*** (7.22)	0.245*** (2936.69)	0.157*** (3.66)	0.223*** (7.70)	0.214*** (7.07)	0.195*** (12.50)
Private capital stock	0.104* (2.45)	0.455*** (9.17)	0.439*** (17.86)	0.408*** (95829.81)	0.0805* (2.24)	0.408*** (969221.86)	0.486*** (15.24)	0.394*** (5993.92)	0.127*** (3.68)	0.405*** (11.14)	0.419*** (11.85)	0.417*** (8.63)
PPP capital stock		0.0343* (2.55)		0.0429*** (9407.63)		0.0334*** (4673.18)		0.0459*** (2065.15)		0.0495*** (4.27)		0.0378** (3.03)
CPIA criteria												
Property Rights and Rules-based governance (c.12)			0.152*** (14.30)	0.150*** (19411.52)								
Quality of Public Administration (c.15)					0.247*** (5.61)	0.101*** (5818.47)						
Transparency, Accountability and Corruption in the Public Sector (c.16)							0.154*** (5.76)	0.102*** (1676.58)				
Debt policy (c.3)									0.0329 (1.29)	0.0765*** (4.07)		
Financial Sector (c.5)											0.132*** (4.33)	0.0719*** (5.67)
LR test	926.9***	1308.4***	1331.5***	1348.6***	953.8***	1322.7***	1231.2***	1327.5***	955.6***	1245.1***	1227.5***	1309.6***

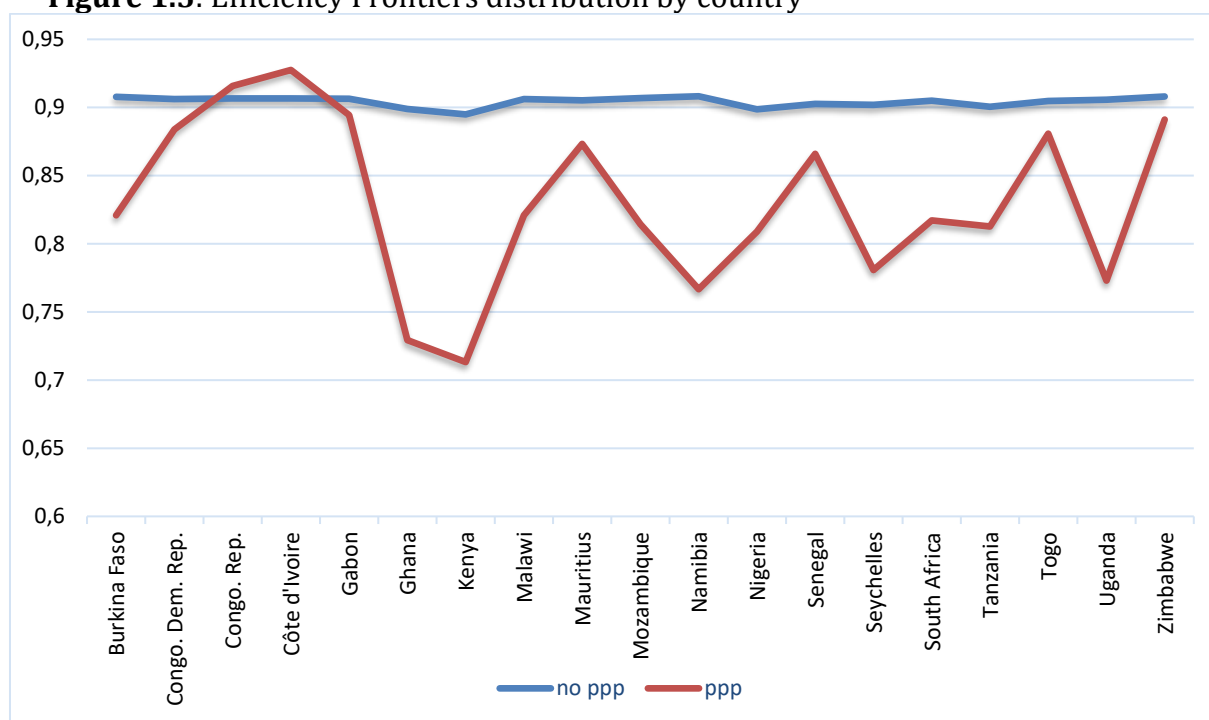
Source: Author's estimation

Note: The table presents the results of the efficiency model estimates comparing the equations without and with PPP capital stock; and when the capital stock is present, it is combined with the CPIA criteria added one by one. The asterisks indicate the level of significance of the t statistics based on the following * p<0.05, ** p<0.01, *** p<0.001

Using the Jondrow and al. (1982) formula, we estimated individual and average inefficiencies. Thus, by comparing the frontiers without and with PPP investments, we find that PPPs have not enabled most of the countries analyzed to positively shift their efficient frontier. Only countries such as the Republic of Congo and Côte d'Ivoire were able to benefit from PPP investments by increasing their efficiency in terms of infrastructure development (**Figure 1.5**.) Indeed, the average level of efficiency with PPP is 83% compared to 90% when PPPs are not considered. This corroborates certain academic findings and adds further fuel to the controversy over the efficiency of PPPs. Indeed, according to the APMG PPP Methodology Guide (2016), the academic community is not unanimous, and some academic reports argue that PPPs do not generate added value (Estache and al. 2012; Grimsey and al. 2005; Grassner and al. 2009). However, the performance of these two countries cannot be justified by their CPIA score in view of the statistical characteristics presented at the **Figure 1.7** because they are not the most efficient. PPPs in Africa have certainly contributed to infrastructure development, which shows their positive and significant contribution. Indeed, the development indicator used is the physical measure of output. For example, for the roads sector, the output considers the number of km of road or for the water sector, the access rate. It is obvious that when a PPP project is carried out in a sector of activity, the project will necessarily contribute to improving the sectoral output or its contribution to GDP (as shown in the previous

sections). However, the question of the efficiency of the project remained. The project may contribute to improving output and may not be efficient. As has been shown by the results obtained. This efficiency can be explained by several factors. These are mainly institutional weaknesses. The descriptive analysis of the CPIA criteria by the box diagram shows that only 4 to 5 countries exceeded the value of 3.5 out of 6 for all the criteria analyzed. Another factor remains the quality of preparation of these PPP projects and the capacities of the States to supervise PPP projects.

Figure 1.5: Efficiency Frontiers distribution by country

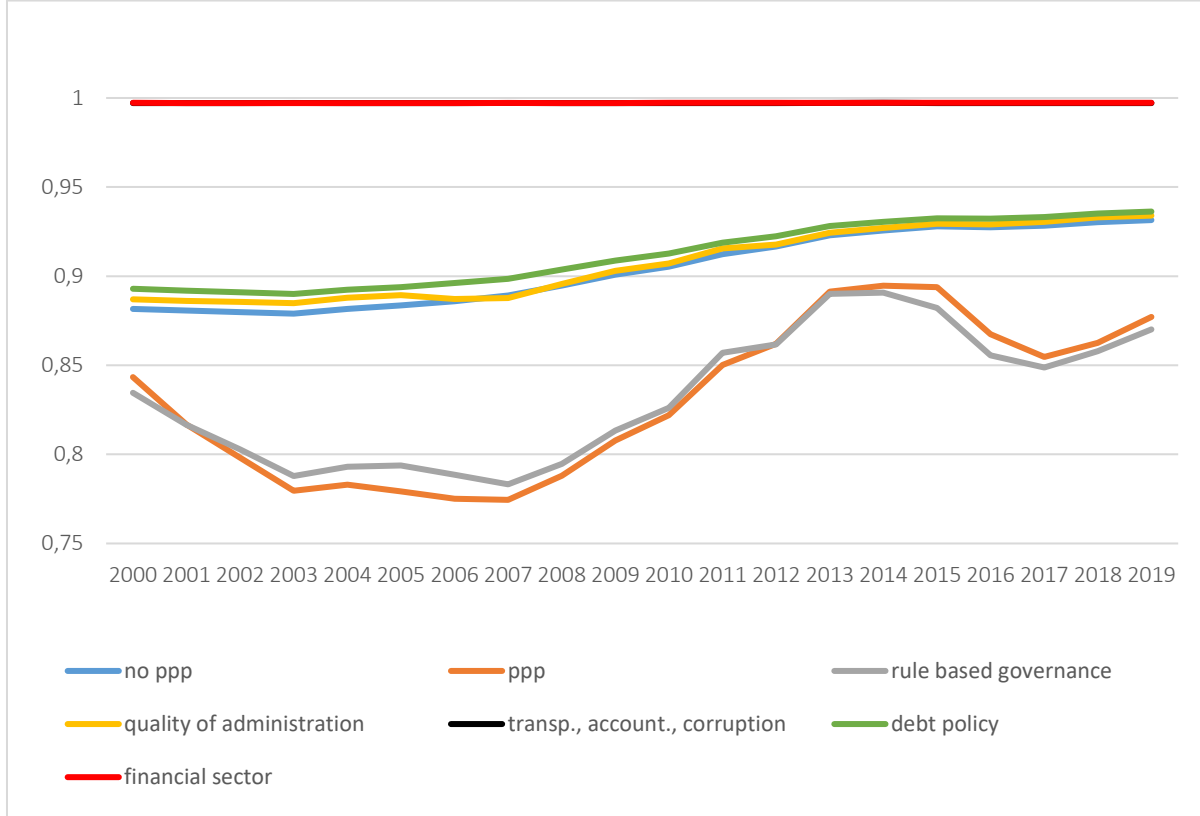


Source: Author's estimation

Note: The figure shows the average efficiency scores with and without PPP investments for all countries

In **Figure 1.6** we graphically analyze the individual contributions of the CPIA criteria and the PPP capital stock in shifting the efficient frontier over time. We see that the criteria: Quality of Public Administration (c.15); Transparency, Accountability and Corruption in the Public Sector (c.16); Debt policy (c.3) and Financial Sector (c.5) pull the frontier upwards. While Property Rights and Rules-based governance (c.12) and PPP capital stock pull down the efficient frontier. However, we find that as time progresses, the PPP capital stock pulls the efficient frontier down less. This could be explained by the fact that countries have better control over the PPP investment environment over time.

Figure 1.6: CPIA and PPP capital stock: push and pull factors across time.



Source: Author's estimation

Note: The chart analyzes the individual contributions of CPIA criteria and PPP capital stock in the shift of the efficient frontier over the analysis period

Beside the raw CPIA data as a proxy for governance indicators and business climate, we were also interested in the dummy values obtained through the CPIA. To do this, we assign for each CPIA, a dummy variable with a value of 1 if the CPIA value exceeds the median value of 3.5 and 0 otherwise. These dummy variables were used instead of the raw CPIA data used in the SFA model estimate. The results (in the appendix) show the same results apart from the Debt policy (c.5) which becomes no longer significant when not combined with the PPP.

1.5.2. The role of PPPs and CPIA criteria as determinants of inefficiency

In this section, we will investigate the role of PPPs and the CPIA criteria as determinants of inefficiency. We opted for this simulated estimation of efficiency scores using CPIA as determinants because efficiency scores are not solely attributable to PPPs. Using their determinants to explain scores for which PPPs are not solely responsible risks skewing the interpretation. In our opinion, it would be more difficult to isolate the effect of each CPIA on inefficiency compared to our current model. Still drawing on the work of Greene (2005a, b), we will repeat the model specified above, this time considering the determinants of inefficiency including PPP investments. The model below will be estimated using the Maximum Likelihood Method (MLM).

u_{it} is a function of the non-stochastic determinants of the inefficiency z_{it} ; δ is the vector of associated parameters to be estimated.

Empirical models: functional and econometric specification

The empirical models used to measure the role of PPPs in reducing distance to the frontier are as follows:

$$\ln aid_{it} = \beta_0 + \beta_1 \ln public_{it} + \beta_2 \ln private_{it} + (v_{it} - u_{it}) \quad (10)$$

with u_{it} is a function of the non-stochastic determinants of the inefficiency and specified as follows:

$$u_{it} = \delta_0 + \delta_1 ppp + \delta_2 rulesbasedgovernance + \delta_3 qualityofadministration + \delta_4 transparencyandcorruption + \delta_5 debtpolicy + \delta_6 financialsector \quad (11)$$

With $v_{it} \sim N(0, \sigma_v^2)$ and $u_{it} \sim N^+(u_{it}, \sigma_u^2)$, $i = 1, \dots, N$, $t = 1, \dots, T$

Results and interpretation

As in the first model, we have ensured the statistical relevance of inefficiency, and the results of the Likelihood Ratio (LR) tests show once again that technical inefficiency plays a non-negligible role in explaining the distance to the production frontier. This allows us to justify the interest of having considered a stochastic frontier rather than a deterministic one. Given that equation (10) is identical to equation (8) except that the determinants are considered, the Cobb-Douglas form remains more appropriate, as shown above by the results of the LR tests.

Table 1.14 reports the results of estimating equation 10 and 11. Unsurprisingly, the coefficients on public and private capital stocks are positive and significant. The average technical efficiency score for the 19 countries selected is around 0.566. This means that, on average, governments are only 57% efficient in developing infrastructure, while their degree of inefficiency is 43%. These results are slightly better than those estimated by the World Bank in 2018 by Barhanoui and al. Indeed, based on data from 2000 to 2015, the efficiency score for sub-Saharan countries was 46%. The difference could be explained by the 4 additional years included in our database and an improvement in the countries' efficiency over time. These efficiency scores are also widely dispersed, ranging from an average minimum over the analysis period of 41% for Zimbabwe to an average maximum of 75% for Ghana.

In a one-step approach, we simultaneously estimated the parameters of the production frontier and the determinants of technical efficiency. The sign of the parameters associated with the determinants of technical inefficiency indicates the effect of the latter on the performance of countries in terms of infrastructure development. The estimation shows that the following variables: PPP capital stock, financial sector (c.5), quality of public administration (c.15), transparency, accountability, and public sector corruption (c.16) are relevant in explaining countries' efficiency in infrastructure development. Indeed, the results indicate that a one percentage point increase in PPP capital stock implies an improvement of around 5% in the African Infrastructure Development Index (AIDI). This remains the smallest contribution of the various determinants analyzed. It is followed by the quality of administration, with an increase of one percentage point

equivalent to a 6.2% improvement in the efficiency of the AIDI. Next comes transparency, accountability, and control of corruption in the public sector, which contributed 7.5% to the improvement in AIDI. Finally, the largest contribution is made by the financial sector with a score of 7.7%. These results are in line with the literature. Reducing corruption in the sector and improving the quality of public administration are bound to increase the efficiency of infrastructure, given its public nature. As far as the financial sector is concerned, governments finance their infrastructure either through taxes or loans. An efficient financial sector helps to mobilize the necessary financial resources for both the public and the private partner under Design, Build and Finance (DBF) contracts.

The other two determinants: debt policy and property rights and rules-based governance, are not significant. However, the negative sign of their coefficient.

Table 1.14: Estimation results for equations 10 and 11 using SFA approach

	expected signs	coef.	z-ratio
Frontier			
Public capital stock	+	0.198***	(7.08)
Private capital stock	+	0.343***	(9.11)
Inefficiency			
PPP capital stock	-	-0.0504***	(-4.51)
Property Rights and Rules-based governance (c.12)	-	-0.0487	(-1.62)
Financial Sector (c.5)	-	-0.0769**	(-2.62)
Quality of Public Administration (c.15)	-	-0.0628*	(-1.98)
Transparency, Accountability and Corruption in the Public Sector (c.16)	-	-0.0749*	(-2.29)
Debt policy (c.3)	-	-0.0178	(-0.86)
LR test		1295.26***	
Number of observations		380	

Source: Author's estimation

Note: Table presents the results of the model estimation with public and private capital stocks as control variables and PPP capital stock and CPIA criteria as determinants of inefficiency added simultaneously. The asterisks indicate the level of significance of the t statistics based on the following * p<0.05, ** p<0.01, *** p<0.001

1.6. Robustness Analysis

In this section, we will try to confirm the robustness of our results obtained by the SFA approach. Indeed, we will use a fixed-effects estimations to analyze the effect of PPPs on the African Infrastructure Development Index (AIDI). In other words, the role of PPPs in moving the efficient frontier and the role of PPPs as determinants of efficiency using a alternative approach.

1.6.1. Alternative estimation of the role of PPPs in efficient frontier shift

Our estimation strategy was to draw on the work of Schmidt and Sickles (1984) and apply a standard fixed effects estimation for equations (8) and (9). The same methodological approach to analyzing the contribution of PPPs to GDP was used. Thus,

based on the results of the same tests carried out previously, we conclude that an estimation by the fixed effects method would fit better our model. The following **Table 1.15** presents the results of our estimation. The results of the models estimated by the fixed effects method confirm the findings obtained using the SFA method. Indeed, we note the positive contribution of both public and private capital stocks to infrastructure development. Also, the contribution of our variable of interest, PPP capital stock, to infrastructure development remains positive and significant. Moreover, as in the SFA approach, the contribution remains positive and significant whenever the PPP capital stock was combined with the CPIAs.

Table 1.15: Estimation results for equations 8 and 9 using FE methods

	no CIA		CIA									
			c.12		c.15		c.16		c.3		c.5	
Frontier	noPPP	PPP	noPPP	PPP	noPPP	PPP	noPPP	PPP	noPPP	PPP	noPPP	PPP
Public capital stock	0.229*** (0.0316)	0.226*** (0.0304)	0.203*** (0.0306)	0.203*** (0.0297)	0.223*** (0.0306)	0.221*** (0.0297)	0.214*** (0.0305)	0.212*** (0.0294)	0.223*** (0.0305)	0.223*** (0.0298)	0.214*** (0.0311)	0.211*** (0.0300)
Private capital stock	0.479*** (0.0342)	0.379*** (0.0377)	0.459*** (0.0329)	0.375*** (0.0364)	0.432*** (0.0344)	0.352*** (0.0373)	0.486*** (0.0329)	0.391*** (0.0363)	0.484*** (0.0330)	0.405*** (0.0375)	0.419*** (0.0364)	0.324*** (0.0391)
PPP capital stock		0.0638*** (0.0116)		0.0552*** (0.0114)		0.0554*** (0.0115)		0.0604*** (0.0112)		0.0495*** (0.0120)		0.0618*** (0.0114)
CIA criteria												
Rule Based Govern. (c.12)			0.146*** (0.0253)	0.129*** (0.0248)								
Quality Public. Adm (c.15)					0.160*** (0.0315)	0.135*** (0.0310)						
Trans. Acc. Corrup. (c.16)							0.154*** (0.0276)	0.146*** (0.0266)				
Debt Policy (c.3)									0.101*** (0.0189)	0.0765*** (0.0194)		
Financial Sector (c.5)											0.132*** (0.0314)	0.125*** (0.0303)
Constant	-4.70*** (0.250)	-3.936*** (0.278)	-4.688*** (0.240)	-4.026*** (0.269)	-4.628*** (0.242)	-3.972*** (0.272)	-5.110*** (0.251)	-4.361*** (0.279)	-5.052*** (0.250)	-4.371*** (0.294)	-4.341*** (0.259)	-3.614*** (0.283)
Observations	380	380	380	380	380	380	380	380	380	380	380	380
R-squared	0.718	0.739	0.742	0.758	0.737	0.753	0.740	0.760	0.738	0.750	0.731	0.751
Number of countries	19	19	19	19	19	19	19	19	19	19	19	19

Source: Author's estimation

Note: The table presents the comparative results between models with PPP combined with CIA and without PPP estimated by FE method. The asterisks indicate the level of significance of the t statistics based on the following * p<0.05, ** p<0.01, *** p<0.001

1.6.2. Alternative estimation of PPPs role as determinants of inefficiency

To confirm the robustness of the results measuring the role of PPPs in reducing the efficient distance to the frontier, we will re-estimate equations 10 and 11 using an alternative approach. As in the section related to PPP as a determinant of GDP, we used a two-step approach. Generally, the strategy for estimating investment inefficiency while incorporating determinants into the analysis involves first estimating deviations from the expected optimal investment, which is reflected in the residuals of the selected model. In the second step, these residuals are regressed on the determinants. For this, we still will draw inspiration from the work of Benlemlih and Bitar (2018).

The results obtained by the fixed effects method confirm the positive and significant contribution of private and public capital stocks to the efficiency of infrastructure development. Regarding our variable of interest, our results show that PPPs contribute to reducing the inefficient distance. Regarding the other determinants of inefficiency, we note, as with the SFA approach, that the financial sector (c.5) and Transparency, Accountability and Corruption (c.16) criteria contribute significantly to the reduction of the inefficient distance. However, the Debt Policy (c.3) that was not significant in the SFA approach becomes significant and contributes to increasing the inefficient distance. Indeed, for most sub-Saharan African countries, a good debt policy implies limiting debt in view of the relatively high level of public debt in these countries. Thus, the use of PPPs (especially users pay PPP) remains the main alternative to finance infrastructure needs without increasing their tax burden too much. As a result, the use of PPPs is more motivated by the financial aspect rather than the gain in efficiency. This may explain the negative relationship between PPP efficiency and debt policy (c.3)

Table 1.16: Estimation results for equations 10 and 11 using FE methods

VARIABLES	Expected sign	inefficiency
Frontier		
Public capital stock	+	0.229*** (0.0316)
Private capital stock	+	0.479*** (0.0342)
Constant		-4.705*** (0.250)
Inefficiency		
PPP capital stock	-	-0.0520*** (0.0128)
Rules-based governance (c.12)	-	-0.0445 (0.0375)
Financial Sector (c.5)	-	-0.0933** (0.0390)
Quality of Public Administration (c.15)	-	0.0648 (0.0412)
Transparency, Account. and Corruption (c.16)	-	-0.129** (0.0517)
Debt Policy (c.3)	-	0.0490* (0.0295)
Constant		1.651*** (0.156)
Observations		380

Source: Author's estimation

Note: The table shows the results of the estimation of equations 6 and 7 in two steps using the GLS method, considering the PPP and KKZ indicators as determinants of inefficiency. The asterisks indicate the level of significance of the t statistics based on the following * p<0.05, ** p<0.01, *** p<0.001

1.7. Summary of Results

PPP and Economic Growth: A Fixed-Effects Model

- Non-combination PPPs make a positive contribution to economic growth
- PPPs combined with the 6 KKZ governance indicators contribute positively to growth

- The efficient frontier declines by 3.5% when PPPs are considered
- PPPs and the following KKZ indicators: corruption control, rule of law, voice and accountability, government effectiveness, quality of regulation help to reduce the inefficient distance. However, political instability is not significant

PPP and Infrastructure Development: Stochastic Frontier Approach

- PPPs without combination contribute positively to infrastructure development
- PPPs combined with the following 5 CPIA criteria: Property Rights and Rules-based governance (c.12), Quality of Public Administration (c.15), Transparency, Accountability and Corruption in the Public Sector (c.16), Debt policy (c.3) and Financial Sector (c.5) contribute to infrastructure development
- The efficient border declines by 7% when PPPs are considered
- The following PPPs and CPIA criteria: Transparency, Accountability and Corruption in the Public Sector (c.16), Quality of Public Administration (c.15), and Financial Sector (c.5) help to reduce the inefficient distance. While the other two criteria are not significant

PPP and Infrastructure Development: Fixed Effects as an Alternative Approach

- PPPs without combination contribute positively to infrastructure development
- PPPs combined with the following 5 CPIA criteria: Property Rights and Rules-based governance (c.12), Quality of Public Administration (c.15), Transparency, Accountability and Corruption in the Public Sector (c.16), Debt policy (c.3) and Financial Sector (c.5) contribute to infrastructure development
- The following PPPs and CPIA criteria: Transparency, Accountability and Corruption in the Public Sector (c.16), and Financial Sector (c.5) help to reduce the inefficient distance. While the Quality of Public Administration criterion (c.15) is no longer significant, and the Debt Policy criterion (c.3) becomes significant and increases the inefficient distance.

1.8. Conclusion

Given the paucity of empirical studies evaluating the effectiveness of public investment in SSA countries and the limited number of empirical studies on the determinants of the effectiveness of public investment, our paper has sought to fill this gap in the literature by proposing an approach to measuring ineffectiveness. In fact, our paper proposes to measure the inefficiency of public investment using an indicator of infrastructure development in Africa (AIDI) which, to the best of our knowledge, has never been used as an output in a stochastic frontier approach. Furthermore, given the lack of macro studies on the contribution of PPPs as most empirical studies on PPPs consist of anecdotal evidence and case studies, our paper analyzed the relationship between PPPs and the inefficiency of public infrastructure investments. Finally, our paper sought to innovate by looking at the determinants of inefficiency as measured by the CPIA criteria. In addition, the paper also looked at the effects of PPPs on economic growth. The effect of PPPs on frontier shifting as measured by GDP was analyzed and the role of PPPs as a determinant of inefficiency alongside KKZ governance indicators.

The paper began by analyzing the contribution of PPPs to economic growth and infrastructure development. Indeed, we observed that multisectoral PPP capital stock, when used as an explanatory variable, negatively shifts the efficient production frontiers for the vast majority of SSA countries for both outputs (GDP and AIDI). Therefore, we wanted to understand the combined effect of PPPs and CPIA criteria (having a causal effect with PPPs and the infrastructure development index) on AIDI. On the other hand, we also analyzed the combined effect of PPPs and KKZ governance indicator on GDP. The results showed an improvement in the contribution of PPPs when combined with the selected CPIA criteria compared to the situation where only PPPs are considered. We also noted a positive and significant contribution of PPP to GDP when combined with KKZ governance indicator.

Secondly, the paper looked at the role of PPPs as determinants of inefficiency. The results showed that PPPs help to reduce inefficiency for both estimation methods (SFA and AIDI as an output; and FE methods and GDP as an output). When GDP is used as an output, we noted the five (06) KKZ governance indicator show the expected negative signs, which mean they contribute to reducing the inefficiency distance. However Political stability despite its negative sign is not significant.

Unsurprisingly, when AIDI is used as an output, the five (05) CPIA criteria selected show the expected negative signs. However, only three (03) of them were significant. These are Financial Sector (c.5); Quality of Public Administration (c.15) and Transparency, Accountability and Corruption in the Public Sector (c.16).

The results obtained show the important role of PPPs and CPIA criteria in infrastructure development. They also showed the positive relation between PPPs, GDP and KKZ governance indicator. However, despite the positive contribution of PPPs to infrastructure development and GDP, their level of efficiency needs to be improved. Indeed, for most countries, PPPs have failed to improve efficiency in terms of both infrastructure development and economic growth. This level of inefficiency can be explained by the relatively low and large disparity encountered in governance indicators and CPIA criteria. In view of the positive impact of these governance indicators when

combined with the PPP, it would be useful to strengthen them to better benefit from the efficiency of PPPs.

Finally, a robustness analysis was carried out using a fixed effects estimation method as an alternative approach to analyze the effect of PPPs and CPIAs on infrastructure development instead of the SFA approach, the results obtained confirmed the robustness of our results. Indeed, we note that PPPs have a positive and significant effect on infrastructure development and even when combined with CPIA criteria. And when they are used as determinants of inefficiency, they help to reduce the inefficient distance as well as the other CPIA criteria used. Apart from the debt policy criteria, which has become significant and positive in our alternative approach.

In the future, it would be good to adopt a more sectoral approach to better analyze the efficiency of PPPs by sector. This is because multi-sector PPP investments do not make it possible to know which PPP sector suffers from more inefficiency.

We cannot conclude this study without outlining certain limitations. The main difficulty lay in measuring PPP investments. Indeed, some PPP investments could end up in the public investment balance sheet, given the absence of clear budgetary accounting in the countries studied. Also, the PPP investments analyzed only represent commitments at the financial closing stage and could therefore differ from the investments carried out.

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Appendices

1.A List of countries

Countries	
Burkina Faso	Namibia
Congo. Dem. Rep.	Nigeria
Congo. Rep.	Senegal
Côte d'Ivoire	Seychelles
Gabon	South Africa
Ghana	Tanzania
Kenya	Togo
Malawi	Uganda
Mauritius	Zimbabwe
Mozambique	

Note: the table presents the list of selected countries based on the availability of data for the analysis of the efficiency of multi-sector PPP investments

1.B Frontier shifting: CPIA as a dummy variable

Table 1.17: Estimation results for equations 8 and 9 using Dummy variables

	no CPIA		CPIA									
	no PPP	PPP	c.12		c.15		c.16		c.3		c.5	
			no PPP	PPP	no PPP	PPP	no PPP	PPP	no PPP	PPP	no PPP	PPP
Frontier												
Public capital stock	0.139** (3.14)	0.198*** (113.33)	0.143*** (3.30)	0.193*** (6.3e+05)	0.135** (3.05)	0.269*** (8.16)	0.248*** (9.31)	0.259*** (2.0e+05)	0.138** (3.10)	0.197*** (5.13)	0.220*** (6572.6)	0.214*** (8.65)
Private capital stock	0.104* (2.45)	0.455*** (361.69)	0.107** (3.11)	0.436*** (1.4e+06)	0.101** (2.88)	0.391*** (14.82)	0.486*** (14.52)	0.383*** (2.4e+05)	0.103** (2.93)	0.453*** (15.46)	0.512*** (1.7e+04)	0.448*** (14.48)
PPP capital stock		0.0343* (3.60)		0.0415*** (1.6e+05)		0.0372*** (7.28)		0.0522*** (1.1e+05)		0.0325*** (3.41)		0.037** (2.92)
CPIA criteria												
Property Rights and Rules-based governance (c.12)			0.253*** (5.28)	0.228*** (2.9e+05)								
Quality of Public Administration (c.15)					0.195*** (4.99)	0.0952*** (18.04)						
Transparency, Accountability and Corruption (c.16)							0.092*** (4.09)	0.095*** (2.5e+04)				
Debt policy (c.3)									0.119*** (3.90)	0.0503 (4.07)		
Financial Sector (c.5)											0.025*** (85.37)	-0.029 (-1.31)
LR test	926.9***	1308.4***	950.3***	1338.7***	930.3***	1308.9***	1231.2***	1307.9***	910.3***	1279.06***	1264.1***	1274.5***

Source: Author's estimation

Note: The table presents the comparative results between models with PPP combined with CPIA (captured by a dummy variable) and without PPP estimated by SFA approach. The asterisks indicate the level of significance of the t statistics based on the following * p<0.05, ** p<0.01, *** p<0.001.

1.C Investments Trend

According to a World Bank report (2017), the adequate provision of infrastructure services has long been considered an essential element of economic development, but Sub-Saharan Africa (SSA) ranks last of all regions in virtually every dimension of infrastructure performance. With infrastructure needs estimated in 2008 at 93.3 billion US dollars per year, the infrastructure deficit is estimated at 48 billion US dollars. Faced with such a deficit, PPP investments can contribute up to 25%, or around 12 billion US dollars, to reducing the deficit, according to Foster and Briceño-Garmendia (2010).

To put the evolution of infrastructure in SSA into perspective, a comparative analysis will be carried out between the different regions in Africa (Centre, East, West and South) and the other regions of the world (ALBA, ASEAN, and the European Union). Then, to understand the effect of investment in SSA, the overall performance of infrastructure will be analyzed, measured using the African Infrastructure Development Index (AIDI) and quality indicator, as well as the correlation between infrastructure investment and these indicators. **Table 1.18** shows the indicators used to measure the performance of infrastructure investments.

Table 1.18 : Infrastructure performance indicators

Index		Measurement unit
AIDI: quantity and access	Assesses the state and development of the 4 major infrastructures (ICT, Transport, Energy and Water) across the country.	100
IQUAL: Quality	Quality of the 5 major infrastructures: state of the infrastructures (ports, roads, railroads, communications, and energy).	7

Note: the table shows the two indicators used in the literature to measure the performance of PPP investments: the quality measured by IQUAL whose value is between 0 and 7 and the quantity and rate of coverage whose value varies between 0 and 100

Comparative analysis of public and PPP investment trends

Figure 1.7 shows that **PPP investments** are largely dominated by Asian countries, particularly those members of the Association of Southeast Asian Nations (ASEAN). In this region, PPP investment averaged 1.5% of GDP per year between 2000 and 2019. PPP investments peaked in 2012 at 2.7% of average GDP. ASEAN countries are followed by the countries of the Bolivarian Alliance for the Americas (ALBA), whose PPP investment averaged 0.5% of their GDP per year over the period 2000 to 2019. It is important to note that PPP investment has fallen sharply since 2000. In third place come the SSA countries, with an average PPP investment equivalent to 0.19% of their GDP. The biggest increase occurred between 2010 and 2012. The countries of the European Union show the weakest trend in terms of PPP investment measured as a percentage of GDP. Over the period analyzed, PPP investment in this region averaged 0.12% of GDP per year.

In sub-Saharan Africa, the average value of PPP is driven by the West region. From 2000 to 2019, PPP investments in this region averaged 0.34% of GDP per year. The West region is followed by the Centre region, with PPP investments equivalent to 0.21% of GDP

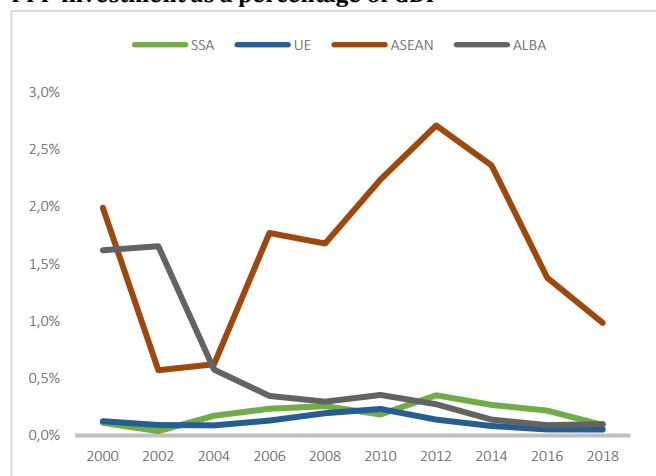
per year. In third place comes the South region with 0.11% of GDP per year. The weakest trend in PPP investment is found in the East region, which averages 0.08% of GDP per year.

The trend in **public investment** differs from that observed in PPP investment. A comparative analysis of trends shows that public investment has been highest in the ALBA countries. Over the analysis period, public investment averaged 8.2% of GDP per year. The ALBA region is followed by the ASEAN countries, where public investment over the same period averaged 5.6% of GDP per year. Lastly, for regions outside Africa, it is the countries of the European Union (EU) that occupy last place, with an average of 4.1% of their GDP allocated to public investment between 2000 and 2017. As a reminder, EU public investment as a proportion of GDP remains the lowest of the regions compared.

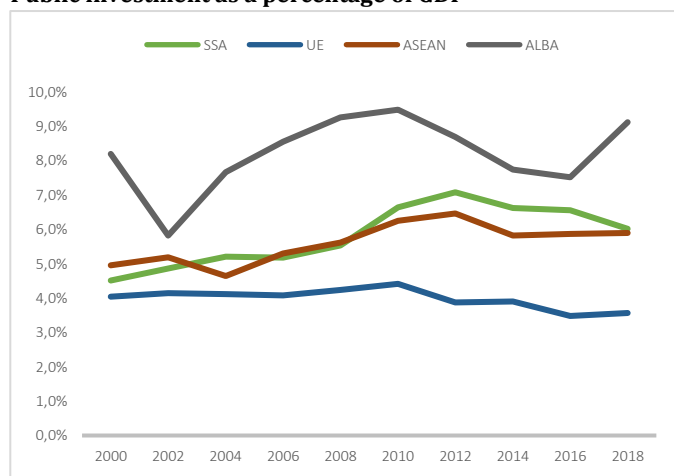
For sub-Saharan Africa, a comparative analysis of the four regions from 2000 to 2019 shows average public investment equivalent to 5.9% of GDP. It should also be noted that the trend in public investment is driven by the Centre region, with an average of 6.8% of GDP per year. It is followed by the East region, where public investment over the same period averaged 5.9% of GDP per year. Next comes the South, with an average of 5.8% of GDP per year over the same period. The West region comes last, with public investment equivalent to an average of 5.2% of GDP.

Figure 1.7: Comparison of public and PPP investment worldwide

PPP investment as a percentage of GDP



Public investment as a percentage of GDP



Source: author's estimate based on PPI, IMF and AfDB data

Note: The figure on the left shows the evolution of the multi-sector capital stock of the SSA as a function of GDP compared to other regions of the world; the figure on the right shows the evolution of the public capital stock as a function of GDP for different regions of the world including SSA

Infrastructure performance in SSA in terms of development

The figure below shows that infrastructure investment performed best in the South region, with an average level of development measured by the AIDI of 33.7 out of 100 in 2019. It is followed by the West region, with an average AIDI in 2019 of 20.7 out of 100. Next comes the Centre region, with an average AIDI in 2019 of 20 out of 100. In last place is the East region, with an average AIDI of 18.4 out of 100. However, in terms of progress in infrastructure development, the East region performed the best over the period analyzed, with a variation of 183%. It is followed by the West region with a rate of 111%.

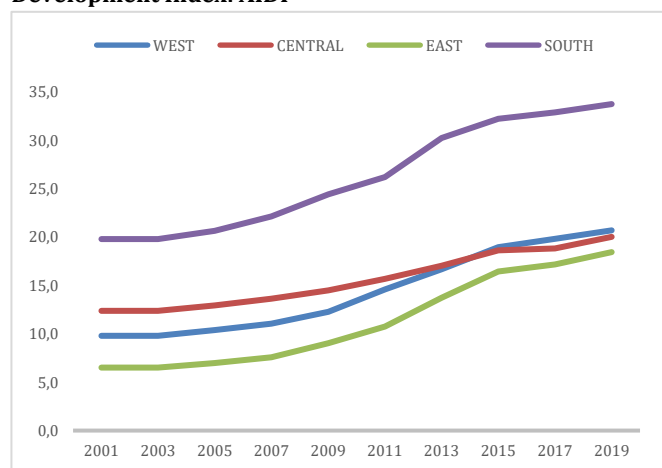
Next comes the South region, with growth of 70%, and lastly the Centre region, with a rate of 62%.

When it comes to infrastructure quality, the South and East regions come out on top, with average scores over the period analyzed of 3.46 and 3.45 out of 7 respectively. In third place comes the West region, with an average score of 3.15 out of 7. In last place we have the Centre region, with an average score of 2.88 out of 7.

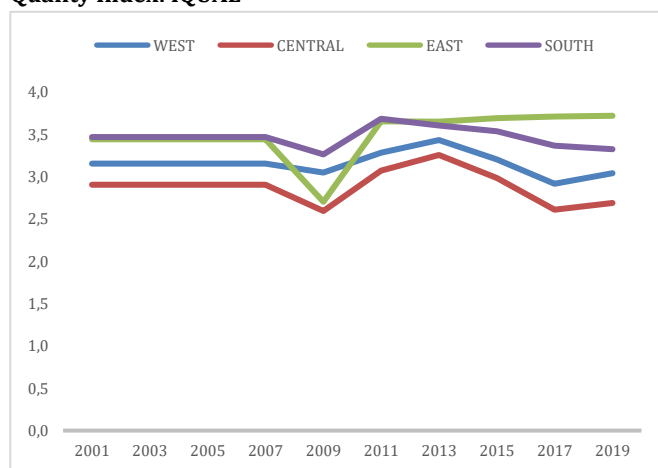
In absolute terms, there is a certain correlation between public investment and PPPs on the one hand and between public investment and AIDI on the other. This relationship is even stronger between AIDI and public investment. However, the relationship between the IQUAL (infrastructure quality), PPP and public investment is less clear. This could be explained by the nature of the quality measurement indicator based on perceptions of the quality and reliability of services obtained from the Global Competitiveness Report produced by the World Economic Forum.

Figure 1.8: Comparison of indicators by region in Africa

Development Index: AIDI



Quality Index: IQUAL



Source: author's estimate based on PPI, IMF, WEF and AfDB database

Note: the figure on the left shows the evolution of the AIDI indicator measuring the quantity and coverage rate for 4 SSA regions; the figure on the right shows the evolution of the IQUAL indicator measuring the quality of infrastructure for 4 SSA regions

1.D PPP notions

1. PPP Concept

According to the World Bank, there is no international consensus on the definition of a "public-private partnership". However, the various definitions of PPPs revolve around the following principles: arrangements, usually medium- to long-term, between the public and private sectors whereby certain services that are the responsibility of the public sector are administered by the private sector, sealed by a clear agreement on common objectives relating to the delivery of public infrastructure and/or services. This definition covers both PPPs providing new assets and services, and those involving existing assets and services. These may be PPPs in which the private entity is fully remunerated by the users of the service, or in which a government agency is responsible for all or part of the payments. Furthermore, the stages of the project transferred to the private entity, such as design, construction, financing, operation, and maintenance, can vary from one contract to another. In all cases, the private entity is responsible for the performance of the project and its operation and takes on a significant share of the risk. On this basis, we can easily see that there can be several types of PPP, depending on the tasks transferred, the nature of the project (service or infrastructure) and the method of payment.

a. Typology

From an institutional point of view, the government and the private partner can set up a structure in the form of a consortium or company to design, build, finance and operate a public infrastructure or service. Partnerships between government and the private sector can also be established on a purely contractual basis. The most typical type is the concession contract, whose golden age in the French-speaking world dates to the 19th century, and which has been used to build infrastructure such as railways, gas and electricity production and distribution facilities, and water supply networks. PPPs can be categorized according to several aspects of the contract or project, or the legal framework within which they operate.

PPPs can be divided according to payment method. Concession PPPs: these are PPPs whose revenues depend on user payments, known in many countries as "concessions". Public-payment PPPs: these are PPPs whose revenues come from public or budgetary funds, also known in English-speaking countries as Private Finance Initiatives (PFIs).

PPPs can also be distinguished according to the project site. The following categories are also common. Greenfield projects: investments in projects recently awarded or under construction under DBFOM-type contracts. Brownfield projects: investments in infrastructure projects that existed before the contract was awarded, or that had previously been greenfield, but are already in operation at the time of investment.

In addition to this categorization of PPPs, there may also be variants of the different types of PPP, which will be defined according to the tasks transferred to the private partner (Design, Build, Maintain, Operate and Finance) or the shareholding structure of the project company or special purpose vehicle - SPV: there are classic PPPs where the shareholding is 100% privately owned; institutional PPPs where the public sector owns the project company 100%; or mixed enterprises (including the private sector) where the public party controls the PPP company. This chapter does not consider this type of

institutional PPP, as the private sector is not sufficiently involved as an investor in the project company's capital, holding a significant share of the equity.

Finally, PPP contracts can be divided according to the mission and nature of the infrastructure. We will distinguish PPPs according to whether they involve infrastructure or public services. There are infrastructure PPPs: those designed to build and manage new infrastructure, and those designed to carry out major upgrades to existing infrastructure. Service PPPs or public service delegations: under which a private partner manages an existing infrastructure or merely provides or implements public services.

Public service delegations are defined as contracts in which the public authority entrusts a public service to a private party, whose remuneration is closely linked to its performance. In countries with a civil law tradition, there are four types of service delegation:

Concession: is a form of management in which the delegating public authority entrusts a person with the task of building a facility and/or operating a public service at its own risk, with remuneration from users. The public sector is involved in approving the concessionaire's tariffs and the level of services rendered. A distinction is generally made between works and/or service concessions.

“Gérance” is a type of partnership in which the public sector retains its assets, while the private sector operates and maintains the public administration's equipment and systems. The private sector does not commit capital and is remunerated by the public sector.

“Régie intéressée” is a contract under which a public entity entrusts a third party with the responsibility of operating a public service, with a profit-sharing arrangement.

“Affermage” is a contract under which a public entity hands over a facility to a third party, who operates it at its own risk. The price paid by the user is generally shared between the public entity, which has financed the investments and is responsible for part of their renewal, and the operator, who is responsible for the day-to-day running of the service and may be required to carry out a certain amount of work.

b. Common features of PPPs

Despite the wide variety of PPP types, there are several features common to all of them.

The nature of the contract: it is relatively long and generally aligned with the life of the infrastructure. In addition, it involves cooperation between the public and private partners on different aspects of the project.

Tasks: the aim of the contract is to transfer tasks to the private partner, while maintaining the project's economic optimum. The tasks to be transferred are as follows: design, construction, maintenance, operation, financing. The public partner concentrates primarily on defining the objectives to be achieved in terms of public interest, quality of service and pricing policy, and monitors compliance with these objectives. The private partner may be entrusted with several tasks, including the design, construction or

conversion of public works or facilities, their financing, maintenance and/or upkeep and/or operation and/or management. PPPs derive their effectiveness from the synergies created between different services: private partners are well placed to propose the best balance between a range of services to promote these synergies.

Financing: PPP financing is provided in part or in full by the private partner, sometimes through complex, structured arrangements involving various players. Private financing may be limited to financing by banks, industrialists, and funds, or it may call on the market, notably through bond issues on behalf of the project company. Public financing, sometimes very substantial, can also be added to private financing in the form of loans to the project company, guarantees or project subsidies.

Performance: as part of the PPP contract, the public authority defines the objectives to be achieved and is responsible for monitoring them. Reliable, quantifiable indicators enable it to better monitor and control the performance of the private partner. This makes it possible to ensure the quality of services and impose penalties when there are breaches of the contract or reward the quality of the private partner's performance. Such an approach provides a strong incentive for the company to deliver quality service.

Risk sharing: PPPs must involve risk sharing between the public and private partners. The risks transferred are generally borne by the public partner in the case of conventional financing. However, risks are transferred to the party best able to bear them. However, PPPs do not necessarily imply that the private partner assumes all, or the greater part of, the risks associated with the operation, which could be detrimental to the economic optimum of the project. Risks are allocated on a case-by-case basis, according to the respective abilities of the parties involved to assess, control, and manage them.

The structure of PPP contracts is often not advantageous for the public sector. Studies show that risk transfer, which is one of the main objectives of PPPs, is not always balanced. For example, Bel and al. (2017) point out that, although PPPs are designed to transfer certain risks to the private sector, in practice, African governments often find themselves bearing hidden risks that can compromise their ability to finance other public services. In addition, the governance structure of PPPs in Africa is often insufficient to ensure equitable risk sharing. Tariq and Zhang (2021) note that donor pressure on public sector inefficiency can lead to restructuring of public services towards privatization or PPP arrangements with risk transfers that are disadvantageous to the state and do not take local realities into account. In addition, the political agenda of decision-makers can undermine the economic optimum of PPP projects. Indeed, certain risks could be borne by the public party to finalize the project before the election deadline. Exposing public finances to budgetary risks over the long term of the contract

Procurement procedures: procedures are longer and more complex than for conventional contracts. The same procedures apply as for conventional contracts, with a few variations specific to PPP: competitive dialogue and unsolicited proposals. The former is used for complex projects where the public entity does not have full control over the project. In the latter, the private partner designs an innovative project of general interest and submits it to the public entity. In general, these unsolicited bids are prohibited in some jurisdictions, while in others legislation provides for reward systems for the private partner when its bid is not selected following a competitive bidding

process, or a competition that is more advantageous for the promoter of the unsolicited proposal than for the others.

2. Advantages and disadvantages of PPPs

a. Advantages of PPPs

For the World Bank Group (2014), it was the financial crisis of 2008 that sparked renewed interest in public-private partnerships (PPPs) in both developed and developing countries. As a result, governments are increasingly turning to the private sector as an additional alternative to fill the financing gap created by the constraints of public budgetary space in the face of the importance of infrastructure investment to develop their economies. There are many reasons why public authorities turn to PPPs. These include: (i) the search for effectiveness and efficiency, (ii) certain political or legal constraints, (iii) the search for innovation, (iv) the technical expertise of private partners, (v) the financial aspect.

One of the main reasons for using a PPP is the financial aspect. Under a PPP, financing is essentially borne by the private partner. This private-sector financing enables the public sector to reduce its need for borrowing or budgetary commitments, and to allocate public resources to other priority areas. Moreover, in a context where governments are struggling to deliver the services for which they are responsible, as the related tasks become increasingly diverse and complex, they are adopting approaches focused on results, efficiency, and innovation. As a result, the role of the state is evolving from that of a service state to that of a guarantor state. This is why the public sector is increasingly turning to PPP contracts, which call for greater responsibility on the part of the private sector. These agreements also simplify public procurement for the public authority, compared with the public market. The public authority has just one interlocutor, the private partner. It is the private partner who bears the transaction costs associated with the many specific contracts it must sign with lenders, the public works authority, users and consumers, rating agencies and other contractors.

PPPs are a means of introducing private-sector technology and innovation into the production of infrastructure and public services. Projects involve private-sector experts, giving the public sector privileged access to potentially new technical expertise. In this hypothesis, PPPs are a means for the local workforce to acquire new technical skills. It enables local private sector capabilities to be developed through joint ownership with major international companies, and as a subcontracting opportunity for local businesses in areas such as public works, electrical works, facilities management, etc. This makes it possible to offer better quality public services.

PPP promotes efficiency and effectiveness. It encourages the private sector to deliver projects on time and on budget. The use of a global contract enables the public authority to know the cost of infrastructure construction and maintenance as soon as the contract is signed, with the private partner committing to its prices, and any cost overruns remaining the responsibility of the private partner. The use of PPPs enables optimum economic efficiency, thanks to the socio-economic surplus arising from the faster completion of a work or service made available to the public. It provides a degree of budgetary certainty by defining the costs of present and future infrastructure projects over time. PPP enables long-term value for money to be achieved, thanks to an

appropriate transfer of risk to the private sector throughout the project: from design/build to operation/maintenance.

Setting up a PPP requires an in-depth analysis of the associated risks, and a detailed study of how they are to be shared between the public and private sectors, according to each party's ability to assume and minimize them. Risk allocation is effective when it guarantees greater efficiency and cost rationalization throughout the life of the project. In PPP projects, risks are assumed by the partner best able to manage them. For example, correcting construction errors during the execution phase that impact on the project's completion time is one of the risks to be assumed by the private sector. However, risks linked to the availability of land, causing delays and indirect costs, are borne by the contracting authority. On the other hand, risks related to unforeseen events during geotechnical excavations can be shared by both parties. The same applies to certain risks associated with force majeure (hand of God).

a. Disadvantages of PPPs

While PPPs offer several advantages, there are also disadvantages in certain circumstances. These PPP risks can significantly undermine effective project implementation. Its first advantage, the financial component, can be the first risk to efficient PPP project implementation. The PPP simply enables the strategic deferral of a public debt that will be paid by consumers (fees) and the state in any case. Because of shortcomings in budgetary accounting, some companies (sometimes deliberately) fail to carry forward certain debts or contingencies on their balance sheet. In a PPP contract, the State may provide guarantees for certain risks it transfers. The materialization of these risks constitutes a commitment with impacts on public finances. Thus, during the term of the contract, the State is obliged to pay rent or fees to the private partner, according to contracts with multiple clauses that are often of little benefit to the State. As a result, PPP contracts present a few risks and adverse effects, particularly for future generations. This impact on national debt, particularly in SSA countries with very high debt-to-GDP ratios, can have a crowding-out effect on other operating expenses and sometimes on other priority infrastructure projects. What's more, the cost of this debt is generally higher, as the private sector will only finance a project when the cash flows linked to its operation will provide a return on investment. This additional cost is borne either by users in the case of a PPP with tolls, or by the government through subsidies. When the project is financed in hard currency, as is the case in the majority of SSA countries that must resort to multilateral or bilateral financing, this entails high exchange risks, as project revenues are in local currency.

The relatively limited PPP capacities of governments represent a major risk to the achievement of project objectives. PPPs are, by their very nature, highly complex contracts in legal, technical, and financial terms. PPP Units or any other public structure in charge of evaluating PPP projects are often ill-equipped technically, financially and above all legally to negotiate balanced contracts with private partners. In fact, the costs of preparing PPP projects are higher than those of projects carried out under conventional contracts.

This lack of PPP capacity on the part of governments can further increase project costs and reduce the level of competition. Indeed, in PPP contracts, a minimum level of

competition must be guaranteed to achieve optimum use of resources. However, the lack of technical and financial capacity on the part of the public entity to prepare quality projects does not allow for competitive situations in the private sector. Faced with this shortcoming, projects are, in some cases, prepared by the private partner in the form of an unsolicited proposal and then proposed to the public entity. These types of projects are generally concluded by direct agreement with the promoter of the unsolicited proposal, without any further competition. This situation gives the promoter of the unsolicited proposal a monopoly position, enabling him to dictate market prices.

Despite their higher preparation costs and longer preparation times than traditional contracts, PPP projects are often subject to renegotiation due to poor project preparation resulting in unbalanced contracts between the parties. Guasch (2004) estimates that renegotiations are frequent and take place early in the project's implementation. In a sample of 1,000 concessions in Latin America and the Caribbean, 41.5% were renegotiated. This represents a rate of 74% if we consider only contracts in the water sector. On average, renegotiations take place 2.2 years after PPP contracts are signed, which seems to reinforce their opportunistic nature. This negotiation process is unquestionably longer than in the case of public procurement for the provision of infrastructure. Renegotiations are criticized both for their lack of transparency and because they can lead to tariff increases, job losses and delays in infrastructure commissioning (Eustache, 2006). While the private party is often blamed, other authors point to the opportunism of the public party, which may renegotiate for electoral purposes (Engel and al., 2006; Guasch and al., 2007).

We can't talk about the advantages and disadvantages of PPPs without remembering that they derive from the new public management approach. In Africa, the advantages of PPPs may be somewhat more mitigated by the fact that governments do not master the tool. Indeed, the evaluation of the effectiveness of public-private partnerships (PPPs) in the context of Sub-Saharan Africa reveals a mixed picture, where the private sector does not always prove to be more efficient than the public sector. This situation raises questions about the assumptions of New Public Management (NPM), which posits that introducing market mechanisms into public management enhances the efficiency and quality of services. However, these assumptions have been challenged both theoretically and empirically, particularly in developed countries, but less so in developing countries.

NPM is based on the idea that competition and results-based management, which are characteristics of the private sector, can be applied to the public sector to improve performance. However, recent studies show that this approach may not apply uniformly in the context of developing countries. For example, according to Morgan and al. (2016), although the private sector is a significant player in providing healthcare in many low- and middle-income countries, its role in achieving universal health coverage (UHC) varies considerably, and its efficiency is often questioned. In many cases, services provided by the private sector may be inaccessible or of lower quality compared to those of the public sector, which challenges the assumption of greater private sector efficiency.

Moreover, the challenges related to the implementation of PPPs in Sub-Saharan Africa, such as poor communication and service fragmentation, can also hinder their effectiveness. Johnson and al. (2018) found that inadequate communication approaches impede the ability of partnerships to achieve their goals, which can be particularly

problematic in the health sector. These coordination and communication issues can limit the positive impact that PPPs are expected to have on the efficiency of public services. Criticism of NPM is further reinforced by studies showing that PPPs can sometimes exacerbate inequalities in access to services. Ouma and al. (2018) highlight that, although the private sector plays a crucial role in access to emergency care, its impact remains poorly documented, and it may fail to meet the needs of the most vulnerable populations.

3. PPP justifications in SSA

In addition to the above-mentioned advantages of PPPs, such as private-sector financing of public infrastructure, efficient risk allocation, transfer of expertise and technology, use of innovative solutions, etc., there are other specific reasons for using PPPs in the SSA region. These include:

The financing gap and budgetary constraints: the difficulties faced by SSA countries in financing major infrastructure projects requiring substantial financial resources justify the use of PPPs. The AfDB's most recent estimates (AEO, 2024) project the financing gap at \$402 billion by 2030. Many African countries have limited fiscal room for maneuver and low fiscal capacity, which means they are not always able to take on major investments. This creates the need for a massive injection of private finance into the public sector. In this context, PPPs are interesting instruments for the long-term structural development of infrastructure and services.

To close the estimated financing gap, they will therefore need, among other things, to increase state tax revenues, improve the efficiency of public spending and demonstrate strong political will. State tax revenues have not increased much in most African countries to reach the 15% of GDP that developing countries need to adequately finance progress towards the SDGs. On top of this, debt levels are quite high. Africa's median public debt ratio, which rose from 54.5% of GDP in 2019 to 64% in 2020, underlines the persistence of the continent's debt burden. Below-target budget revenues and such high indebtedness put SSA countries in a position to seek concessional financing from multilateral development institutions. These institutions have limited concessional financial resources, which fall short of the countries' needs.

Private sector development and diversification of financing: In view of the role that the private sector must play in implementing PPPs, budget constraints and limited concessional financing, SSA states should sharpen their private sector development strategy. Structuring and supporting the local and regional private sector is crucial to the success of public-private partnerships (PPPs) in Africa. For PPPs to be truly "development tools" in the service of the region's emergence, it is essential to closely involve the local and international private sector in major national and regional projects.

States can diversify their sources of financing by accessing international private finance. PPPs offer a unique opportunity to mobilize private capital, which can come from a variety of sources such as banks, industrialists, and investment funds. In addition, capital markets represent another avenue of financing, notably through bond issues. The use of financial markets also creates opportunities for regional institutional investors, such as social security funds and insurance companies. These bond issues offer institutional investors

the chance to invest in long-term securities, meeting their need for secure, profitable long-term investments.

By diversifying their funding sources in this way, governments can reduce their dependence on traditional financing and increase the resources available for development projects. This approach not only improves the financial viability of infrastructure projects but also strengthens the role of regional institutional investors in the continent's economic development.

Development of local private sector: Small and medium-sized enterprises (SMEs) and small and medium-sized industries (SMIs) also have a role to play in the implementation of PPPs. Unfortunately, infrastructure projects are generally reserved for large multinationals. Some countries have legislated to require local content in PPP projects. However, the implementation of these requirements sometimes lacks political will. For example, in Madagascar, despite the adoption of a specific PPP law in 2015, the implementing decree for smaller-scale PPPs has still not been adopted. Yet it is in these smaller-scale PPPs that the local private sector could create value by entering PPP contracts with state-owned land consolidators. By participating in national or regional PPP projects, SMEs will benefit from long-term contracts, often guaranteed by the state or supranational entities. These medium-term contracts present a much lower level of risk than usual contracts, enabling SME-SMIs to present secure medium-term business plans. With a more stable financial outlook, these companies will have easier access to bank financing, enabling them to invest and develop the local and regional production base. As a result, the regional private banking sector will have opportunities to finance local SME-SMIs with significantly reduced risks. This will enable them to grant financing more easily and play a greater role in financing the local and regional economy.

To maximize these benefits, it is essential to ensure that the local economic fabric (SMEs) is well integrated into PPP projects within the various economic zones that make up SSA. In addition, it is advisable to include in procurement rules a "bonus" system for business groupings that involve local companies the most, right from the bidding stage. These measures aim to ensure that PPPs are not only instruments of economic development, but also catalysts for strengthening and structuring the local and regional private sector.

African integration through infrastructure development: Another reason why SSA countries need PPPs is that regional markets are very poorly integrated when it comes to infrastructure services, notably electricity, energy, water, and sanitation. This is exacerbated by the weakness of the regional economic communities (RECs), which suffer from insufficient capacity and are poorly structured to make or even attract the necessary regional investments. In addition, many governments have not worked sufficiently with the private sector to develop and improve regional infrastructure. Unfortunately, these regional infrastructures, which must ensure integration, require enormous resources that governments alone cannot mobilize. This is why it is necessary for SSA countries to resort to private financing within the framework of PPPs, which have significant direct positive effects. First, this mobilization enables increased financing of basic infrastructure, both economic and social. For example, in the economic sphere, PPPs facilitate the development of transport, energy, water and sanitation projects, as well as information and communication technologies (ICT). In addition, PPPs enable the widespread use of innovative and complex forms of financing, characterized by high financial leverage.

Blended finance mechanisms or green bonds are instruments that can attract significant private investment while promoting the implementation of resilient infrastructure.

Finally, based on the level of corruption observed on the continent, the negative effects of corruption on inclusive economic growth and the means deployed to remedy it, PPPs, through more transparent contracting procedures and by increasing the level of competition, can help reduce the risks of corruption.

1.E List of variables and sources

Variables Name	Unit	Variables definition	Sources
RegionGeo		Geographic region	Sahel and West Africa Club
RegionEco		Economic region	InOnAfrica
\$Total_ippp_m	in millions of constant 2017 international \$	<i>Sum of the PPP investments of the different sectors</i>	Private Participation to Infrastructure
\$Total_kppp_m	in millions of constant 2017 international \$	<i>Sum of depreciated PPP capital stock since the 1st PPP investment in a given country</i>	Author estimates
rGDP	in millions of 2017 US\$	<i>Real GDP at constant 2017 national prices</i>	Penn World Table version 10
\$igov_m	in millions of constant 2017 international \$	<i>General government investment (gross fixed capital formation)</i>	MFI, capital stock 2017
\$kgov_m	in millions of constant 2017 international \$	<i>General government capital stock (constructed based on "igov_m\$")</i>	MFI, capital stock 2017
\$ipriv_m	in millions of constant 2017 international \$	<i>Private investment (gross fixed capital formation)</i>	MFI, capital stock 2017
\$kpriv_m	in millions of constant 2017 international \$	<i>Private capital stock (constructed based on private investment flows "ipriv_m\$")</i>	MFI, capital stock 2017
ippp_m\$courr	in millions of currents US\$	<i>PPP investments of the different sectors</i>	Private Participation to Infrastructure
\$ipp_m	in millions of constant 2017 international \$	<i>PPP investment since the 1st PPP investment in a given country</i>	Private Participation to Infrastructure
\$kppp_m	in millions of constant 2017 international \$	<i>PPP capital stock (constructed based on "ipp_m\$")</i>	Author estimates
AIDI_Output			
AIDI_Global	0 - 100 best	<i>monitor the statuts and proress of the 4 major infrastructure (TIC, Transport, Energy and Water) development accross the country</i>	African Development Bank
WEF output			
WEF_Global	1-7 best	<i>Quality of 5major infrastructure: assess the state of infrastructure (ports, roads, railroads, communications, and energy)</i>	The Global Competitiveness Index Historical Dataset © 2007-2017 World Economic Forum Version 20180712
CPIA			
CPIA_Global	1-6 strong	<i>provides the average score of all the assessment components of policies and institutions covering: Economic Management, Structural Policies, Social Inclusion/Equity, Governance, Infrastructure Development and Regional Integration.</i>	African Development Bank
ConCorrup	Estimate of governance (ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance)	<i>Reflects perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests.</i>	The World Governance Indicators, 2020
RuleLaw	Estimate of governance (ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance)	<i>Reflects perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence.</i>	The World Governance Indicators, 2020
ReguQuali	Estimate of governance (ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance)	<i>Reflects perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development.</i>	The World Governance Indicators, 2020
GovEffec	Estimate of governance (ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance)	<i>Reflects perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies.</i>	The World Governance Indicators, 2020
VoicNAccoun	Estimate of governance (ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance)	<i>Reflects perceptions of the extent to which a country's citizens can participate in selecting their government, as well as freedom of expression, freedom of association, and a free media.</i>	The World Governance Indicators, 2020
PoliStabili	Estimate of governance (ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance)	<i>Political Stability and Absence of Violence/Terrorism measures perceptions of the likelihood of political instability and/or politically motivated violence, including terrorism.</i>	The World Governance Indicators, 2020
RuleBasedGov	1-6 strong	<i>Property Rights and Rule-based Governance</i>	African Development Bank
BudFinManag	1-6 strong	<i>Quality of Budgetary and Financial Management</i>	African Development Bank
QualPubAdm	1-6 strong	<i>Quality of Public Administration</i>	African Development Bank

TrasPAccCorr	1-6 strong	<i>Transparency, Accountability and Corruption in the Public Sector</i>	African Development Bank
BusRegEnv	1-6 strong	<i>Business Regulatory Environment</i>	African Development Bank
DeptPol	1-6 strong	<i>Debt Policy</i>	African Development Bank
FiscPol	1-6 strong	<i>Fiscal Policy</i>	African Development Bank
RevMob	1-6 strong	<i>Efficiency of Revenue Mobilization</i>	African Development Bank
FinSector	1-6 strong	<i>Financial Sector Development</i>	African Development Bank
MonPol	1-6 strong	<i>Monetary Policy</i>	African Development Bank

2. Measuring PPP Efficiency: a sectoral analysis of Electricity and Ports

Abstract: Adopting a sectoral approach, the second chapter proposes to measure the role of PPP investments in the ports and electricity sectors in shifting the efficient production frontier as well as their role in the electricity sector as determinants of inefficiency through stochastic frontier analysis. Using a stochastic frontier approach and fixed-effects estimation, the results showed a positive contribution of sectoral PPPs in the efficient frontier shift. However, the contribution of PPPs in the ports sector (3%) is greater than that of the electricity sector (1%). For the electricity sector, PPPs, credit to the private sector and the financial sector criterion (c.5) contribute to bridging the inefficient distance. While the criterion of quality of budgetary and financial management (c.13) increases the inefficient distance. In the port sector, trade openness, exchange rate and debt policy (c.3) reduce the inefficient frontier, while monetary policy (c.1) increases the inefficient frontier.

Keywords: Sub-Saharan Africa, Public-Private Partnership, Stochastic frontier, fixed-effects, CPIA, Electricity, Ports

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2.1. Introduction

The low level of both public and private investment in Africa, particularly in sub-Saharan Africa, is a major constraint to economic growth, as has been pointed out by several studies carried out by multilateral institutions (World Bank, 2011; OCDE, 2014; FMI, 2014). Africa's infrastructure needs are enormous. The latest estimates by Foster and Briceño-Garmendia (2010) put the figure at 93.3 billion US dollars a year. Faced with such a need for infrastructure, Sub-Saharan African countries have considerably increased their public investment. Indeed, in 2018, the Infrastructure Consortium for Africa (ICA) report on infrastructure financing trends revealed that funding reached a new record of US\$100.8 billion. A 24% increase on 2017 and a 38% increase on the 2015-2017 average. This record increase could not have been achieved without the contribution of the private sector through its investments. To this end, the SSA states have taken several initiatives to facilitate the private sector's participation in infrastructure investments. These include initiatives to improve the business climate. For example, in June 2012, the Conference of Heads of State and Government of the West African Economic and Monetary Union (UEMOA) called on member states and institutions to adopt a PPP-oriented mode of governance. Several African states have adopted new PPP laws and set up PPP Units. Regional and continental Institutions have adopted PPP strategic frameworks (BOAD, AfDB). According to the World Bank (2018, 2019), for most African states, there has been an increase in reforms aimed at facilitating the business climate to attract more investment. In 2020, these efforts led to a sharp rise in private sector investment. Private sector commitments reached 19 billion US dollars in 2020 (ICA, 2020).

Despite this rise in investment, especially in the private sector, which reached a record high in 2020, it should be noted that Africa has seen a drop in commitments over the last three years, marked by limited funding from China combined with the effects of the COVID-19 pandemic. This context does not help the already high financing gap. Indeed, infrastructure needs have been estimated at between \$130 billion and \$170 billion a year (African Economic Outlook, 2018). Faced with growing infrastructure needs and an unfavorable context, the question of investment efficiency is added.

According to Foster and Briceño-Garmendia (2010), of the US\$93.3 billion annual need for infrastructure spending, up to US\$17 billion could be found simply by using existing resources more efficiently. Questioning the efficiency of investments involves, among other things, defining the output measurement indicator and the determinants of this efficiency.

To get a better idea of the effectiveness of infrastructure investments, we first need to look at investment trends by sector. Investments are generally divided between social and economic infrastructure. In our paper, we are more interested in economic infrastructure. Investments in economic infrastructure are divided into four main sectors: ICT, Transport, Water and Energy. Although the trend analysis will focus on the four main sectors, the paper will place greater emphasis on the Energy sector, in particular the electricity sub-sector, and the Transport sector, in particular ports. These two sub-sectors were chosen due to the availability of information on their PPP projects compared to the other two sectors.

Traditionally, public investment studies on Africa have focused more on the relationship between public investment and economic growth (Murray and Lauer, 2000; Herrera and Pang, 2005; Gupta and al., 2007). When it comes to sectoral studies, these focus more on public investment (Maatala and al., 2019; Tongzon and al. 2005; Wanke and Barros, 2015; Albouchi and al., 2007) and the issue of sectoral PPP investment is very rarely addressed in the literature. Also, these studies on public investment in Africa have largely been carried out on a national rather than continental scale (Miningou, 2012; Diagne and al. 2014; Naoussi and al. 2019). Finally, the question of the determinants of public investment efficiency is rarely addressed in the literature (Barhoumi and al. 2018). When it is addressed, the determinants generally used are institutional and governance factors (Grigoli and Mills, 2013; Soumaila, 2017 and Albino-War and al. 2014).

In the face of this literature gap, our paper looks at: i) the efficiency of PPP infrastructure investments in the electricity and ports sub-sectors in SSA and ii) the role of determinants of PPP investments measured by the CPIA criteria and some classic determinants. In other words, it would be interesting to measure the determinants of PPP investments differently, notably through the CPIA criteria, and to use these CPIA criteria as determinants of the efficiency of electricity investments.

In summary, this paper aims to measure the efficiency of ports and electricity PPP investments respectively on container traffic and electricity coverage rate by comparing the production frontiers with and without PPP investments. More importantly, for the electricity sub-sector, the effect of PPP investments will be analyzed alongside the different AfDB CPIA criteria used as proxies for the determinants of PPP investments including. Thus, for the electricity sub-sector, we will test two hypotheses. The first is whether PPP investments combined with the CPIA criteria shift the production frontiers of SSA countries. Secondly, we will investigate the role of PPP investments together with CPIA criteria on the inefficiency of public investments. Furthermore, we will also analyze the effect of structural changes, measured by various instability crises, using dummy variables. For the Ports sub-sector, the first hypothesis is to measure the effect of PPP investments (without combining CPIA criteria) on efficient production frontiers. Secondly, we will analyze the effect of CPIA criteria as determinants of inefficiency alongside with some classic determinants. For the Electricity sub-sector, the paper covers 34 SSA countries; that of Ports covers 18 countries. The analysis period for both sub-sectors is from 2000 to 2019.

Our modelling strategy was as follows: first, we estimated the PPP capital stock for each sub-sector (Ports and Electricity) based on PPP investments taken from the World Bank's PPI database, in line with the PPP knowledge Lab's definition of a PPP. The perpetual inventory method was used to calculate PPP capital stocks for each sub-sector. The initial capital stock was assumed to be zero prior to the first PPP investment in each sector. The rate of depreciation is based on the country's income level, as estimated by the World Bank.

Once the sectoral PPP capital stocks had been estimated, the determinants of PPP investments were captured by the CPIA criteria. The CPIA criteria selected depend on their Granger non-causality test with both sub-sectors output and PPP capital stocks. Next, we analyzed the effect of each sectoral PPP capital stock on the displacement of its efficient production frontier. The analysis was carried out using a Cobb-Douglas

production function with the public capital stock, the non-PPP private capital stock and the sectoral PPP capital stock (combined with CPIA for the Electricity sub-sector and without CPIA combination, for the Ports sub-sector), used as inputs. The residuals are defined as the sum of the idiosyncratic error term and an additional term measuring the shortfall (technical inefficiency) in relation to the maximum output used. Next, we compared the frontiers obtained with and without the sectoral PPP capital stock.

We then analyzed the effect of CPIA criteria and some classic variables as determinants of inefficiency on the level of production measured by the various sectoral outputs. Indeed, for the Electricity sub-sector, we explore the relative importance of the sectoral PPP capital stock alongside CPIA criteria considered as exogenous variables in reducing or increasing technical inefficiency. For the Ports sub-sector, only the effect of CPIA criteria and some classic variables on the variation in technical inefficiency is analyzed.

The results obtained made it possible to identify the various CPIA criteria that could be used as proxies for the determinants of PPP investments. For the electricity sub-sector, two CPIA criteria: Financial Sector (c.5) and Quality of Budgetary and Financial Management (c.13), both of which have a Granger non-causal relationship, with both sector outputs and sector PPP capital stocks. We also analyzed the role of Exchange rate and credit to private sector as determinants. Furthermore, despite the positive and significant contribution of PPP investments to access to electricity, the shifting of the frontiers remains very limited without or with PPP investments. When electricity PPP investments are used as determinant of inefficiency, we note their contribution to reducing inefficiency distance to the frontier, as does Financial Sector criteria (c.5) and the variable: credit to the private sector. However, the Budget and Financial Quality criterion (c.13) does not contribute to improving access to electricity.

For the Ports sub-sector, Exchange rate, Trade openness and three CPIA criteria were selected: Monetary Policy (c.1), Debt Policy (c.3) and Quality of Public Administration (c.15), all of which have a Granger non-causal relationship with the sector's output and PPP investments. The results showed a significant and positive contribution of PPP investments to container traffic. In addition, Ports PPP investments improved the efficient production frontier by an average of around 3% compared to the situation without PPP investments. Used as determinants of inefficiency, Exchange rate, Trade openness, Debt Policy (c.3) and Quality of Public Administration (c.15) criteria contribute to improving the level of container traffic, while the Monetary Policy (c.1) criteria contributes negatively to container traffic.

Finally, to test the robustness of our results, alternative approaches were used to estimate our models. The results obtained through the estimation of models using fixed effects methods and generalized least squares confirmed the findings in both sectors. However, for the port sector, when monetary policy (c.1) and the quality of administration (c.15) are used as determinants of inefficiency, their effect is not significant.

The rest of the paper is organized as follows: section 2 presents the literature review on assessing sectoral investment efficiency. Section 3 contains the stochastic frontier analysis. Section 4 presents the alternative approaches. Section 5 gives a summary of results. Finally, section 6 concludes the paper.

2.2. Literature Review

PPPs can help to improve the efficiency of infrastructure projects by harnessing the expertise of the private sector (Moszoro and Gasiorowski, 2008). However, the evaluation of the performance of sectoral PPP investments can be problematic due to several factors. These factors may be related to data, evaluation methodologies, performance indicators (Roulet and al., 2015), or institutional governance (Marty and Reverdy, 2018). In addition to these challenges, there is also the fact that the literature on the economic impact of PPPs is very limited and often focuses on private-sector involvement in infrastructure. In general, the economic contribution of PPPs is limited to case studies comparing a before and after PPP situation (Fabre and Straub, 2019), where it is very difficult to establish a solid basis for comparison.

The first challenge in evaluating the economic impact of PPPs in general remains the availability and quality of data. Roulet and al. (2015) note that the reliability of results primarily depends on the data used. Indeed, such data can be incomplete and difficult to obtain. For example, energy production levels and the performance of energy infrastructure may not be accessible, which makes analyzing the sector's performance very challenging. Furthermore, in most studies assessing PPP performance, a control group with the same characteristics as the PPP has been identified. Identifying such a group is not an easy task due to endogeneity issues (Kossaï and al., 2010) which may come from three main sources: measurement errors, reverse causality and selection bias (Wooldridge, 2012).

Moreover, the number of stakeholders involved in the implementation of projects in the energy sector can exacerbate the difficulty in measuring performance, as it may vary depending on the stakeholders, making it challenging to establish reliable and consensual performance indicators (Roulet and al., 2015). The results of econometric analyses can vary significantly depending on the specifications and methods used. Marty and Reverdy (2018) emphasize the importance of selecting appropriate indicators and analysis methods to ensure that the results are reliable and relevant. For example, the findings of Gassner and al. (2009) regarding private sector participation in energy financing, obtained through the difference-in-difference methodology combined with Propensity Score Matching, differ from those obtained using a fixed-effects panel analysis.

In addition to these challenges related to evaluating the sectoral performance of PPPs, factors such as government policies, market fluctuations, and investment decisions can interact in complex ways. This makes it difficult to establish causal relationships, which can lead to inaccurate conclusions regarding the effectiveness of investments (Araujo and al., 2010).

The difficulty in establishing performance indicators for PPPs is common across all sectors. In the port sector, for instance, the diversity of PPP objectives makes it challenging to create uniform indicators. According to Merk and al. (2011), port performance is influenced by a variety of factors, including governance policies, infrastructure, and market dynamics. Another challenge in developing these indicators is that they primarily focus on performance and do not account for the enhancement of accountability and transparency among the involved actors (Barone and al., 2016). Additionally, the complexity of governance structures in the port sector can create

ambiguities regarding the responsibilities and roles of different stakeholders (Gallouj and al., 2015). Gesualdi-Fecteau and Vallée (2018) echo this by stating that institutional factors, such as regulations and public policies, have a direct impact on the ability of PPPs to achieve their objectives, highlighting the importance of institutional reforms in achieving efficiency goals.

For example, Estache and al. (2002) studied the effect of port reforms in Mexico. The authors point out that during the 1990s, the need to increase port efficiency led most Latin American and Caribbean countries to implement reforms aimed at introducing more competition by allowing firms to participate in production. Using panel data from 11 ports between 1996 and 1999, they estimated that the reforms increased the average level of efficiency by around 5 percentage points, while the average growth rate in port efficiency was between 2.8% and 3.3%.

In a complementary study, Estache and al. (2004) decomposed the productivity changes that occurred for Mexico's 11 main ports between 1996 and 1999, two years after the reforms. Using a DEA decomposition approach of a Malmquist TFP (Total Factor Productivity) index, the authors found that TFP in Mexican ports increased by 4.1% per year from 1996 to 1999. Despite the potential limitations of the DEA approach to studying efficiency in port sectors, Wanke and al. (2015) used this approach to assess the impact of PPPs on scale efficiency in Brazilian ports. Using 2012 data from 27 ports in Brazil, the authors concluded that PPPs appear to be an effective means, within the Brazilian regulatory system, that can move port operations towards their most productive size given that PPPs have a positive impact on port scale efficiency.

While there are a few studies that have measured the impact of PPP investments in certain sectors, it is very rare to find studies that have used PPPs as determinants of inefficiency in infrastructure development. However, Chen and Guo (2020) analyzed from 2000 to 2017, the efficiency of transport investments for 20 countries participating in the 21st Century Maritime Silk Road Initiative using an SFA approach. The authors found that PPPs, in general, improve investment efficiency. In a new study, Chen (2021), uses data from 31 Chinese provinces covering the period 2003 to 2018 to assess the efficiency of infrastructure investments as well as that of PPPs compared with investments made by the Government. The results obtained show a very low efficiency score of 0.449 for infrastructure investments. In addition, the author found that PPP investments increased the efficiency of infrastructure investments more than Government investments alone.

2.3. Stochastic boundary analysis

2.3.1. Data

For the Electricity sub-sector, the study sample comprises 34 countries in Sub-Saharan Africa (SSA). For the Ports sub-sector, our sample comprises 18 countries. The time horizon covers the period from 2000 to 2019. Countries were selected based on PPP investment experience in both sub-sectors. In addition, only PPP projects in the PPI database meeting the definition of a PPP as indicated by PPP Knowledge Lap were selected. Consequently, all privatization projects (partial or total), short-term leasing and management contracts, as well as merchant projects in which a private developer builds a new facility in a liberalized market, and for which the government provides no

guarantee of revenue or payment, are excluded from this database. To ensure the consistency of the database, a field survey was carried out to collect data on PPP investments in certain countries.

Choice of model outputs

According to the literature, infrastructure efficiency is generally measured by means of a (physical) productivity or quality indicator. Thus, for the **electricity sub-sector**, a productivity indicator has been used. This indicator is the rate of access to electricity. It is taken from the World Bank (WDI) database.

For the **ports sub-sector**, we also used a productivity indicator. However, this indicator has been developed by us to align with the estimation methodology of the African infrastructure development index (AIDI). In fact, the indicator used results from the World Bank (WDI) database on container traffic in ports, measured in TEU and then standardized on a scale of 1 to 100 to keep the same proportions as the AIDI developed by the AfDB. Other outputs could have been used, such as port fees trends. However, the challenge lies in the availability of data. Indeed, the challenges of measuring port fees trends in SSA stem from data limitations, diverse pricing systems, currency fluctuations, regulatory changes, infrastructure disparities, and external influences. These factors contribute to the complexity and variability in tracking trends over time.

Instead of the non-parametric method, DEA, the standard approach very often used in the literature (FMI, 2015a; Grigoli and Kapsoli, 2013; Albino-War and al. 2014), we will use a parametric SFA approach with a view to provide food for thought on the results obtained using a different approach.

Choice of model inputs

For both sub-sectors, private-sector participation in infrastructure financing will be captured on the one hand by sectoral PPP investments, and on the other by private investments not carried out as PPPs. To measure non-PPP private investment, the private capital stock estimated by the IMF will be used as a proxy. Three inputs are therefore considered: public investment, sectoral PPP investment and private capital stock. As a reminder, the sectoral PPP capital stock was built up from the base of projects meeting the definition of a PPP retained in the document and estimated by the perpetual inventory method using an investment depreciation rate provided by the World Bank based on a ranking of countries according to their income. The other two capital stocks were already estimated by the IMF. PPP sector investments are broken down over five years as in IMF (2015a) to consider, the lead time for project implementation.

Choosing the determinants of inefficiency

For the Electricity sub-sector, given that our paper focuses on the effects of PPP sector investments on shifting the efficient frontier and reducing the distance to the efficient frontier, it is imperative to consider the determinants of PPP investments. It also turns out that the determinants of PPP investments are relatively like the determinants used to measure the inefficiency of public investments, with the exception that PPP determinants

are more exhaustive. As a reminder, the variables generally used in the literature as determinants of public investment inefficiency can be divided into two categories: macroeconomic variables and institutional and governance variables. PPP determinants measured as proxies for country CPIA criteria will be retained as determinants of inefficiency. To the best of our knowledge, this is a novelty in the literature. Furthermore, they will be used as determinants of inefficiency.

A table describing all the variables to be used, and their sources can be found in the appendix. The list of countries is also presented in the appendix.

Granger non-causality

The **Table 2.1** shows the optimal delay, z-bar tilde statistics and p-values of the Granger non-causality test for the two sub-sectors (Ports and Electricity). The test is performed on the relationship between output and the determinants of inefficiency on the one hand, and between the PPP sector capital stock and the determinants of inefficiency on the other, in a heterogeneous panel by Juodis, Karavias and Sarafidis (2021). To analyze the shift of the efficient frontier without or with PPP as well as the role of PPP as a determinant of inefficiency, only CPIA criteria (or determinants) with a Granger non-causal effect (CPIA Criteria $\rightarrow$ Output) and (CPIA Criteria $\rightarrow$ PPP) will be retained.

Table 2.1 : JKS (2012) Granger non-causality test results

ELECTRICITY						
	(1)			(2)		
	H0: Determinants do not Granger cause Output			H0: Determinants do not Granger cause PPP		
CPIA (Determinants)	Optimal lag	z-bar tilde	p-value	Optimal lag	z-bar tilde	p-value
Monetary Policy (c.1)	1	1.92	0.055	1	-2.20	0.028*
Fiscal Policy (c.2)	1	2.84	0.005**	1	1.73	0.083
Debt Policy (c.3)	1	2.40	0.005**	1	0.26	0.798
Financial sector (c.5)	1	6.25	0.016*	1	5.63	0.000***
Business Regulatory Environment (c.6)	1	-1.70	0.088	1	-2.81	0.005**
Property Rights and Rule-based Governance (c.12)	1	2.24	0.025*	1	1.88	0.06
Quality of Budgetary and Financial Management (c.13)	1	3.71	0.000***	1	-2.74	0.006**
Efficiency of revenue mobilization (c.14)	1	1.54	0.123	1	-0.59	0.552
Quality of Public Administration (c.15)	1	1.00	0.316	1	-3.54	0.00***
Transparency, Accountability and Corruption in the Public Sector (c.16)	1	2.23	0.026*	1	-1.10	0.273
PORTS						
	(1)			(2)		
	H0: Determinants do not Granger cause AIDI			H0: Determinants do not Granger cause PPP		
CPIA (Determinants)	Optimal lag	z-bar tilde	p-value	Optimal lag	z-bar tilde	p-value
Monetary Policy (c.1)	1	6.33	0.000***	1	-3.28	0.001**
Fiscal Policy (c.2)	1	5.35	0.000***	1	-1.36	0.174
Debt Policy (c.3)	1	7.42	0.000***	1	3.48	0.001**
Financial sector (c.5)	2	6.66	0.000***	1	-0.85	0.394
Business Regulatory Environment (c.6)	1	2.72	0.007**	1	-1.39	0.165
Property Rights and Rule-based Governance (c.12)	1	3.05	0.002**	1	0.25	0.803
Quality of Budgetary and Financial Management (c.13)	1	6.55	0.000***	1	-1.44	0.150
Efficiency of revenue mobilization (c.14)	1	4.77	0.000***	1	-1.52	0.129
Quality of Public Administration (c.15)	1	3.23	0.001**	1	6.70	0.000***
Transparency, Accountability and Corruption in the Public Sector (c.16)	1	1.77	0.077	1	3.30	0.001**

Source: Author's estimation

Note: The table displays the results of non-causality in the sense of granger as a function of the value for the two sectors: electricity and Ports. For electricity, column (1) analyses the non-causal relationship of the determinants (CPIA) to the output (Coverage ratio). The measure column (2) analyzes the non-causal relationship of determinants (CPIA) to input (PPP). For ports, column (1) analyzes the non-causal relationship of determinants (CPIA) to output (level of container traffic). The measure column (2) analyzes the non-causal relationship of determinants (CPIA) to input (PPP).

2.3.2. Stochastic frontier model specification and estimation methods

Two approaches are generally used to measure economic inefficiency: the parametric approach or stochastic frontier analysis (SFA) and the non-parametric approach or data envelopment analysis (DEA) technique (Murillo-Zamorano, 2004). Despite their advantages and disadvantages, empirical studies seem to confirm that neither approach is preferable to the other (Bjurek, Hjalmarsson and Forsund, 1990; Ray and Mukherjee,

1995; Chakraborty, Biswas, and Lewis, 2001). In line with this logic, a parametric approach has been chosen for our paper instead of a non-parametric one.

The choice of model is guided by the institutional and production environments in which the Electricity and Ports sub-sectors to be studied operate, and by the data used. To this end, the basic model used in our study is specified as follows:

$$y_{it} = \alpha_i + f(x_{it}, \beta) + v_{it} - \eta_i - u_{it}^* \quad (1)$$

y_{it} is taken to be the output of i^{th} country in year t ; α_i is the fixed effect representing heterogeneity between different countries; $f(x_{it}, \beta)$ is the production technology (Cobb-Douglass or Translog); x_{it} is a vector of input quantities of i^{th} country in year t ; β is the vector of associated parameters to be estimated; v_{it} is the idiosyncratic error term; $(\eta_i + u_{it})$ is the total inefficiency of which the first (positive) term η_i is the persistent and the second (also positive) u_{it} is the time-varying inefficiency.

Equation (1) represents the stochastic production frontier considering inefficiency, represented by two positive terms: $(\eta_i + u_{it})$. Apart from the randomness represented by the error term v_{it} , the deviation of production from the frontier of country i at time t is due to its technical inefficiency $(\eta_i + u_{it})$.

While identifying the magnitude of persistent inefficiency may be important, at least for panel data with a short time T (Kumbhakar and Heshmati, 1995), there is no economic rationale for or against considering individual effects as persistent inefficiency (Kumbhakar and al., 2014). In our paper, the time horizon, T , is relatively large and considering this persistent inefficiency is to say that there has been no progress in either sub-sector since 2000. Consequently, the persistent inefficiency η_i will not be retained. Thus, Model 1 can be rewritten as follows:

$$y_{it} = \alpha_i + f(x_{it}, \beta) + v_{it} - u_{it}^* \quad (2)$$

Model 2 separating individual heterogeneity from time-varying inefficiency is like the model proposed by Greene (2005a). In our model, α_i is the fixed effect. Consequently, an incidental parameter problem arises (Neyman and Scott, 1948). To circumvent this problem Greene (2005b) proposes a solution by assuming that the u_{it}^* follows a semi-normal distribution, including N dummy variables for all α_i ranging from 1, ..., N and estimating by the Maximum Likelihood method without any transformation.

Electricity sector

2.3.3. The role of PPPs in moving the production frontier

In this section, we will analyze the role of PPP investments in the electricity sub-sector. Indeed, we will analyze their role in shifting the frontier as measured by the rate of access to electricity. In this document, PPP investments in the electricity sector are defined as all PPP projects carried out by a given country during the analysis period.

Drawing on the work of Greene (2005a,b), the model below will be estimated using the Maximum Likelihood Method (MLE).

$$y_{it} = \alpha_i + X_{it}\beta + \varepsilon_{it}, \quad (3)$$

$$\varepsilon_{it} = v_{it} - u_{it} \quad (4)$$

$$v_{it} \sim N(0, \sigma^2_v), \quad (5)$$

$$u_{it} \sim N^+(0, \sigma^2_u), i = 1, \dots, N, t = 1, \dots, T \quad (6)$$

v_{it} represent the random error terms, independently distributed according to the normal distribution; u_{it} are the non-negative random error terms, which are assumed to account for technical inefficiency in production and are iid according to the semi-normal distribution.

This section of the paper analyses the role of PPP investment in the electricity sector, combined with its determinants as measured by the CPIA criteria³, in shifting the efficient production frontier. In addition to the CPIA criteria, we have added the exchange rate to assess its effect on access to electricity, as explained above."

$$y_{it} = \alpha_i + X_{it}\beta + Y_{it}\gamma + (v_{it} - u_{it}) \quad (7)$$

$$y_{it} = \alpha_i + X_{it}\beta + Y_{it}\gamma + Z_{it}\delta + (v_{it} - u_{it}) \quad (8)$$

y_{it} is taken as the logarithm of production in the i^{th} country in year t . This production is measured by the rate of access to electricity for each country. X_{it} , Y_{it} and Z_{it} are the vectors of the i^{th} country's input quantities in year t , measured respectively by the logarithm of the public investment capital stock, the logarithm of the private capital stock and the logarithm of the PPP capital stock in the electricity sector, combined with the CPIA criteria added one by one. The role of the CPIA criteria without combination with the PPP capital stock will also be analyzed to compare effects.

In equation (7), the maximum rate of access to electricity depends on the public capital stock (X) and the private capital stock (Y). In equation (8), the frontier shifts when, in addition to X and Y , the PPP sector capital stock variable associated with the CPIA criteria and exchange rate are added to the list of explanatory variables. Among the CPIA criteria, two (02) have a Granger non-causal relationship with both the output, rate of access to electricity, and the PPP sector capital stock. These are: Financial Sector (c.5), Quality of Budgetary and Financial Management (c.13).

We now need to assess the marginal contribution of PPP investments in the electricity sector combined with the two (02) determinants: Financial Sector (c.5), Quality of Budgetary and Financial Management (c.13) and the exchange rate. Thus, we will compare the following equations: 7 and 8. This involves comparing the equations when $\delta = 0$ and when $\delta \neq 0$.

³ According to the causality test, only two criteria meet the conditions: c.5 and c.13.

The estimated coefficients of equations (7) and (8) are presented in **Table 2.2**. Regarding the statistical relevance of inefficiency, the results of the Likelihood Ratio (LR) tests show that technical inefficiency plays a non-negligible role in explaining distance from the production frontier. This justifies our decision to consider a stochastic rather than a deterministic frontier.

Having analyzed the statistical relevance of inefficiency, in a second step we tested the most appropriate form of production function between Translog and Cobb-Douglas. To do this, we tested for both models, i.e., the one including the PPP capital stock ($\delta \neq 0$) and the one not including the PPP capital stock ($\delta = 0$) with the null hypothesis $H_0: \beta_4 = \beta_5 = \beta_6 = \beta_7 = \beta_8 = \beta_9 = 0$ or $\beta_3 = \beta_4 = \beta_5 = 0$ respectively. If the null hypothesis is accepted, then the Cobb-Douglas specification will be the most suitable. With the LR test based on the following statistic: $LR = -2\{\ln[L(H_0)/L(H_1)]\}$ where $L(H_0)$ and $L(H_1)$ correspond to the Cobb-Douglas and Translog likelihood functions respectively, we accept the null hypothesis in both models. We find when there is no PPP capital stock ($\delta = 0$) a LR test = -1.9617 which is lower than $\chi^2 (3 ; 0.001) = 15.357$ (according to the Kodde and Palm table) and when PPP capital stock is in the model ($\delta \neq 0$), a LR test = -1.8577 which is lower than $\chi^2 (6 ; 0.001) = 21.666$ (according to the Kodde and Palm table). In both models we cannot reject the null hypothesis. Consequently, the Cobb-Douglas form is more appropriate.

Unsurprisingly, the results presented in **Table 2.2** show the positive and significant contribution of public and private capital stocks to access to electricity both with and without the presence of PPP capital stock in the equation. Concerning our variable of interest, we find that PPP investments in the electricity sector (PPP capital stock) are significant and contribute positively to access to electricity. More importantly, we find that when PPP capital stock is combined with an CPIA criteria, its contribution to infrastructure development remains significant and positive. When the CPIA criteria are considered alone, without combining them with PPP investments in electricity, the results show that public and private capital stocks remain positive and significant. However, Financial Sector (c.5) and Quality of Budgetary and Financial Management (c.13) are not significant.

When we consider the exchange rate, we observe that the results remain the same. The stocks of public and private capital remain positive and significant with or without the combination of the exchange rate. Furthermore, the exchange rate is positive and significant when integrated without combining it with PPPs. When the exchange rate is combined with the stock of PPP capital, we note a positive and significant contribution of the latter to the rate of access to electricity. This result can be explained by the exchange regime adopted by the analyzed countries. Indeed, although the exchange regimes vary, most of the countries in our database follow a fixed or managed float exchange rate regime. In addition, in some countries, electricity production relies more on local resources (hydropower, solar, etc.), thereby reducing the impact of exchange rate volatility. In summary, a stable and favorable exchange rate can facilitate PPP investments, reduce import costs, and improve the profitability of electricity projects, which contributes to increasing the rate of access to electricity.

Table 2.2 : Estimation results for equations 7 and 8 (Electricity) using SFA

	no CPIA		CPIA				Exchange Rate	
	no PPP	PPP	c5		c13		no PPP	PPP
			no PPP	PPP	no PPP	PPP		
Frontier								
Public capital stock	0.390*** (11.10)	0.470*** (9.24)	0.387*** (11.07)	0.457*** (8.91)	0.388*** (11.02)	0.471*** (9.27)	0.399*** (111.4)	0.500*** (10.06)
Private capital stock	0.332*** (9.45)	0.243*** (4.92)	0.299*** (7.79)	0.214*** (4.10)	0.326*** (8.98)	0.230*** (4.45)	0.325*** (9.27)	0.231*** (4.83)
PPP capital stock		0.041** (2.93)		0.043** (3.10)		0.0404** (2.88)		0.036** (2.80)
CPIA criteria								
Financial Sector (c.5)			0.072 (2.11)	0.068 (1.74)				
Quality of Budgetary and Financial Management (c.13)					0.0195 (0.70)	0.0325 (0.90)		
Exchange Rate							8.07e-11** (2.82)	-2.79e-10 (-0.74)
LR test	1719.2***	1034.5***	1723.3***	1027.1***	1701.9***	1012.9***	1845***	1048.6***

t statistics in parentheses

* p<0.05, ** p<0.01, *** p<0.001

Source: Author's estimation

Note: The table presents the comparative results between models with PPP and without PPP, while accounting for the interactions between PPP, the exchange rate, and CPIA criteria added one by one. The asterisks indicate the level of significance of the t statistics based on the following * p<0.05, ** p<0.01, *** p<0.001

Using the Jondrow and al. (1982) formula, we estimate individual and average inefficiencies. Comparing the frontiers without and with PPP investments, we find that the frontiers are virtually identical. However, PPP investments in the electricity sector have slightly improved access to electricity. In other words, our results show perfect efficiency when PPP investments in the power sector are considered. However, without these PPP investments, our results show an average decline in efficiency of 1% over the analysis period.

Analysis of Structural changes related to instability

Given the political instability experienced by some countries during the analysis period, we will consider the effects of this instability in our results. This instability will be measured using a dummy variable, with a value of 1 for instances of civil war, coups, or post-election crises, and 0 otherwise. **Table 2.3** provides an overview of the different crises experienced by the countries included in the database during the analysis period.

Table 2.3: Political, Social, and Military Crises from 2000 to 2021

Country	Period of Crisis
Sierra Leone	1991-2002 (civil War)
Côte d'Ivoire	2002-2007 (politico-military Crisis), 2010-2011 (Post-election Crisis)
Democratic Republic of Congo (DRC)	1998-2003 (Second Congo War)
Chad	2005-2010 (Riots and armed conflicts)
Burundi	1993-2005 (Civil War), 2015 (Post-election Crisis)
Kenya	2007-2008 (Post-election Crisis)
Angola	1975-2002 (Civil War)
Mali	2012 (Coup d'état and rebellion in the north)
Burkina Faso	2014 (Insurrection and fall of Compaoré), 2015 (Coup d'état)
Guinea	2008 (Coup d'état), 2009 (Conakry Massacre)
Niger	2010 (Coup d'état)
Togo	2005 (post-election crisis)
Mali	2012 (Coup d'état and rebellion in the north)
Madagascar	2009 (Political crisis)

Note: This table lists all political, economic, and military crises that occurred in the analyzed countries during the period from 2000 to 2019

The results of the estimation, taking instability into account, are not different from the previously obtained results. Indeed, when the two CPIA criteria are not considered, and an interaction is created between the new variable measuring instability and the PPP capital stock, we find that both public and private capital stocks remain positive and significant. The PPP capital stock also remains positive and significant. When the interaction is created between the new variable measuring instability and the two CPIA criteria, we observe that the contribution of the three capital stocks remains positive and significant. However, none of the interactions are significant. This suggests that instability has not had a significant effect on the electricity access rate. This could be explained by the fact that before implementing PPP investments, a thorough risk analysis is conducted, and risk mitigation measures related to instability are proposed. Furthermore, private investors are often protected by clauses that guarantee project continuity. Additionally, multilateral development institutions (such as the World Bank, the African Development Bank, and other development finance institutions) continue to support energy access projects even in countries affected by crises. Finally, the nature of certain crises does not have a widespread impact across the entire territory. Some crises are concentrated in specific areas, while more stable regions may continue to benefit from improvements in electricity access.

Table 2.4: Estimation of equations 7 and 8 considering instability

	no CPIA		CPIA							
	no PPP	PPP	c.5		c.5*Instability		c.13		c.13*Instability	
			no PPP	PPP	no PPP	PPP	no PPP	PPP	no PPP	PPP
Frontier										
Public capital stock	0.498*** (9.47)	0.478*** (9.10)	0.387*** (11.07)	0.457*** (8.91)	0.487*** (9.14)	0.464*** (8.72)	0.388*** (11.02)	0.471*** (9.27)	0.497*** (9.42)	0.494*** (9.66)
Private capital stock	0.280*** (5.80)	0.231*** (4.59)	0.299*** (7.79)	0.214*** (4.10)	0.264*** (5.25)	0.208*** (3.94)	0.326*** (8.98)	0.230*** (4.45)	0.263*** (5.12)	0.223*** (4.38)
PPP capital stock		0.041** (2.93)		0.043** (3.10)		0.043** (3.09)		0.0404** (2.88)		0.036** (2.80)
Instability*PPP	0.005 (0.70)	0.003 (0.39)								
CPIA criteria										
Financial Sector (c.5)			0.072 (2.11)	0.068 (1.74)	0.047 (1.17)	0.059 (1.49)				
Instability*PPP*c.5					0.001 (0.55)	0.0005 (0.25)				
Qual. Bud. and Financ. Management (c.13)							0.0195 (0.70)	0.0325 (0.90)	0.040 (1.11)	0.029 (0.83)
Instability*PPP*c.13									0.0011 (0.51)	-0.0002 (-0.12)
LR test	1710.6***	1023.0***	1723.3***	1027.1***	1019.0***	1011.7***	1701.9***	1012.9***	1011.0***	1028.6***

Source: Author's estimation

Note: Note: The table presents the comparative results between models with PPP and without PPP, while accounting for the interactions between PPP, instability, and CPIA criteria. The asterisks indicate the level of significance of the t statistics based on the following * p<0.05, ** p<0.01, *** p<0.001

2.3.4. The role of PPP as determinants of inefficiency

In this section, we will investigate the role of PPP investments in the electricity sector and the CPIA criteria selected as determinants of inefficiency. Still drawing on the work of Greene (2005a, b), we will repeat the model specified above, this time considering the determinants of inefficiency including PPP investments. In addition to these determinants, we will also analyze the role of credit extended to the private sector, considering its role in financing infrastructure through PPPs. The model below will be estimated using the Maximum Likelihood Method (MLE).

$$y_{it} = \alpha_i + X_{it} \beta + \varepsilon_{it}, \quad (9)$$

$$\varepsilon_{it} = v_{it} - u_{it} \quad (10)$$

$$u_{it} = f(z_{it} \delta), \quad (11)$$

$$v_{it} \sim N(0, \sigma^2_v), \quad (12)$$

$$u_{it} \sim N^+(u_{it}, \sigma^2_u), i = 1, \dots, N, t = 1, \dots, T \quad (13)$$

u_{it} is a function of the non-stochastic determinants of inefficiency z_{it} ; δ is the vector of associated parameters to be estimated.

Empirical models: Functional and econometric specification

The empirical model used to measure the role of PPPs and CPIA as determinants of inefficiency is as follows:

$$\ln \text{infcovr}_{it} = \beta_0 + \beta_1 \ln \text{public}_{it} + \beta_2 \ln \text{private}_{it} + (v_{it} - u_{it}) \quad (14)$$

with u_{it} specified as follows:

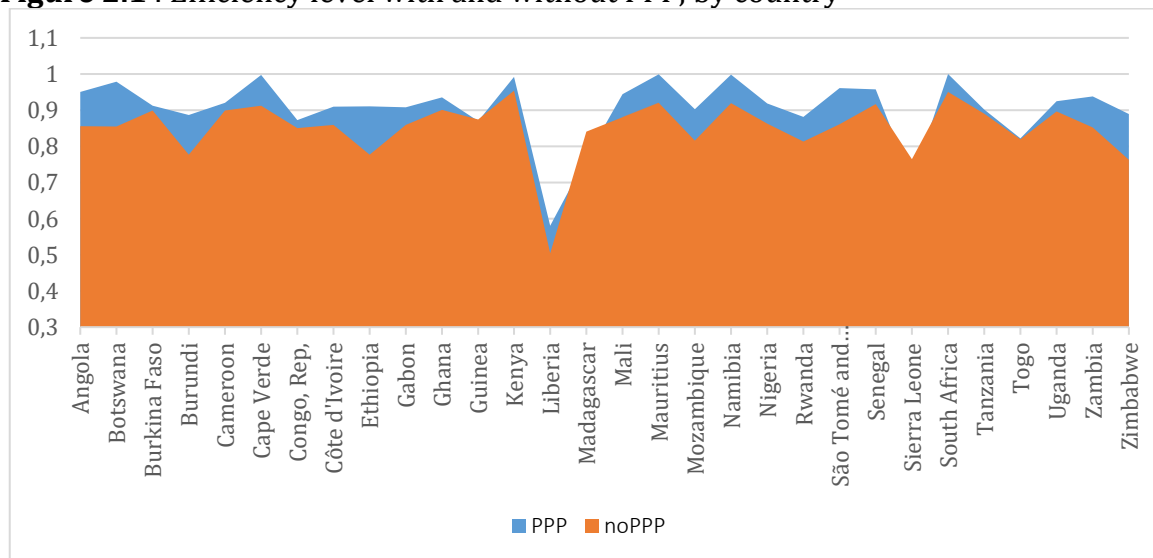
$$u_{it} = \delta_0 + \delta_1 \text{ppp} + \delta_2 \text{budgetaryandfinancialmanagement} + \delta_3 \text{financialsector} + \delta_4 \text{creditprivatesector} \quad (15)$$

In summary, we will measure the effect of PPP investments in the electricity sector, as well as that of the CPIA criteria and credit to the private sector, on the rate of access to electricity.

As in the first model, we have ensured the statistical relevance of inefficiency, and the results of the Likelihood Ratio (LR) tests show once again that technical inefficiency plays a non-negligible role in explaining distance from the production frontier. This justifies our decision to consider a stochastic rather than a deterministic frontier. Given that equation (14) is identical to equation (7) except that the determinants are considered, the Cobb-Douglas form remains more appropriate, as shown above by the results of the LR tests.

The average technical efficiency without PPPs but including the determinants of inefficiency as well as credit to private sector, is 84.5%. When PPPs are considered, we note an increase in efficiency, reaching 91.3%. Thus, we can say that PPPs have helped reduce the inefficiency gap from 15.5% to 8.7%. These efficiency scores with PPP are also widely dispersed, ranging from an average minimum over the analysis period of 58% for Liberia to an average maximum of 99% for Mauritius and South Africa. The figure below shows the level of inefficiency in the various countries.

Figure 2.1 : Efficiency level with and without PPP, by country



Note: The table shows the average efficiency level of countries with and without considering PPPs as determinants of efficiency, while keeping the other determinants. For most countries, PPPs have helped reduce the inefficiency gap.

In a one-step approach, we simultaneously estimated the parameters of the production frontier and the determinants of technical efficiency. In **Table 2.5**, we report the results of estimating equation 14. Unsurprisingly, the coefficients on public and private capital stocks are positive and significant. The sign of the parameters associated with the determinants of technical inefficiency indicates their effect on country performance in terms of access to electricity. The estimation shows that the following variables: PPP investments in electricity, the financial sector (c.5), the Quality of Budgetary and Financial Management (c.15) and credit to private sector are relevant in explaining country efficiency in access to electricity. Indeed, the results indicate that PPP investments in the electricity sector contribute to reducing inefficiency in access to electricity. As far as the financial sector is concerned, it's important to remember that governments finance their infrastructure either through taxes or borrowing. An efficient financial sector helps to mobilize the necessary financial resources for both the public and the private partner within the framework of contracts (Design, Build and Finance) to finance the energy sector, thereby promoting access to electricity. This is confirmed by the sign and the level of significance of private sector credit, as it allows companies to access the necessary financing to invest in electricity production, distribution, and transmission infrastructure. Additionally, private sector credit facilitates public-private partnerships (PPPs), which can be essential for attracting additional capital to the energy sector. However, Quality of Budgetary and Financial Management (c.15) increases inefficiency. This result can be explained by the fiscal sustainability reforms proposed by Technical and Financial Partners (TFPs) and supported by governments. These budgetary reforms, aimed at improving public finance management, focus on increasing revenues and reducing expenditure, particularly by cutting subsidies, especially in the energy sector. These lower subsidies result in less affordable electricity tariffs, thus limiting access.

Table 2.5 : Estimation results for equations 14 and 15 (Electricity)

	expected signs	coef.	z-ratio
Frontier			
Public capital stock	+	0.357***	(9.66)
Private capital stock	+	0.0901***	(2.86)
Inefficiency			
PPP capital stock	-	-0.424***	(-3.59)
Financial Sector (c.5)	-	-2.594***	(-3.90)
Quality of Budgetary and Financial Management (c.13)	+	0.870***	(3.50)
Credit to private sector	-	-0.198***	(-5.19)
LR test		2070.5***	
Number of observations		419	

Source: Author's estimation

Note: Results of the equation considering PPPs as determinants of inefficiency alongside the CPIA criteria and credit to private sector. The asterisks indicate the level of significance of the t statistics based on the following * p<0.05, ** p<0.01, *** p<0.001

Ports sector

2.3.5. The role of PPPs in shifting the frontier

This section of the paper focuses on the role of PPP investments in the Ports sector. Indeed, we will analyze their role in frontier shifting measured by an index developed by us, as explained in the output selection section. This indicator measures container traffic at port level, estimated in TEU (Twenty-foot Equivalent Units), which is then normalized (1 to 100) to reflect the same proportions as the AfDB's Aidi indicator. We chose this output because collecting data on containerization rates in ports in Sub-Saharan Africa (SSA) since 2000 presents several challenges. Many ports in SSA have historically lacked comprehensive data collection systems. This makes it difficult to access consistent and accurate records on container movements and containerization rates over time, especially for the early 2000s. In addition, we did not control for growth rate while measuring the impact of Public-Private Partnerships (PPPs) in Ports Sub-Saharan Africa (SSA) because of the heterogeneity in PPP Projects in the sector. Indeed, the different PPP projects we have in our database vary widely in size, scope, and duration, making it difficult to generalize their impact based solely on the overall growth rate. Furthermore, PPPs in ports sector often aim to improve the efficiency of the services without necessarily leading to an immediate increase in growth. PPP investments in the ports sector represent all PPP projects carried out by a given country during the analysis period. For instance, in South Africa, despite the many ports the country has, only the port of Durban is listed as a PPP according to the PPI database and it is listed for year 2019. Given that the investments are spread over 5 years and our analysis period ends in 2019, the investment in the Port of Durban has not been considered.

As for the electricity sector, we will use the same model presented above, with the same estimation methods. Thus, the model inspired by the work of Green (2005a, b) will be estimated using the Maximum Likelihood method (MLE). The model preserves the same technical specificities presented above, both in terms of error and technical efficiency.

This section of the paper analyzes the role of PPP investments in the ports sub-sector, without combining them with the determinants measured by the CPIA criteria, as was the case in the electricity sub-sector. Given that no interaction is expected between the determinants and the PPP capital stock for the ports sector, it is not relevant to analyze the interactions between structural changes related to insecurity and the determinants measured by the CPIA criteria. The role of PPP investments is measured in terms of the shift in the efficient frontier.

$$y_{it} = \alpha_i + X_{it}\beta + Y_{it}\gamma + (v_{it} - u_{it}) \quad (7)$$

$$y_{it} = \alpha_i + X_{it}\beta + Y_{it}\gamma + Z_{it}\delta + (v_{it} - u_{it}) \quad (8)$$

y_{it} is taken as the logarithm of production in the i^{th} country in year t . This production is measured by 20-foot equivalent units (TEU) container traffic at the various ports. As in the previous section, X_{it} , Y_{it} and Z_{it} are the vectors of the i^{th} country's input quantities in year t , measured respectively by the logarithm of the public investment capital stock, the logarithm of the private capital stock and the logarithm of the PPP capital stock in the port sub-sector.

In equation (7), maximum TEU container traffic depends on public capital stock (X) and private capital stock (Y). In equation (8), the frontier shifts when, in addition to X and Y, the PPP sector capital stock variable is added to the list of explanatory variables. We will now assess the marginal contribution of PPP investments in the port sector. Thus, we will compare the following equations 7 and 8 with each other. This involves comparing the equations when $\delta = 0$ and when $\delta \neq 0$. The estimated coefficients of equations (7) and (8) are shown in **Table 2.6**. Regarding the statistical relevance of inefficiency, the results of the Likelihood Ratio (LR) tests show that technical inefficiency plays a non-negligible role in explaining distance from the production frontier. This justifies our decision to consider a stochastic rather than a deterministic frontier.

Having analyzed the statistical relevance of inefficiency, in a second step we tested the most appropriate form of production function between Translog and Cobb-Douglas. To do this, as for the electricity sector, we tested for both models, i.e. the one including the PPP capital stock ($\delta \neq 0$) and the one not including the PPP capital stock ($\delta = 0$) with the null hypothesis $H_0: \beta_4 = \beta_5 = \beta_6 = \beta_7 = \beta_8 = \beta_9 = 0$ or $\beta_3 = \beta_4 = \beta_5 = 0$ respectively. If the null hypothesis is accepted, then the Cobb-Douglas specification will be the most suitable. With the LR test based on the following statistic: $LR = -2\{\ln[L(H_0)/L(H_1)]\}$ where $L(H_0)$ and $L(H_1)$ correspond to the Cobb-Douglas and Translog likelihood functions respectively, we accept the null hypothesis in both models. We find when there is no PPP capital stock ($\delta = 0$) a LR test = -0.7402 which is less than $\chi^2(3; 0.001) = 15.357$ (according to the Kodde and Palm table) and when PPP capital stock is in the model ($\delta \neq 0$), a LR test = -1.4895 which is less than $\chi^2(6; 0.001) = 21.666$ (according to the Kodde and Palm table). In both models we cannot reject the null hypothesis. Consequently, the Cobb-Douglas form is more appropriate for both models.

Unsurprisingly, the results show the positive and significant contribution of public and private capital stocks to the development of container traffic in ports sub-sector, both with and without the presence of PPP capital stock in the equation. Concerning our variable of interest, we find that PPP investments in the ports sub-sector (PPP capital stock) are significant and contribute positively to container traffic growth.

Table 2.6 : Estimation results for equations 7 and 8 (Ports) using SFA

	no CPIA	
	no PPP	PPP
Frontier		
Public capital stock	0.192*** (3.09)	0.345*** (693.51)
Private capital stock	0.444*** (8.40)	0.439*** (1076.6)
PPP capital stock		0.0428** (396.75)
LR test	774.46***	517.36***

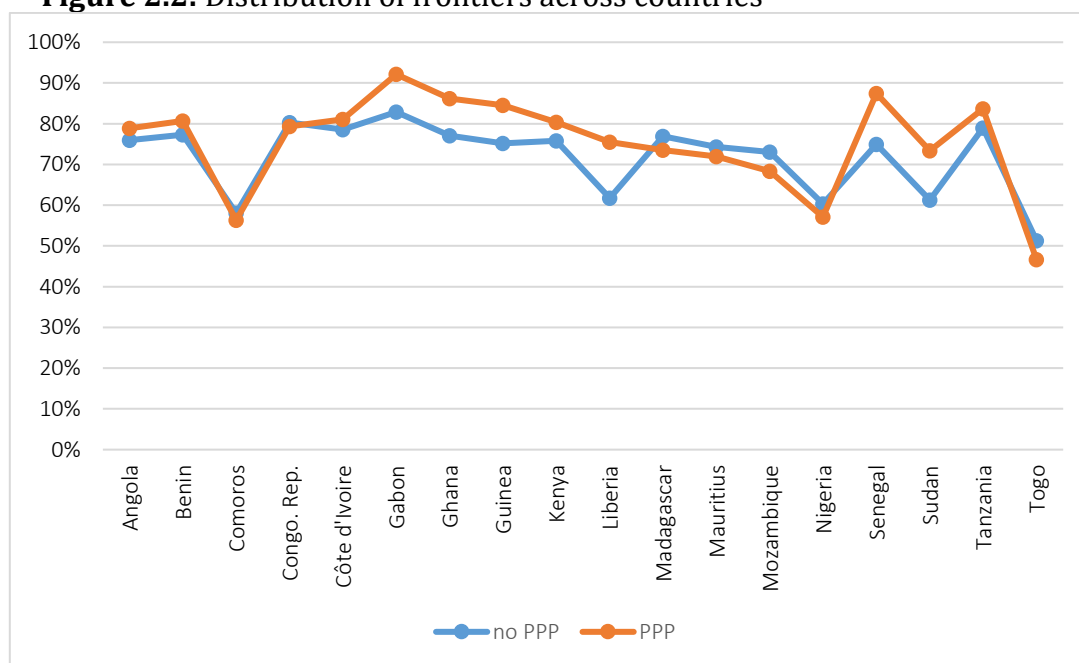
t statistics in parentheses *p<0.05, **p<0.01, ***p<0.001

Source: Author's estimation

Note: The table presents the results of estimating efficiency models in the port sector comparing the equations with and without PPP capital stock. The asterisks indicate the level of significance of the t statistics based on the following * p<0.05, ** p<0.01, *** p<0.001

Using the Jondrow and al. (1982) formula, we estimate individual and average inefficiencies. Comparing frontiers without and with PPP investments, we find that PPPs in the ports sub-sector have positively shifted the efficient frontier for most countries. Indeed, the average inefficiency without PPP is 28%, while the average inefficiency with PPP investments is around 25%. In short, PPPs in the ports sub-sector improved efficiency by 3%. Although most countries have benefited from the positive effects of PPP investments, the effects remain very dispersed across countries, as can be seen in figure below. Indeed, the countries that have increased their container traffic the most with PPP investments remain: Liberia (+14%), followed by Senegal (+13%) and Sudan (12%). In contrast, countries such as Togo (-4.7%), Mozambique (-4.7%) and Madagascar (-3.4%) benefited less from PPP investments during the analysis period.

Figure 2.2: Distribution of frontiers across countries



Source: Author's estimation

Note: The figure presents the results of estimates comparing efficiency frontiers with and without PPP investments, for countries

2.3.6. The role of inefficiency Determinants in reducing the distance

In this section, we will investigate the determinants of inefficiency in the ports sub-sector when PPP investments are present in the explanatory variables. The determinants of inefficiency are selected based on their Granger non-causal relationship with the output and PPP investments, as presented above in the section on selecting the determinants of inefficiency. Thus, three (03) determinants of inefficiency were selected for the ports sub-sector: Monetary Policy (c.1); Debt Policy (c.3) and the following governance indicator: Quality of Public Administration (c.15). In addition to these determinants measured by the CPIA criteria, we will focus on the classical determinants that impact container traffic according to the literature (Keller and al., 2017; Nguyen, 2019), particularly trade openness and the exchange rate. Drawing again on the work of Greene (2005a, b), we will repeat the model specified above, this time considering the above-mentioned determinants of inefficiency. The model (9) will be estimated using the Maximum Likelihood Method (MLM) as we did for the electricity sub-sector.

Empirical models: Functional and econometric specification

Empirical models for measuring the role of determinants in reducing distance to the border can be written as follows:

$$\text{Ln} \text{aidi_port}_{it} = \beta_0 + \beta_1 \text{Lnpublic}_{it} + \beta_2 \text{Lnprivate}_{it} + \beta_3 \text{Lnppp}_{it} + (v_{it} - u_{it}) \quad (16)$$

with u_{it} specified as follow:

$$u_{it} = \delta_0 + \delta_1 \text{monetarypolicy} + \delta_2 \text{debtpolicy} + \delta_3 \text{publicadministration} + \delta_4 \text{tradeopenness} + \delta_5 \text{exchangerate} \quad (17)$$

As in the electricity sub-sector model, we have ensured the statistical relevance of inefficiency, and the results of the Likelihood Ratio (LR) tests show once again that technical inefficiency plays a non-negligible role in explaining distance from the production frontier. This justifies our decision to consider a stochastic rather than a deterministic frontier. Given that equation (16) is identical to equation (7) except that the determinants are considered, the Cobb-Douglas form remains more appropriate, as shown above by the results of the LR tests.

In a one-step approach, we simultaneously estimated the parameters of the production frontier and the determinants of technical efficiency. Unsurprisingly, the coefficients for public, private and PPP capital stocks are positive and significant. The sign of the parameters associated with the determinants of technical inefficiency indicates significant effect on country performance in terms of container traffic levels in ports. The estimation shows that the following variables: i) Monetary Policy (c.1) contributes to increasing inefficiency in container traffic. This negative relationship can be explained by the restrictive monetary policies adopted by several of the analyzed countries (Angola, Kenya, Ghana, Malawi, Mozambique, Nigeria, Zimbabwe) to address high inflation exceeding 15% (according to World Bank data). These policies could have included interest rate hikes to control inflation, which may have had repercussions on infrastructure investments, including in ports, consequently limiting port traffic. Regarding debt policy (c.3), the results unsurprisingly show a positive relationship between port traffic efficiency and a good debt policy. Indeed, a good debt policy prevents payment defaults. However, several empirical studies have shown that sovereign defaults coincide with decreases in trade integration. Kohlscheen and O'Connell (2008) highlight that during default episodes, there is a significant decline in trade credit from commercial banks, which can severely limit a country's ability to engage in international trade. This reduction in trade credit can lead to a decrease in import and export activities, as businesses may struggle to finance their transactions (Mendoza and Yue, 2012). One of the consequences of a sovereign default is that it becomes more difficult for a country not only to borrow from foreigners, but also to trade with them. Finally, concerning the determinant Quality of Public Administration (c.15), the results show a positive relationship between the level of efficiency of port traffic and the performance of public administration. This relationship comes as no surprise, given the high administrative content of port activities. The positive contribution of the exchange rate to the reduction of inefficiencies in port traffic can be explained by several economic factors. A favorable exchange rate for imports increases the demand for foreign products, leading to an increase in port traffic related to the import of these goods (Chen and Novy, 2011).

Exchange rate fluctuations can also encourage businesses to diversify their trade. This can further increase traffic in ports as companies seek to maximize their business opportunities. This aligns with the positive relationship observed between trade openness and the improvement of port traffic efficiency. Indeed, trade openness allows countries to access new markets, resulting in an increase in imports and exports. According to Mlambo (2021), who studies the performance of ports in certain African countries in relation to trade, seaports are essential for facilitating international trade, which consequently promotes an increase in port traffic. **Table 2.7** shows the results of estimating equations 16 and 17.

Table 2.7: Estimation results for equations 16 and 17 (Ports) using SFA

	Expected signs	Coef.	z-ratio
Frontier			
Public capital stock	+	0.295***	(4.84)
Private capital stock	+	0.362***	(5.94)
PPP capital stock	+	0.036*	(2.16)
Inefficiency			
Monetary Policy (c.1)	-	1.425***	(4.22)
Debt Policy (c.3)	-	-0.726***	(-2.70)
Quality of Public Administration (c.15)	-	-1.258***	(-3.97)
Trade Openness	-	-4.532***	(-5.46)
Exchange Rate	-	-0.001***	(-2.89)
Cons		1.027	(1.04)
LR test		536.51***	
Number of observations		281	

Source: Author's estimation

Note: Results of the equation considering the CPIA criteria as determinants of inefficiency alongside and Trade openness and Exchange rate. The asterisks indicate the level of significance of the t statistics based on the following

* p<0.05, ** p<0.01, *** p<0.001

2.4. Alternative approach estimation

We will now use an alternative approach to estimate the effect of PPPs in the two sectors: Electricity and Ports. This alternative estimation approach allows us to test the robustness of the previously obtained results. Our dataset consists of panel data. With such data, the two standard estimation methods are the fixed effects model and the random effects model, as they allow for controlling for unobserved country-specific characteristics that may influence the performance of PPP investments (Baltagi, 1995).

Electricity sector

2.4.1. Role of PPPs in moving the production frontier

Methodological approach

To estimate the effect of PPPs on shifting the efficiency frontier using our panel data, it would first be important to identify the effect associated with each individual (an effect that does not vary over time but does vary from one individual to another). Consequently, the models we will use in this study are simple linear models with the following functional form:

$$y_{it} = \alpha_i + X_{it}\beta + \varepsilon_{it} \quad (18)$$

y_{it} is taken as the logarithm of production in the i^{th} country in year t . This production is measured by the rate of access to electricity for each country. X_{it} is a vector of the i^{th} country's input quantities in year t , measured by the logarithm of the public investment capital stock, the logarithm of the private capital stock and the logarithm of the PPP capital stock in the electricity sector. The PPP capital stock is combined with the CPIA criteria added one by one as we did previously for the electricity sector. β is the vector of associated parameters to be estimated; ε_{it} is the idiosyncratic error term.

The identification of the most suitable model for our data will be carried out in several steps. First, we will verify whether the data-generating process is homogeneous or heterogeneous using the Fisher specification test. In other words, we need to distinguish between a specific effect and a common effect. In the second step, the Hausman test will be conducted to choose the most appropriate model between the fixed effects model and the random effects model. We will then ensure that the error terms are homoscedastic and not autocorrelated. For this purpose, heteroscedasticity and autocorrelation tests will be performed to confirm the validity of these estimators. A unit root test will be conducted to ensure that our estimates meet standard statistical properties. Finally, we will check for cointegration between the variables in our model to ensure a long-term relationship between them.

Presentation and Interpretation of Results

The result of the Fisher individual effects specification test, $F(2,642) = 452.92$ with $\text{Prob} > F = 0.0000$, rejects the null hypothesis of no individual effects at the 5% significance level. Therefore, there are specific individual effects in the model, measured by the α_i .

Using panel data is thus well-suited to the situation we describe. However, this specific effect can either be individual or random. Therefore, the specification test to decide whether the specific effects are random or not needs to be performed. The most widely used test for this is the Hausman test. In this case, we test two hypotheses: Null hypothesis (H_0): The specific effects are not correlated with the explanatory variables. If this hypothesis is true, the random effects model is more efficient and should be used.

Alternative hypothesis (H1): The specific effects are correlated with the explanatory variables.

The chi-squared statistic calculated has a p-value below the 5% threshold: $\chi^2(2) = 34.81$ with $\text{Prob} > \chi^2 = 0.0000$. Therefore, we reject the null hypothesis. This means that the specific effects of the entities are correlated with the explanatory variables. Consequently, the fixed effects model should be preferred, as the random effects model would be biased.

To recall, the Fisher statistic obtained after regression according to the estimation of a fixed effects model confirms the heterogeneity of individuals in the form of a fixed effect. However, a necessary condition for applying one of these estimators is that the errors must be homoscedastic and non-autocorrelated. Therefore, it is important to perform heteroscedasticity tests to ensure the validity of these estimators. A modified Wald test is performed to test the specific hypothesis of homoscedasticity between the countries in the sample. Null hypothesis (H0): There is no heteroscedasticity, meaning that the variance of the errors is constant across all countries and periods. Alternative hypothesis (H1): There is heteroscedasticity, meaning that the variance of the errors varies across countries or periods. The chi-squared statistic calculated has a p-value below the 5% threshold: $\chi^2(34) = 115887.62$ with $\text{Prob} > \chi^2 = 0.0000$. Thus, we reject the null hypothesis, indicating the presence of heteroscedasticity. With the Wooldridge test, we checked for error autocorrelation. The following hypotheses were tested: Null hypothesis (H0): There is no autocorrelation in the errors. Alternative hypothesis (H1): There is autocorrelation in the residual errors. The test results show $F(1,33) = 18.690$ and a p-value of 0.0001. Since the p-value is less than 0.05, we reject the null hypothesis. Consequently, there is autocorrelation in the residual errors.

Another test equally important as the previous ones is the unit root test. Indeed, most of the statistical properties of estimation methods apply to stationary variables (non-trending and non-stationary). Therefore, it is essential to ensure the stationarity of our variables. To this end, the Levin, Lin, and Chu (2002) unit root test was conducted to ensure that our estimates meet standard statistical properties. Given that some variables were not stationary at their level, we performed a first-difference transformation before conducting the test again. **Table 2.8** shows the test results for the various variables used in this section.

Table 2.8 : Levin, Lin and Chu unit root test results

Variables	Statistic (P-value)
Public capital Stock	-2.8712** (0.0020)
Private capital Stock	-2.9368*** (0.0017)
PPP capital Stock	0.1371 (0.5545)
d(PPP capital Stock)	-3.3244*** (0.0004)
Financial Sector (c.5)	-1.7686* (0.0385)
Quality of Budgetary and Financial Management (c.13)	-0.9820 (0.1631)
d(Quality of Budgetary and Financial Management c.13)	-7.4549*** (0.0000)
Credit to private sector	-0.3146 (0.3765)
d(Credit to private sector)	-6.0550*** (0.0000)
Exchange Rate	-0.6311 0.2640
d(Exchange Rate)	-5.4499*** (0.0000)

Source: Author's estimation

Note: Results of Levin, Lin and Chu unit root test show that all variables are stationary in first differences or stationary at level. The asterisks indicate the level of significance of the t statistics based on the following * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

A regression of one of these variables on the others could lead to "spurious" results. To avoid this issue, we will perform a cointegration test to verify whether the variables are cointegrated. Indeed, a necessary condition for cointegration is that the series must be integrated of the same order; otherwise, they cannot be cointegrated. Authors such as Pedroni (1999), Kao (1999), and Westerlund (2007) have proposed cointegration tests that are applicable to panel data. The results presented in **Table 2.9** indicate mixed evidence regarding the presence of cointegration among the variables being tested. While 6 tests suggest that a long-run relationship exists, 3 tests do not find sufficient evidence to reject the null hypothesis.

Table 2.9: Results of Cointegration Test

Test	Stat	P-Value
Westerlund	Variance Ratio	
	-1.8440*	0.0326
Pedroni	Modified Phillips-Perron	
	3.1285***	0.0009
	Phillips-Perron	
	-13.0435***	0.0000
	Augmented Dickey-Fuller	
	-8.6790***	0.0000
Kao	Modified Dickey-Fuller	
	-2.3590**	0.0092
	Dickey-Fuller	
	-1.0366	0.1500
	Augmented Dickey-Fuller	
	-0.2193	0.4132
	Unadjusted Modified Dickey-Fuller	
	-2.4155**	0.0079
	Augmented Dickey-Fuller	
	-1.0608	0.1444

Source: Author's estimation

Note: The table shows the results of the three cointegration tests: Westerlund, Pedroni, and Kao. Out of the 9 tests conducted, 3 reject cointegration. The asterisks indicate the level of significance of the t statistics based on the following * p<0.05, ** p<0.01, *** p<0.001

Considering the results from the various tests conducted, we will proceed with the estimation of a fixed-effects model with heteroskedasticity correction for the initial model, which only considers the three capital stocks (PPP, Public, and Private). For the other models incorporating different interactions—namely, the PPP determinants identified through the Granger causality test (Financial Sector (c.5) and Quality of Budgetary and Financial Management (c.13)) and the exchange rate—the same tests were performed.

Table 2.10 presents the results of the estimation of the different models confirming the findings from the SFA method, both in terms of the direction of the contribution of the various variables to efficiency, as measured by access to electricity, and their significance.

Table 2.10: Estimation results using FE methods (Electricity) using FE method

	no CPIA		CPIA				Exchange Rate (RE)	
	no PPP	PPP	c5		c13		no PPP	PPP
			no PPP	PPP	no PPP	PPP		
Frontier								
Public capital stock	0.391*** (10.82)	0.473*** (8.93)	0.389*** (10.78)	0.461*** (8.59)	0.389*** (10.74)	0.475*** (8.94)	0.388*** (10.62)	0.417*** (7.72)
Private capital stock	0.329*** (9.09)	0.235*** (4.52)	0.299*** (7.55)	0.211*** (3.86)	0.323*** (8.62)	0.221*** (4.08)	0.300*** (8.26)	0.179*** (3.42)
PPP capital stock		0.042** (2.87)		0.044** (3.00)		0.0413** (2.82)		0.0623*** (4.21)
CPIA criteria								
Financial Sector (c.5)			0.0687 (1.93)	0.060 (1.45)				
Quality of Budgetary and Financial Management (c.13)					0.0197 (0.68)	0.0331 (0.88)		
Exchange Rate							8.18e-11** (2.71)	-2.91e-10 (-0.75)
_cons	-3.640***	-3.885***	-3.538***	-3.718***	-3.627***	-3.868***	-3.319***	-7.33***
Observations	678	421	678	421	678	421	678	421

Source: Author's estimation

Note: The table presents the comparative results between models with PPP and without PPP estimated by FE and RE methods, while accounting for the interactions between PPP, the exchange rate, and CPIA criteria. The asterisks indicate the level of significance of the t statistics based on the following * p<0.05, ** p<0.01, *** p<0.001

2.4.2. The role of PPP as determinants of inefficiency

Methodological approach

In this section, we will analyze the effect of PPP investments as a determinant of inefficiency. As a reminder, PPPs are used to achieve efficiency gains, which is why they are considered here as determinants of inefficiency. In addition to PPPs, the study will also focus on CPIA criteria, such as the Financial Sector (c.5) and the Quality of Budgetary and Financial Management (c.13). Given the high correlation between the Financial Sector (c.5) and the financial openness variable, we have opted not to include it in our model. However, credit to the private sector has been retained.

To analyze the effect of the determinants on efficiency, as measured by access to electricity, we will adopt a two-step approach. Generally, the strategy for estimating investment inefficiency while incorporating determinants into the analysis involves first estimating deviations from the expected optimal investment, which is reflected in the residuals of the selected model. In the second step, these residuals are regressed on the determinants. For this, we will draw inspiration from the work of Benlemlih and Bitar (2018), Zhong and Gao (2017), Cook and al. (2019), Li and Liao (2014), Chen and al. (2011), and Biddle and al. (2009).

At this stage, the model is estimated based on the investments of countries, which are expected to influence the electricity access rate. The model includes the inputs that explain the level of investment in the electricity sector: public, private, and PPP investments. The residuals (the differences between the actual coverage rate and the rate predicted by the model) represent the deviations from the expected optimal coverage level. These residuals are considered an approximation of the investment inefficiency

measured by the electricity access rate. The empirical specification of the model is as follows:

$$\ln \text{infcovr}_{it} = \beta_0 + \beta_1 \ln \text{public}_{it} + \beta_2 \ln \text{private}_{it} + (v_{it} - e_{it}) \quad (19)$$

In the second step, the residuals obtained from the first step are regressed on the four variables identified as determinants of inefficiency. These determinants are PPP, Financial Sector (c.5), Quality of Budgetary and Financial Management (c.13), and credit to the private sector. This step allows for the identification of factors that contribute to investment inefficiencies in the electricity sector. The empirical specification of the equation is as follows:

$$\hat{e}_{it} = \delta_0 + \delta_1 \ln \text{ppp} + \delta_2 \text{budgetaryandfinancialmanagement} + \delta_3 \text{financialsector} + \delta_4 \text{creditprivatesector} \quad (20)$$

Presentation and Interpretation of Results

As in the section concerning the role of PPPs in moving the production frontier, several tests were conducted to determine the estimation method for our equations. The results obtained indicate that the errors are heteroscedastic and autocorrelated. Therefore, we opted for estimation using the generalized least squares (GLS) method.

Table 2.11 presents the results of our estimation. The results obtained from the two-step approach confirm those obtained through the SFA approach. Indeed, all variables are significant and retain the same signs. However, it is important to note a decrease in the level of significance for the two inputs: public capital stock and private capital stock. Regarding our variable of interest, the PPP capital stock, its contribution to reducing the efficient distance remains significant and positive.

Table 2.11 : Estimation results for equations 19 and 20 using GLS

	expected signs	coef.	z-ratio
Frontier			
Public capital stock	+	0.118*	(2.49)
Private capital stock	+	0.086*	(1.97)
_cons		1.401***	(7.21)
Inefficiency			
PPP capital stock	-	-0.058***	(-8.15)
Financial Sector (c.5)	-	-0.150***	(-4.58)
Quality of Budgetary and Financial Management (c.13)	+	0.093**	(3.08)
Credit to private sector	-	-0.002***	(-5.00)
_cons		-2.957***	(-29.01)
Number of observations		421	

Source: Author's estimation

Note: The table shows the results of the estimation of equations 19 and 20 in two steps using the GLS method, considering the determinants of inefficiency. The asterisks indicate the level of significance of the t statistics based on the following * p<0.05, ** p<0.01, *** p<0.001

Ports sector

2.4.3. Role of PPPs in moving the production frontier

Methodological approach

In this section, we will estimate the effect of PPPs on the movement of the efficient frontier using our panel data, adopting an alternative approach to compare the results with those obtained from the SFA approach. To do this, we will compare the following two equations:

$$y_{it} = \alpha_i + X_{it}\beta + Y_{it}\gamma + v_{it} \quad (21)$$

$$y_{it} = \alpha_i + X_{it}\beta + Y_{it}\gamma + Z_{it}\delta + v_{it} \quad (22)$$

y_{it} is taken as the logarithm of production in the i^{th} country in year t . This production is measured by 20-foot equivalent units (TEU) container traffic at the various ports. As in the previous section, X_{it} , Y_{it} and Z_{it} are the vectors of the i^{th} country's input quantities in year t , measured respectively by the logarithm of the public investment capital stock, the logarithm of the private capital stock and the logarithm of the PPP capital stock in the port sub-sector; v_{it} is the idiosyncratic error term.

As with the port sector, the identification of the most suitable model for our data will be done in several steps. We will need to perform the Hausman test to choose the most appropriate model between the fixed effects model and the random effects model. We must also ensure that the error terms are homoscedastic and not autocorrelated. A unit root test will be conducted to ensure that our estimates meet standard statistical properties. Finally, we will check the cointegration of the variables in our model to ensure a long-term relationship between them.

Presentation and Interpretation of Results

The specification test to determine whether the specific effects are random or not is most commonly the Hausman test. The calculated chi-squared statistic has a p-value above the 5% threshold: $\chi^2(2) = 0.91$ with $\text{Prob} > \chi^2 = 0.6352$. We cannot reject the null hypothesis. This implies that the specific effects of the entities are not correlated with the explanatory variables. Therefore, the random effects model is preferred.

Next, a modified Wald test was conducted to test the specific hypothesis of homoscedasticity among the countries in the sample. The calculated chi-squared statistic has a p-value below the 5% threshold: $\chi^2(18) = 5683.79$ with $\text{Prob} > \chi^2 = 0.0000$. We reject the null hypothesis. Thus, we are facing heteroscedasticity.

With the Wooldridge test, we checked for autocorrelation of the errors. The results of the test yield an $F(1, 17) = 150.32$ and a p-value = 0.0000. Since the p-value is less

than 0.05, we reject the null hypothesis. Therefore, there is autocorrelation in the residual errors.

Another equally important test is for the presence of a unit root. The unit root tests of Levin, Lin and Chu (2002), Im–Pesaran–Shin, and Harris-Tzavalis were conducted to ensure that our estimates meet standard statistical properties. Since some variables were not stationary at level, we proceeded to first differencing before conducting the test again. The table below shows the results of the tests for the various variables used in this section.

Table 2.12: Levin, Lin and Chu unit root test results (Ports)

Variables	Statistic (P-value)
Electricity coverage rate	1.6897 (0.9545)
d(Electricity coverage rate)	-1.6934* 0.0452
Public capital Stock	-3.4783** (0.003)
Private capital Stock	-2.5125** (0.006)
Monetary Policy	-1.8731* (0.03)
Quality of Public Administration	-1.0272 (0.1522)
d(Quality of Public Administration)	-4.2647*** (0.0000)
Commercial Openness	-0.4900 (0.3121)
d(Commercial Openness)	-5.3661*** (0.0000)
Exchange Rate	1.5376 0.9379
d(Exchange Rate)	-40385*** (0.0000)

Source: Author's estimation

Note: Results of Levin, Lin and Chu unit root test show that variables are stationary in first differences or stationary at level. The asterisks indicate the level of significance of the estimators. The PPP and Debt Policy variables were tested using the Im–Pesaran–Shin and Harris-Tzavalis tests and are stationary at level and first difference, respectively. The asterisks indicate the level of significance of the t statistics based on the following * p<0.05, ** p<0.01, *** p<0.001

Finally, we conducted a cointegration test to check if the variables are cointegrated. The results showed in **Table 2.13** indicate mixed evidence regarding the presence of cointegration among the variables being tested. While 7 tests suggest that a long-run relationship exists, 2 tests do not find sufficient evidence to reject the null hypothesis.

Table 2.13: Results of Cointegration Test (Ports)

Test	Stat	P-Value
Westerlund	Variance Ratio	
	-1.5967	0.0552
Pedroni	Modified Phillips-Perron	
	1.0773	0.1407
	Phillips-Perron	
	-2.8189**	0.0024
	Augmented Dickey-Fuller	
	-1.8576*	0.0316
Kao	Modified Dickey-Fuller	
	-2.3354**	0.0098
	Dickey-Fuller	
	-2.7730**	0.0028
	Augmented Dickey-Fuller	
	-4.0676***	0.0000
	Unadjusted Modified Dickey-Fuller	
	-5.0582***	0.0000
	Augmented Dickey-Fuller	
	-3.7175***	0.0001

Source: Author's estimation

Note: The table shows the results of the three cointegration tests: Westerlund, Pedroni, and Kao. Out of the 9 tests conducted, 3 reject cointegration. The asterisks indicate the level of significance of the t statistics based on the following * p<0.05, ** p<0.01, *** p<0.001

Based on the results of the various tests conducted, we will proceed with an estimation using the generalized least squares (GLS) method.

The results of the two models estimated by the GLS method, presented in the table below, confirm the findings obtained using the SFA method. We can conclude that PPPs have positively contributed to shifting the efficient frontier. The other inputs (public and private capital stocks) remain positive and significant.

Table 2.14: Estimation results for equations 7 and 8 (Ports) using GLS

	no CPIA	
	no PPP	PPP
Frontier		
Public capital stock	0.379*** (6.39)	0.253*** (3.27)
Private capital stock	0.260*** (5.53)	0.275*** (4.96)
PPP capital stock		0.120*** (5.50)
_cons	-4.922*** (-16.80)	-4.267*** (-11.50)
Observations	359	281

Source: Author's estimation

Note: The table presents the comparative results between models with PPP and without PPP estimated by GLS method. The asterisks indicate the level of significance of the t statistics based on the following * p<0.05, ** p<0.01, *** p<0.001

2.4.4. The role of PPP as determinants of inefficiency

Methodological Approach

In this section, we will analyze the effect of the determinants of inefficiency. To analyze the effect of the determinants on efficiency measured by container traffic, we have adopted a two-step approach, like the one used in the electricity sector. We have also drawn inspiration from the works of Benlemlih and Bitar (2018), Zhong and Gao (2017), Cook and al. (2019), Li and Liao (2014), Chen and al. (2011), and Biddle and al. (2009).

In the first step, the model is estimated based on the investments of countries, which are expected to influence the level of container traffic, particularly public, private, and PPP investments. The empirical specification of the model is as follows:

$$\ln \text{aidi_port}_{it} = \beta_0 + \beta_1 \ln \text{public}_{it} + \beta_2 \ln \text{private}_{it} + \beta_3 \ln \text{ppp}_{it} + (v_{it} - u_{it}) \quad (23)$$

In the second step, the residuals obtained from the first step are regressed on the five variables selected as determinants of inefficiency. These determinants are monetary policy, debt policy, quality of public administration, trade openness, and exchange rate. This step allows us to identify the factors that contribute to investment inefficiencies in the port sector. The empirical specification of the equation is as follows:

$$\hat{u}_{it} = \delta_0 + \delta_1 \text{monetarypolicy} + \delta_2 \text{debtpolicy} + \delta_3 \text{publicadministration} + \delta_4 \text{tradeopenness} + \delta_5 \text{exchangerate} \quad (24)$$

Presentation and Interpretation of Results

As with the previous sections, several tests were conducted to determine the most appropriate estimation method. The results indicate that the errors are heteroscedastic and autocorrelated. Therefore, we opted for estimation using the generalized least squares (GLS) method.

Table 2.15 presents the results of our estimation. The results obtained from the two-step approach confirm those obtained from the SFA approach. Indeed, all the variables used as inputs (public, private, and PPP capital stocks) are significant and positive. Regarding the determinants of inefficiency, we note that the following determinants—debt policy, trade openness, and exchange rate—contribute to reducing the inefficiency distance to the frontier, as in the SFA model. However, the determinants of monetary policy and quality of public administration are not significant despite their negative sign.

Table 2.15: Estimation results for equations 16 and 17 (Ports) using GLS

	Expected signs	Coef.	z-ratio
Frontier			
Public capital stock	+	0.253**	(3.27)
Private capital stock	+	0.275***	(4.96)
PPP capital stock	+	0.120***	(5.50)
_cons		-4.267***	(-11.50)
Inefficiency			
Monetary Policy (c.1)	-	-0.0567	(-0.71)
Debt Policy (c.3)	-	-0.176*	(-2.35)
Quality of Public Administration (c.15)	-	-0.339	(3.67)
Trade Openness	-	-1.542***	(-5.99)
Exchange Rate	-	-0.00005***	(-2.22)
Cons		2.301***	(7.47)
Number of observations		281	264

Source: Author's estimation

Note: Results of the equation considering the CPIA criteria as determinants of inefficiency alongside and Trade openness and Exchange rate. The asterisks indicate the level of significance of the t statistics based on the following

* p<0.05, ** p<0.01, *** p<0.001

2.5. Summary of Results

Electricity Sector

PPP and access to electricity: SFA approach

- PPPs without combination contribute positively to access to electricity
- PPPs combined with the CPIA criteria: Financial Sector (c.5), Quality of Budgetary and Financial Management (c.13) and Exchange rate contribute positively to access to electricity.
- Structural breakdowns as measured by political instability have no effect on the positive contribution of PPPs to access to electricity.
- The efficient frontier shifts positively by 1% when PPPs are considered
- PPPs, credit to the private sector and the CPIA Financial Sector criterion (c.5) help to reduce the inefficient distance. While the Quality of Budgetary and Financial Management criterion (c.13) increases the inefficient distance.

PPP and Access to Electricity: Fixed Effects as an Alternative Approach

- PPPs without combination contribute positively to access to electricity
- PPPs combined with the CPIA criteria: Financial Sector (c.5), Quality of Budgetary and Financial Management (c.13) and Exchange rate contribute positively to access to electricity.
- PPPs, credit to the private sector and the CPIA Financial Sector criterion (c.5) help to reduce the inefficient distance. While the Quality of Budgetary and Financial Management criterion (c.13) increases the inefficient distance.

Ports Sector

PPP and Container Traffic: SFA approach

- PPPs without combination contribute positively to container traffic
- The efficient border shifts positively by 3% when PPPs are considered
- The following CPIA criteria: Trade Openness, Exchange rate, Debt Policy (c.3) and Quality of Public Administration (c.15) decrease the inefficient frontier while Monetary Policy (c.1) increases the inefficient frontier.

PPP and Container Traffic: Fixed Effects as an Alternative Approach

- PPPs without combination contribute positively to container traffic
- The efficient border shifts positively by 3% when PPPs are considered
- The following CPIA criteria: Trade Openness, Exchange rate, Debt Policy (c.3) decrease the inefficient frontier while Monetary Policy (c.1) increases the inefficient frontier. Quality of Public Administration (c.15) is no longer significant

2.6. Conclusion

The efficiency of infrastructure investments and the role of PPP investments in Sub-Saharan Africa has not been the subject of many empirical studies. Added to this is the absence of macro studies on the contribution of PPPs, as most empirical studies on PPPs consist of anecdotal evidence and case studies analyzing a before-and-after PPP situation. Finally, there is the limited number of studies on the determinants of inefficiency in infrastructure investments. On this basis, our paper has attempted to fill this gap by proposing to analyze the efficiency of investments in two infrastructure sub-sectors: Electricity and Ports. The paper also looked at the determinants of inefficiency, proposing a new approach using CPIA criteria alongside some classic determinants. In addition to these CPIA criteria, the paper also analyzed the role of PPP sector investments on access to electricity. Finally, another novelty is the use of a new indicator in the ports sub-sector as an output to measure the efficiency of Ports sector infrastructure investments.

Before analyzing the efficiency of sectoral infrastructure investments, we first had to identify, for each sub-sector (Ports and Electricity), the CPIA criteria with a Granger non-causal relationship, to be able to use them as determinants of inefficiency. The choice of CPIA criteria was dictated by the different determinants of PPP investments, which happen to be the same as the determinants used in the literature when analyzing the efficiency of infrastructure investments.

For the electricity sub-sector, the tests identified two CPIA criteria: Financial Sector (c.5) and Quality of budgetary and financial management (c.13). We also analyzed the effect of exchange rate and Credit to the private sector. Regarding the shifting of the efficient frontier, the results showed a positive contribution of the inputs: public, private investments and PPPs to access to electricity. However, the contribution of PPP sector investments to shifting the efficient frontier remains negligible. The results show perfect efficiency when PPP investments in the electricity sector are considered. However, without these PPP investments, the results show an average decline in efficiency of 1% over the analysis period. More importantly, we find that when PPP capital stock is combined with an CPIA criteria or exchange rate, its contribution to the electricity rate access remains significant and positive. As for the role of PPP capital stock as a determinant of inefficiency, the results show that it contributes to improving access to electricity, as does criteria financial sector (c.5) and credit to private sector. While criteria Quality of budgetary and financial management (c.13) contributes negatively to access to electricity. Finally, the average technical efficiency without PPPs but including the determinants of inefficiency as well as credit to private sector, is 84.5% versus an increase reaching 91.3% when PPPs are considered. These efficiency scores are also widely dispersed, ranging from an average minimum over the analysis period of 58 % for Liberia to an average maximum of 99% for Mauritius and South Africa. We also analyzed the effect of instability, measured by various crises, on PPPs in the electricity sector. The results showed a non-significant effect for several reasons discussed in the document.

For the Ports sub-sector, three CPIA criteria were selected: Monetary Policy (c.1), Debt Policy (c.3) and Quality of Public Administration (c.15) alongside with trade openness and exchange rate. In terms of shifting the efficient frontier, the results showed a significant and positive contribution of PPP sector investments to container traffic. The average inefficiency without PPP sector investments is 28%, while the average inefficiency with

PPP is around 25%, i.e., a 3% improvement with PPP. Used as determinants of inefficiency, the Debt Policy (c.3), Quality of Public Administration (c.15), trade openness and exchange rate contribute to improving the level of container traffic, while the Monetary Policy (c.1) criteria contributes negatively to container traffic.

To ensure the robustness of our results, our models were estimated using an alternative approach. The results from the estimation using fixed effects methods with heteroskedasticity correction or GLS confirm the robustness of our findings, except for the port sector, where the contribution of Monetary Policy and the Quality of Public Administration became non-significant in our alternative approach.

The results obtained show a positive contribution from PPP investments in the ports and electricity sub-sectors. With a view to improving the efficiency of investments in sectoral infrastructures (Ports and Electricity), governments should further strengthen the following CPIA criteria: Financial Sector (c.5); Quality of Public Administration (c.15) and Debt Policy (c.3). To promote port activities, governments should also enhance their trade openness and adopt monetary policies that support exchange rate stability. Regarding Quality of Budgetary and Financial Management (c.13) governments should ensure, its impact on low-income households in terms of access to electricity. In the future, it would be interesting to investigate the contribution of PPP investments in other sectors, such as water or roads, when data permit.

We cannot conclude this study without outlining certain limitations. The main difficulty lay in measuring PPP investments. Indeed, some PPP investments could end up on the public investment balance sheet, given the absence of clear budgetary accounting in the countries studied. Also, the PPP investments analyzed only represent commitments at the financial closing stage and could therefore differ from investments carried out.

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Appendices

2.A List of countries

Electricity sector	Ports sector
Liberia	Angola
Ethiopia	Benin
Sierra Leone	Comoros
Malawi	Congo. Rep.
Burundi	Ivory Coast
Zimbabwe	Gabon
Rwanda	Ghana
Comoros	Guinea
São Tomé and Príncipe	Kenya
Namibia	Liberia
Botswana	Madagascar
Gambia. The	Mauritius
Madagascar	Mozambique
Mali	Nigeria
Cape Verde	Senegal
Burkina Faso	Sudan
Angola	Tanzania
Chad	Togo
Guinea	
Mauritius	
Gabon	
Ivory Coast	
Zambia	
Togo	
Congo. Rep.	
Mozambique	
Senegal	
Uganda	
Tanzania	
Cameroon	
Ghana	
South Africa	
Kenya	
Nigeria	

2.B CPIA criteria as a proxy for PPP determinants

The Country Policy and Institutional Assessment (CPIA) conducted by the African Development Bank (AfDB) serves as a comprehensive diagnostic tool used to evaluate the quality of policies and the performance of institutional frameworks in each of the 54 African countries on an annual basis. This assessment is designed to gauge a country's capacity to foster sustainable growth, reduce poverty, and effectively utilize development assistance. The CPIA places particular emphasis on evaluating key elements that are within the country's control, rather than focusing on outcomes such as national incomes and growth rates. By concentrating on policy and institutional quality, the CPIA aims to identify areas of strength and opportunities for improvement, thus providing a nuanced understanding of each country's developmental landscape and informing strategic planning and resource allocation by the AfDB and other stakeholders.

For each country, the outcomes of the CPIA exercise yield an overall score, five cluster scores, and individual scores for all 18 criteria of the questionnaire (**Figure 2.3**). The cluster scores aggregate specific criteria, while the overall CPIA score from the AfDB is calculated as the simple average of the five cluster scores. Each score ranges from 1 (very weak) to 6 (very strong), and these scores are updated annually for all 54 African countries.

In addition to the individual country assessments, the AfDB also uses these scores to facilitate comparative analysis and to establish the annual harmonized list of Fragile Situations in collaboration with the World Bank. For this purpose, the AfDB discloses a simple average score that combines the scores from clusters A, B, C, and D. This consolidated approach helps in identifying and categorizing countries based on their relative levels of policy and institutional performance, thereby aiding in the allocation of resources and support to those in fragile situations.

Figure 2.3 : Breakdown of the 18 CPIA criteria by group



Source: FRMN, AfDB

According to the literature (Hammami and al., 2006; Kasri and al., 2015; Hyun and al., 2019; Kumar, 2019; Kaur and al., 2020), the determinants of PPP investments can be classified into five categories: fiscal constraints, macroeconomic conditions, market conditions, governance, and financial sector development.

The **budgetary constraint** category is decisive for a government in determining whether it can use PPPs, as it will need to have sufficient financial resources to pay the private partner, especially in the case of public-pay PPPs. In fact, countries that can generate enough revenue are less constrained by budgetary constraints and are less likely to resort to PPPs. Also, when a country has a heavy debt burden, it will be less inclined to use PPPs. The following variables are used in the budget constraint category: budget deficit and public debt. The novelty in this paper is that the CPIA will be used as a proxy. Thus, for the budget constraint category, two CPIA Economic Management criteria will be used: *fiscal policy* and *debt policy*.

The **macroeconomic stability** category is reassuring for private partners. A country with stable macroeconomic conditions, particularly controlled inflation, and exchange rates, is more attractive to PPPs. In the literature, the variables used for this purpose are inflation, M2 money supply in relation to GDP and foreign exchange reserves. Thus, in the CPIA criteria, these variables are better captured by *monetary and exchange rate policy*.

The **market conditions** category also remains a good indicator for the private sector, especially in the case of user-pay PPPs and public-pay PPPs. In the first case, it is the ability of service users to pay that is assessed. In the second case, the government's ability to pay is assessed through its tax and non-tax revenues. The more revenue a government has, the more likely it is to be able to honor its commitments. The literature generally uses the following variables: population and GDP per capita to measure demand and purchasing power respectively. In the context of the CPIA, the most appropriate criterion is *revenue mobilization*.

In the **governance** category, the link between PPP investment and the quality of institutions must be verified. Private partners will be more inclined to enter a long-term partnership with a country if the regulatory environment within that country is transparent. Also, a country with strong and effective institutions will be more likely to attract PPP investment. The variables generally used to test this are: the corruption index, the rule of law index and country risk. In our paper, these variables are replaced by the CPIA governance criteria as well as a structural policy criterion, namely: *property rights and rules-based governance, the quality of budgetary and financial management, the quality of public administration, transparency, accountability and corruption in the public sector and the business regulatory framework*.

Finally, the **financial sector development** category is a decisive factor, as a developed financial sector encourages the full participation of the private sector in infrastructure financing. In the literature, the variable Domestic credit provided to the private sector by banks is used. In this paper, the *financial sector* criterion will be used.

To sum up, the choice of the CPIA criteria instead of the variables listed in the literature is explained by the fact that in the CPIA, the emphasis is placed on key elements over which the country has control rather than on results (as is the case for most variables)

influenced by elements outside the country's control (CPIA 2022 Guide, World Bank). More specifically, the CPIA assesses the extent to which a country's policies and institutional framework support sustainable growth and poverty reduction, and therefore the effective use of development aid.

Due to the nature of PPP financing in Africa, which primarily comes from abroad, and considering the two sectors being analyzed, we will also examine the effects of exchange rate volatility. In the energy sector, where part of the financing and technology comes from foreign sources, exchange rate volatility could impact electricity prices and consequently the rate of access to electricity.

2.C List of variables and sources

Variables Name	Unit	Variables definition	Sources
RegionGeo		Geographic region	Sahel and West Africa Club
RegionEco		Economic region	InOnAfrica
\$Total_ippp_m	in million of constant 2017 international \$	Sum of the PPP investments of the different sectors	Private Participation to Infrastructure
\$Total_kppp_m	in million of constant 2017 international \$	Sum of depreciated PPP capital stock since the 1st PPP investment in a given country	Author estimates
\$igov_m	in million of constant 2017 international \$	General government investment (gross fixed capital formation)	MFI, capital stock 2017
\$kgov_m	in million of constant 2017 international \$	General government capital stock (constructed based on "igov_m\$")	MFI, capital stock 2017
\$ipriv_m	in million of constant 2017 international \$	Private investment (gross fixed capital formation)	MFI, capital stock 2017
\$kpriv_m	in million of constant 2017 international \$	Private capital stock (constructed based on private investment flows "ipriv_m\$")	MFI, capital stock 2017
Primary sector	5 different sectors	Sector that receives the investment	Private Participation to Infrastructure
Subsector	7 different subsectors	Sub-Sector that receives the investment	Private Participation to Infrastructure
ippp_m\$curr	in million of currents US\$	PPP investments of the different sectors	Private Participation to Infrastructure
\$ippp_m	in million of constant 2017 international \$	PPP investment since the 1st PPP investment in a given country	Private Participation to Infrastructure
\$kppp_m	in millions of constant 2017 international \$	PPP capital stock (constructed based on "ipp_m\$")	Author estimates
AIDI_Port	0 - 100 best	Container port traffic (TEU: 20-foot equivalent units)	Author normalization of World Bank, WDI
Ports	TEU: 20-foot equivalent units	Container port traffic	World Bank, WDI
Electricity	% of population	Access to electricity	World Bank, WDI
CPIA_Global	1-6 strong	provides the average score of all the assessment components of policies and institutions covering: Economic Management, Structural Policies, Social Inclusion/Equity, Governance, Infrastructure Development and Regional Integration.	African Development Bank
RuleBasedGov	1-6 strong	Property Rights and Rule-based Governance	African Development Bank
BudFinManag	1-6 strong	Quality of Budgetary and Financial Management	African Development Bank
QualPubAdm	1-6 strong	Quality of Public Administration	African Development Bank
TrasPAccCorr	1-6 strong	Transparency, Accountability and Corruption in the Public Sector	African Development Bank
BusRegEnv	1-6 strong	Business Regulatory Environment	African Development Bank
DeptPol	1-6 strong	Debt Policy	African Development Bank
FiscPol	1-6 strong	Fiscal Policy	African Development Bank
RevMob	1-6 strong	Efficiency of Revenue Mobilization	African Development Bank
FinSector	1-6 strong	Financial Sector Development	African Development Bank
MonPol	1-6 strong	Monetary Policy	African Development Bank
ConCorrup	Estimate of governance (ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance)	Reflects perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests.	The World Governance Indicators, 2020
RuleLaw	Estimate of governance (ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance)	Reflects perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence.	The World Governance Indicators, 2020
ReguQuali	Estimate of governance (ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance)	Reflects perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development.	The World Governance Indicators, 2020
GovEffec	Estimate of governance (ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance)	Reflects perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies.	The World Governance Indicators, 2020
VoicNAccoun	Estimate of governance (ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance)	Reflects perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media.	The World Governance Indicators, 2020
PoliStabili	Estimate of governance (ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance)	Political Stability and Absence of Violence/Terrorism measures perceptions of the likelihood of political instability and/or politically motivated violence, including terrorism.	The World Governance Indicators, 2020

2.D PPP investment trends by sector

To put into perspective the evolution of total PPP investments in SSA, a comparative analysis of the different regions (Central, East, West and South) of Africa is required. The trend analysis of PPP infrastructure investments in SSA is carried out for the two sectors mentioned above: Energy and Transport. **Table 2.16** presents a set of indicators for measuring the performance of infrastructure investments.

Table 2.16 : Sector infrastructure performance indicators

Indicator	Energy	Transport
Aidi_sector: Quantity and accessibility		Container traffic
Infcovr: accessibility	Access to electricity	

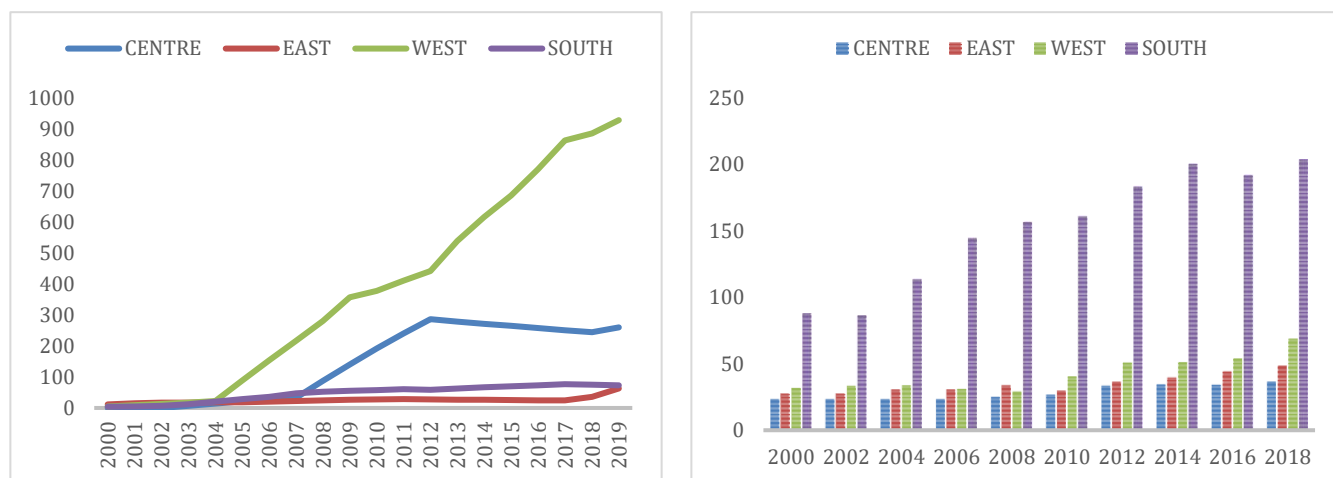
Note: Table shows the two indicators used for the two sectors. The rate of access to electricity (World Bank data) for the energy sector and the level of container traffic (World Bank normalized data) for port transport. It is important to note that according to the literature, the effectiveness of infrastructure PPPs is measured by the coverage rate or the quality of service

In the **Transport** sector, given the unavailability of data for many SSA countries on certain sub-sectors such as road (number of km of paved roads), rail (km of rail or goods transported) and airport (number of passengers or goods transported), the document focused on the port sector where data was available. Thanks to data from the PPI (World Bank), we can see that the West region has the highest PPP capital stock, notably with all port concessions in the Economic Community of West African States (ECOWAS) (Senegal, Togo, Nigeria, Ghana, Côte d'Ivoire, Guinea, etc.). This explains the upward trend in PPP capital stock in this region. Regarding the variation in container traffic in the West region, it should be noted that there was an initial increase from 2000 to 2004, with a peak in traffic estimated at 334962 TEU. The second increase in traffic began in 2008, reaching 686832 TEU in 2018. The second increase occurred between 2007 and 2010, when most ECOWAS ports switched to concession contracts (PPP). In the South region, the upward trend in capital stock is also much less marked than in the West. However, container traffic is higher in the South region. In the Centre region, we had to wait until 2003 to see the first PPP in the sector. Capital stock has been trending upwards, peaking in 2012 at 286.7 million international dollars. This is the region with the lowest traffic, just behind the East region. This could be due to the region's landlocked nature. Although with lower traffic and capital stock, the East region shows a capital stock trend relatively like that of the Centre region, with a first peak in 2011 worth 28.4 million international dollars and a second in 2018 worth 35.7 million.

Figure 2.4 : PPP container traffic and capital stock, by region

Transport: Port PPP capital stock

Transport: container traffic



Source: author's estimate based on PPI data, WDI (World Bank)

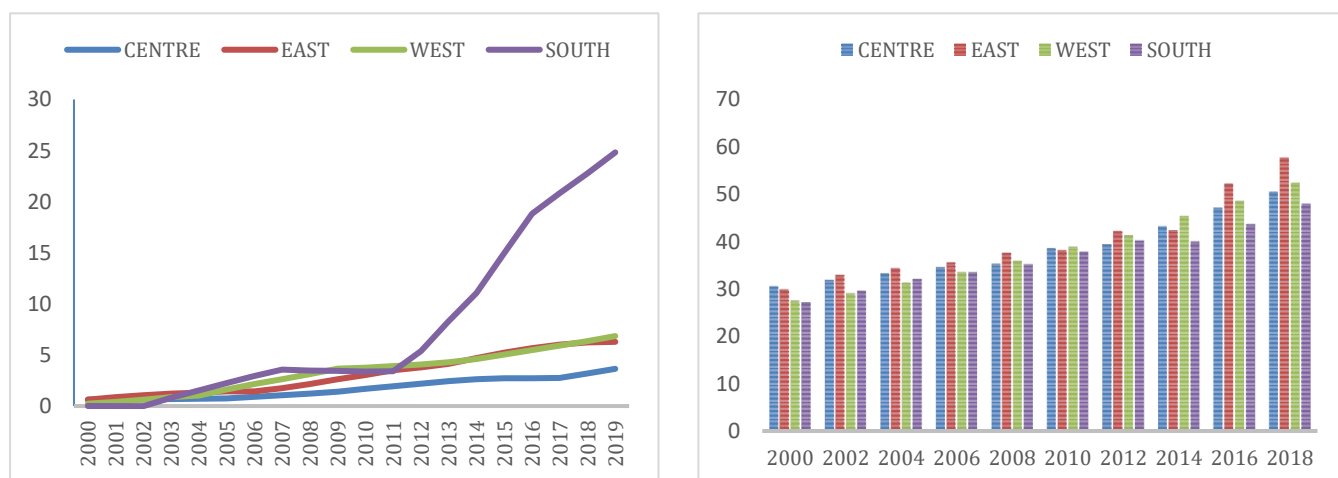
Note: The figure on the left shows the evolution over time of the PPP capital stock in the port sector for the 4 SSA regions. The figure on the right shows the evolution of container traffic over time for 4 SSA regions

The **Energy** sector is marked by a non-negligible jump in capital stock in the South region from 2012 onwards, while in the other three remaining regions the upward trend in capital stock is constant. This jump in PPP capital stock in the South region did not translate into a marked increase in access to electricity during this period. What is also noteworthy is that the upward trend in PPP capital stock in all regions is led by the South region, followed by the West, East and Central regions. This upward trend is also observed in access to electricity. However, it is not in the same order as the trend observed in capital stock. Indeed, the East region leads the way in terms of access to electricity, with a rate of around 58%, followed by the West with a rate of 52%, the Centre region with 50.3% and finally the South region with a rate of 47.8%.

Figure 2.5 : Access to electricity and PPP capital stock, by region

Energy: Electricity PPP capital stock

Energy: access rate



Source: author's estimate based on PPI data, WDI (World Bank)

Note: The figure on the left shows the evolution over time of the PPP capital stock in the energy sector for the 4 SSA regions. The figure on the right shows the evolution of the rate of access to electricity over time for 4 regions of the SSA.

3. PPPs Performance in ICT, Water and Road sectors: Does Governance really matter?

Abstract: The paper proposes to measure the comparative performance of countries with PPP investments compared to countries without PPP investments, in three different sectors: ICT, Water and Roads, based on propensity score matching (PSM) and confirmed by an IPW approach, while controlling for governance framework. To do this, the factors affecting the probability of a country carrying out a PPP were identified before measuring the effect of PPP investments on development indicators while controlling for governance framework related to the adoption of a PPP law and the PPP capacities of States. The results show that PPP investments improved the number of phone and internet subscriptions and the rate of access to water compared to indicators for countries without PPP investments. For roads, the results obtained by PSM are not significant, whereas the MMG approach leads to a positive effect of PPPs on road quality. For the roads and water sectors, the adoption of a PPP law does not have a significant effect on the probability of carrying out a PPP, unlike the ICT sector where the effect is negative. PPP capacities do not have a significant effect on the likelihood of a PPP in ICT sectors. While the capabilities of preparing and managing PPP contracts have a negative effect on the probability of carrying out a PPP in the roads sector. For the water sector, procurement capacity decreases the likelihood of a PPP.

Keywords: Public-Private Partnership, Governance, Water, ICT, Roads, Propensity Score Matching, IPW

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3.1. Introduction

Over the past decade, public-private partnerships have emerged as an essential financing mechanism for fostering infrastructure development in Africa. Many countries in sub-Saharan Africa are facing budgetary constraints that limit the financing needed to develop their infrastructure, with a financing gap estimated at \$93 billion per year (Foster and Briceño-Garmendia), compared with an annual financing level of \$45 billion, more than half of which is financed by the public sector (Dabiré and al., 2022). According to an OECD report (2011) on support for infrastructure financing in Africa, the deficit cannot be absorbed by public funding sources. According to Salawu and Fashlin (2015), PPPs are the only viable alternative for bridging the infrastructure gap facing African countries. Indeed, PPPs enable governments to draw on the financial resources of the private sector, reducing the immediate financial burden on their public finances. Beyond the financial resources that can be mobilized by private partners, innovation and efficiency in the construction and delivery of public infrastructure and services remain the main reasons why governments turn to PPPs. PPPs can enable projects to be implemented on time, reduce lifecycle costs, and improve performance through private-sector incentives (Medimagh and al., 2019). They also make it easier to identify and allocate project risks to the party best able to bear them, thus promoting rational use of resources.

Aware of the advantages that PPPs can offer when properly structured, the countries of sub-Saharan Africa (SSA) have taken a several initiatives to promote PPP investment to close the infrastructure gap and achieve the sustainable development goals they have set themselves. According to the most recent survey conducted by the African Legal Support Facility (ASLF) in 2023, of the 54 African countries, 42 have adopted PPP legislation. This highlights the importance of the PPP governance framework for Sub-Saharan African countries. The West and Central African regions have the highest number of countries with PPP legislation, apart from Equatorial Guinea and Gambia. However, it is in the Eastern and Southern regions that fewer PPP-specific laws have been passed. Of the 12 countries making up the Southern region, four (04) remain without PPP legislation. These include Botswana, Eswatini, Lesotho and South Africa. The other countries in the East region without a PPP law are Comoros, Eritrea, Seychelles, and South Sudan. The period 2015-2017 saw the most PPP laws passed, with a record 16. In addition to these PPP laws, 41 countries have at least one PPP unit. Unfortunately, the adoption of these PPP laws and the creation of PPP Units have not directly translated into an increase in PPP investments. According to the Private Participation in Infrastructure database, from 2013 to 2023, only 292 PPP projects reached financial close for a total amount of over \$60 billion. The leading sector of activity is electricity, followed by ports with almost \$12 billion. Next come ICT and roads. Put into perspective with the continent's needs, the balance sheet looks highly unsatisfactory. Several factors may explain the limited number of PPP investments in SSA, despite the continuing improvement in the regulatory framework for PPPs. Indeed, the first challenge remains the complexity or lack of regulatory and legal frameworks. Although some countries have adopted PPP laws, decrees implementing certain provisions of these laws are still pending. This is the case in Madagascar, for example, where the implementing decree for smaller-scale PPPs has not yet been adopted. Another challenge remains that of the country's economic and political framework. Private investors are looking for stability and predictable returns on investment. Indeed, Hammami and al. (2006); Kumar (2019) revealed that macroeconomic stability measured by foreign exchange reserves and inflation, as well as good governance measured by the

corruption index, country risk and rule of law index, are determinants of private sector participation in infrastructure development.

Although the level of PPP investment in SSA remains relatively low compared with other regions of the world, the fact remains that PPPs are of growing interest to SSA countries, given the various initiatives aimed at promoting them. While they are praised by policymakers, some case studies of PPP projects lead us to question their performance. While some PPP projects are presented as success stories, this is not the case for other PPP projects that have been renegotiated. It is important to highlight the large number of PPP projects that have been renegotiated (Guasch and al., 2003; Bitran and al., 2013). Moore and al. (2014) list 399 PPP projects that have been renegotiated between 1992 and 2011. In SSA, we can cite a few major projects that have been renegotiated: the Port of Maputo project (Mozambique), the Dakar-Diamniadio freeway project (Senegal), the Azito power plant project (Côte d'Ivoire), the Libreville water management and sanitation project (Gabon), etc. Despite the growing interest in PPPs in the public debate, there are no systematic studies evaluating the actual performance of these types of contracts (Fabre and al., 2023). In this chapter, we will look at the performance of PPP investments in sub-Saharan Africa in three different sectors: water, ICT, and roads. Initially, one of the reasons why public authorities resort to PPPs is the quest for efficiency and effectiveness. Indeed, PPPs can improve the quality and efficiency of infrastructure and services and facilitate innovation in their development (Carbonara and al., 2018). In the literature, the performance or role of PPPs is often limited to case studies comparing pre- and post-project situations (Fabre and al., 2019). Moreover, in the case of case studies, the role of PPPs is assessed by the criteria of completion time, cost, infrastructure quality or level of coverage (Farty and al., 2013; Mazouz, 2009). This makes global analysis of the role of PPPs in each sector difficult, as analyses are based on specific projects.

To fill this gap in the literature, this chapter will attempt to assess the role of PPPs in three different sectors: roads, ICT, and water. This analysis will be based on all PPPs implemented in each of the three above-mentioned sectors. The difficulty in such an assessment lies in the fact that the probability of making a PPP investment in each sector of activity in each country is not random. In general, countries with an adequate PPP environment and sector regulation are more likely to attract PPP investments (Hammami and al. 2006). Given that the decision to invest in PPP in each sector in each country is not random, we will use a quasi-experimental research method to compensate for the absence of randomization (White and al., 2014). To do this, two groups of countries are created: i) a first group of countries called the treated group with sectoral PPP investment (Water, ICT and Roads) and ii) a second group of countries with no PPP investment in these sectors (one sector at a time), called the control group. For the Water and ICT sectors, the expected outcome will be the effect of PPPs on the level of coverage or rate of access to water and the number of fixed-line telephone and Internet subscriptions, respectively. For the roads sector, the expected result will be the effect of PPPs on the quality of road infrastructure. We will then control for selection bias using the Propensity Score Matching approach to ensure that the characteristics of the countries in the two groups are comparable. Our approach is based on a three-stage process: the first stage consists in determining the factors explaining the assignment to the model under study. The factors are chosen based on their potential to influence the probability of a country belonging to the treated group, and on the results. These factors are known as PPP determinants. In addition to these determinants, we will analyze the effect of the adoption of a PPP law and

the PPP capacities of the States on the results. The second stage of our approach is the estimation of propensity scores, which correspond to the probability of a country benefiting from a PPP investment in each sector (Water, ICT and Roads). These propensity scores are estimated using a logit model. Once the propensity scores had been estimated, their quality confirmed and the common support zone determined, we finally proceeded to the matching stage using the nearest-neighbor method, confirming the results obtained with one of the following two methods: kernel matching or radius matching. We then analyzed the results (output) for each sector: the coverage rate (Water, ICT) and quality level (Road) in the treated group versus the matched control group, to measure the effect of PPP investments in each sector. Finally, robustness tests were carried out to ensure the reliability of the results obtained. Indeed, two alternative approaches will be used: the Inverse Probability Weighting (IPW) approach and the Generalized Method of Moments (GMM) approach. Furthermore, to ensure that the estimates obtained are not due to mere coincidence, the placebo effect will also be analyzed. Finally, we will conduct heterogeneity tests to determine whether institutional quality and the level of a country's development affect the relationship between sectoral PPP investments and their respective outputs.

In the ICT sector, the results show that countries with PPPs had a higher rate of ICT infrastructure coverage than countries without PPP investments in this sector. In other words, PPP investments led to an increase in the number of telephone and Internet subscriptions and these results are not sensitive to the quality of institutions but vary with the level of development of the countries. This coverage rate increases further if we consider the adoption of a PPP law in the country, and improve government capacity in the evaluation, procurement, and management of PPP projects. As for the effect of PPPs on water access rates, the results show that countries with PPPs have a better coverage rate than countries without PPP investments. Furthermore, the results are sensitive to the quality of institutions and level of development of the countries. However, neither the adoption of a PPP-specific law, nor the improvement of PPP player capacities had a significant effect on the coverage rate. As for the effect of PPPs on road quality, the results are not significant. However, the adoption of a PPP-specific and the improvement in PPP player capabilities, even if they are not significant, indirectly improved road quality. For each sector, robustness tests were conducted using an alternative approach (IPW, GMM) to confirm the results obtained. However, for road sector, the GMM approach concluded that PPPs made a positive and significant contribution on road quality.

The remainder of the chapter is organized as follows: section 2 presents a review of the literature. Section 3 deals with the analysis of the effect of PPP investments, with a presentation of the data and methodology. Section 4 presents the results of the analysis. Section 5 deals with the robustness analysis. Section 6 gives a summary of the different results. Finally, section 7 concludes the chapter.

3.2. Literature on PPP Performance

PPPs can help improve the efficiency of infrastructure projects, by benefiting from the know-how of the private sector (Moszoro and Gasiorowski, 2008). One motivation for using PPPs as an alternative means of financing infrastructure acquisition is the potential long-term gain in terms of efficiency and effectiveness (i.e., achieving desired outcomes in a timely and cost-effective manner). Their profitability remains a key element and contributes greatly to infrastructure development. This makes this mode of financing an

attractive tool for governments seeking to mobilize capital for the efficient delivery of public infrastructure (Kumar and al., 2021). To benefit fully from the efficiency of PPP investments, it is important to have a good grasp of the contours of these financing methods.

Before awarding a project to a private partner within the framework of a PPP, a rigorous multi-stage evaluation of the project is required. This project appraisal begins with the project identification phase and ends with financial closing.⁴ Beyond rigorous project appraisal, certain prerequisites must be met by countries wishing to make efficient PPP investments. Indeed, it is important for countries to define a regulatory framework surrounding the implementation of their PPP investments. Although several African countries (South Africa; Mozambique; Senegal; Togo; Ghana; etc.) have launched PPP investments without a specific PPP framework, it is important to note that the absence of a clear regulatory framework has led to challenges in terms of contract management and transparency (World Bank, 2009; AfDB, 2010).

Although they are linked, some of the drivers of efficiency gains in PPPs relate to a potential increase in allocative efficiency, notably the maximization of expected benefits, whereas most efficiency gains relate to risk management, cost management and innovation brought about by the private sector (APMG, 2016). One of the reasons why governments resort to these procurement methods is purely financial. Indeed, PPPs make it possible to mobilize the financial resources of the private sector to build public infrastructure, thereby helping to alleviate pressure on public finances (Yescombe, 2013). This financing approach enables governments to partner with the private sector to develop infrastructure essential to their development, while limiting dependence on public funds (Yuan and al. 2009; Grimsey and Lewis, 2004). However, PPPs can pose budgetary risks. That's why, before embarking on these types of contracts, which are long-term, risk-sharing between the two parties (public and private) is carried out during the evaluation phase, and the risks are allocated to the party better equipped to bear them (Osei-Kyie and Chan, 2015; Ke and al., 2010). This efficient sharing of risks between the two parties (public and private) also makes PPPs more advantageous than traditional financing (Akintoye and al., 2003). Risk transfer lies at the heart of efficiency gains and is an important factor in value-for-money. One of the risks generally transferred by the public authority to the private sector is construction risk (time, cost, and quality), as the latter is better able to manage this risk. This is what Hodge and al. (2007) report in their review of PPPs, notably the private sector's performance in delivering projects on time and on budget. Grimsey and al. (2004) also provide an in-depth analysis of the benefits of PPPs, including improved cost-benefit ratios through more timely completion of construction phases by the private sector. Another advantage of PPPs is the reduction in maintenance costs. Indeed, when in a PPP contract, the private partner is responsible for infrastructure maintenance, it minimizes its costs by improving the quality of infrastructure construction (EIB, 2011; OECD, 2012). Cost reduction can also be achieved through contract flexibility. The fact that PPP contracts focus on results rather than inputs gives the private sector scope for innovation in project delivery (Hart, 2003).

⁴ PPP Certification Guide, 2016: the 6 stages of PPP project appraisal are generally broken down as follows: project identification and screening, appraisal and preparation, structuring and drafting; procurement (contract award and signature); contract management - construction); contract management - operation.

PPP contracts don't only offer advantages, which is why the literature is not unanimous on their overall performance. PPPs are much more complex than traditional procurement methods and can have disadvantages. As a reminder, one of the factors that makes African governments resort to this mode of financing is the financial aspect, which can also be detrimental to the performance of a PPP. Indeed, PPPs when poorly structured constitute budgetary risks and can have a negative impact on public finances. (World Bank, 2015; IMF, 2018; Tariq and Zhang, 2021). Given their complexity compared with conventional procurement methods, PPPs require special attention from contracting authorities. Unfortunately, one of the reasons for the lack of PPP performance in Africa is the limited capacity of governments (Farlam, 2005). In a study of case studies of PPP projects in sub-Saharan Africa, Yescombe (2015) highlights the negative effects of the lack of capacity of public decision-makers in negotiating PPP contracts.

On a sectoral scale, PPPs have been the subject of several studies. However, most of the literature on sector PPPs is limited to case studies comparing pre- and post-project situations (Fabre and Straub, 2019). In these cases, the indicators generally used are completion times, cost variations, infrastructure quality or coverage levels following project completion (Farty and al., 2013; Mazouz, 2009).

Although Europe (France and Spain) saw its first road transport concessions in the 60s, it was not until the 90s that SSA saw its first concessions in this field (Estache and De Rus, 2000). In the road sector, it is more difficult to set performance targets in terms of access, unlike other sectors (water and electricity) where it is easier to establish them (Rozenberg and Fay, 2019). However, the literature does report some studies of PPP performance in the road sector using construction costs as an indicator. Blanc-Brude and al. (2009) found a 24% overrun in unit cost per km on a sample of 227 road projects financed by the European Investment Bank between 1900 and 2005.

PPP performance in the water sector is generally measured by coverage or quality indicators. For the latter indicator, what is used as a proxy in the literature is service continuity, notably the length of time the service was available, the frequency of interruptions or water losses (water that enters the distribution system but is not billed). Gassner and al. (2009) compared the performance of public water services offered by privately managed companies with those offered by state-owned companies. The results showed an 18% increase in sales for the privately-run companies, as well as an increase in subscriptions. Unfortunately, the results of the service quality indicators were not conclusive. Moreover, given the missing data, it was impossible to use a matching approach. Kirkpatrick (2006), analyzing the efficiency of water services in Africa, found that privately-run utilities outperformed public utilities. While a good deal of research seems to show that private utilities outperform public utilities in the provision of water services, a review of literature in the field by Porcher and Saussier (2018) seems to prove the opposite. Indeed, in developed countries, Bhattacharyya and al. (1995) and Shih and al. (2004) found that state-owned companies outperformed private ones. The access or coverage indicator is only relevant in developing countries, since developed countries have already achieved universal access. Comparing performance between private and public utilities, several studies have found that private sector participation in the provision of water services increases the rate of access to water (McKenzie and Mookherjee, 2003; Gassner and al., 2009; Andres and al., 2013).

Regarding the performance of PPPs in the ICT sector, it is more difficult to find a credible article addressing the subject, as in this sector, there is more talk of privatization than PPPs (Fabre and Straub, 2023). The lack of PPP projects in the sector is confirmed by Andres and al. (2008), who were unable to identify a PPP (concession) from 1990 to 2004 in the Latin American water sector. However, the findings of Fink and al. (2003), although focused on partial privatizations, could be considered to better understand PPPs in the ICT sector. To measure the performance of PPPs in the telecoms sector, a commonly used indicator of coverage or access is the number of fixed telephone subscriptions. Indeed, Andres and al. (2008) found an increase in the number of fixed-line subscriptions for partially privatized ICT services.

3.3. Analysis of the impact of PPP investments: Data and methodology

3.3.1. Data

The data used in this chapter comes mainly from the World Bank's Private Participation in Infrastructure (PPI) database. These include PPP investments in the various sectors selected: water, ICT, and road transport. As a reminder, the World Bank's PPI database lists all projects involving private sector participation. This chapter focuses solely on PPP investments that meet the PPP knowledge Lap definition of a PPP. Data on public investment comes from the IMF database (capital stock, 2017). Data on the PPP regulatory framework comes from a survey by the African Legal Support Facility (ALSF). Data on variables used as determinants of PPP investments come from several sources, including: The World Governance Indicators, 2020; the World Bank, WDI; Pen World Table version 10; and CPIA from the African Development Bank. Regarding the outputs used to measure the effect of PPP investments, three (03) sources were used. For outputs measuring quality, the World Economic Forum (WEF) database was used. For outputs measuring infrastructure coverage and development, the World Bank's WDI database and the African Development Bank's AIDI were used respectively.

For the **road sector**, to have a balanced database, the period of analysis selected was 2011 to 2017. The output analyzed in this sector is road quality measured by the WEF indicator. The sample selected includes six (06) SSA countries with PPP investments during this period, out of a total of 40 countries. According to the **Table 3.1**, of these six (06) countries, only three (03) had adopted specific PPP legislation.

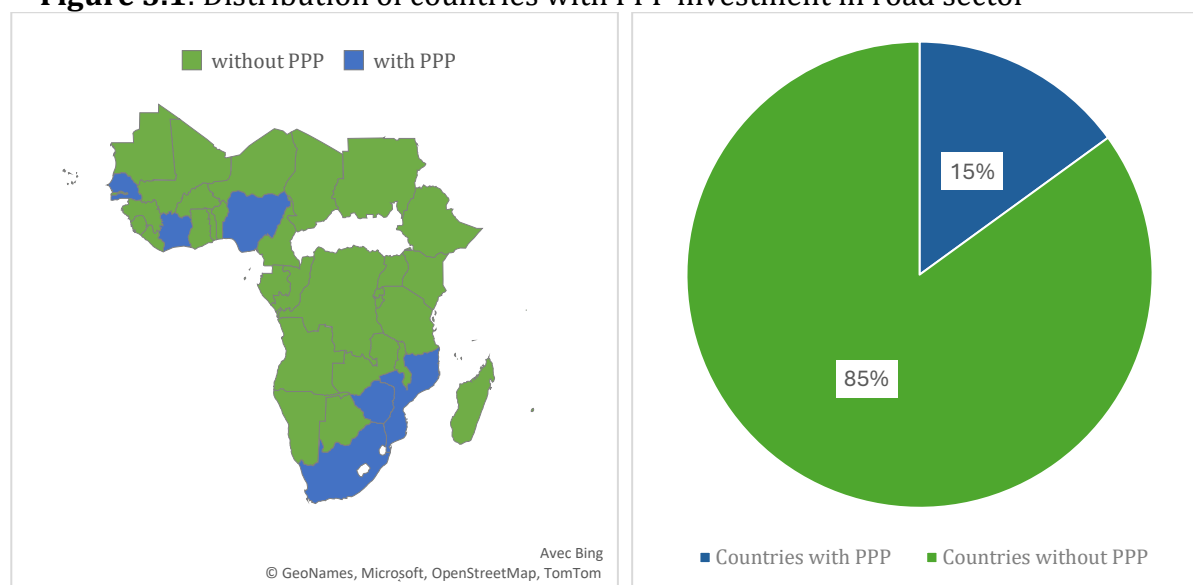
Table 3.1: Country performance indicators in the roads sector

	<i>Number of countries</i>	<i>PPP Law</i>	<i>Road Quality</i>	<i>Road Aidi</i>
<i>Countries with PPP</i>	6	3	3,41	7,68
<i>Countries without PPP</i>	34	21	3,32	9,89
<i>Total</i>	40	24		

Note: The table presents the characteristics of countries (PPP law, infrastructure indicators) according to whether they have made PPP investments in the road sector.

According to the **Figure 3.1**, countries with a PPP investment represent 15% of the sample. Whereas countries with no PPP investment in the road sector over the analysis period represent 85%. Looking more closely at the indicator measuring road quality in the group of countries with PPPs in the road sector from 2011 to 2017, it averages 3.41 out of 7. The average score for countries with no PPP investments in the road sector over the same period is 3.32 out of 7. For the road infrastructure development indicator, it is estimated at an average of 7.68 out of 100 for countries with PPP investments, versus 9.89 out of 100 for countries with no PPP investments over the analysis period.

Figure 3.1: Distribution of countries with PPP investment in road sector



Note: The figure on the left shows the countries with and without PPP investments on the map. The right-hand figure shows the repair as a percentage of countries with or without PPP investment in the road sector

For the **Water sector**, the analysis period 2007 to 2017 has been selected to have a balanced database. For this sector, the output used to measure the impact of PPPs is the percentage of people using at least basic drinking water services measured by the World Bank (WDI). The sample selected includes eight (08) SSA countries with PPP investments during this period, out of a total of 40 countries. According to the **Table 3.2**, of these eight (08) countries, only half (04) had adopted a specific PPP law.

Table 3.2: Country performance indicators in the water sector

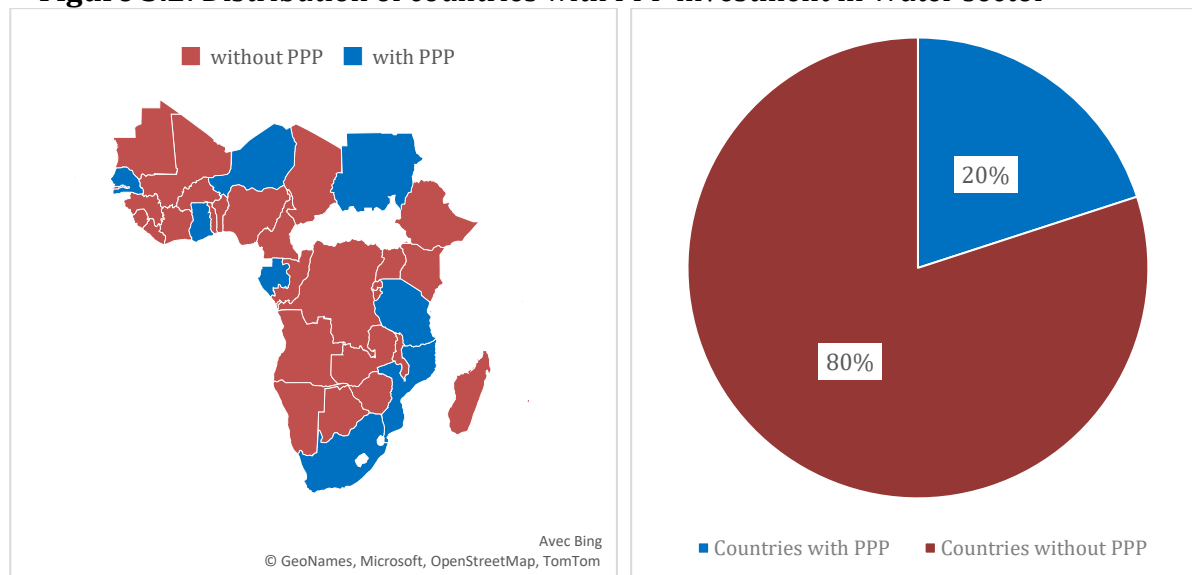
	<i>Number of countries</i>	<i>PPP Law</i>	<i>Water access</i>	<i>Water Aidi</i>
<i>Countries with PPP</i>	8	4	64,25	54,12
<i>Countries without PPP</i>	32	21	64,40	56,18
<i>Total</i>	40	25		

Note: The table presents the characteristics of countries (PPP laws, infrastructure indicators) according to whether they have made PPP investments in the water sector.

According to **Figure 3.2**, countries with PPP investments represent around 20 % of the sample. Countries with no PPP investments in the water sector over the analysis period account for 85%. In the group of countries with PPP investments, the average AIDI sector indicator measuring access to an improved water source and sanitation facilities over the period 2007 to 2017 is estimated at 64.25 out of 100, while that of countries with no PPP investments in the same sector and over the same period is on average 64.40 out of 100.

As for the indicator measuring the percentage of people using at least basic drinking water services of the World Bank (WDI), it is estimated on average at 54.12 out of 100 for countries with PPP investments versus 56.18 out of 100 for countries without PPP investments over the analysis period.

Figure 3.2: Distribution of countries with PPP investment in Water sector



Note: The figure on the left shows on the map the countries with and without PPP investments in the water sector. The right-hand figure shows the percentage of reparations of countries with or without PPP investment in the water sector

For the **ICT sector**, to have a balanced database, the analysis period selected was from 2012 to 2017. The output used in this sector is the percentage of fixed-line telephone subscriptions measured by the World Bank's WDI. The sample selected includes 14 SSA countries with PPP investments during this period, out of a total of 40 countries. According to the **Table 3.3**, of these 14 countries, only 6 had adopted specific PPP legislation.

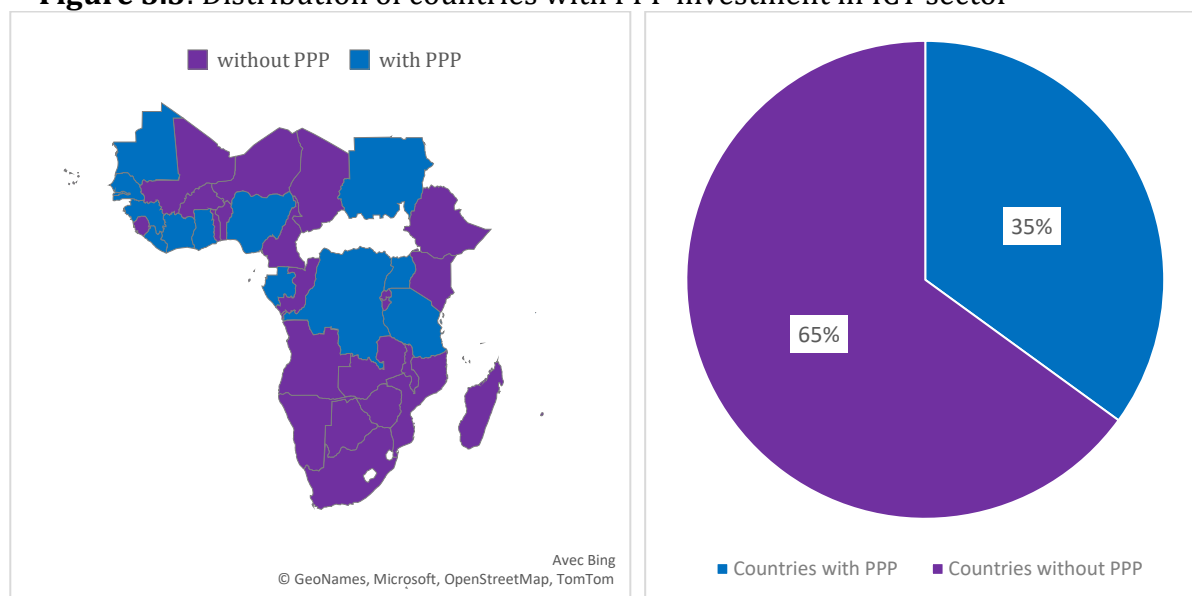
Table 3.3: Country performance indicators in ICT sector

	<i>Number of countries</i>	<i>PPP Law</i>	<i>Fixed telephone subscriptions</i>	<i>ICT Aidi</i>
<i>Countries with PPP</i>	14	6	18,74	10,43
<i>Countries without PPP</i>	26	18	15,40	9,49
<i>Total</i>	40	24		

Note: The table presents the characteristics of countries (PPP law, infrastructure indicators) according to whether they have made PPP investments in the ICT sector

According to the figure below, countries with a PPP investment represent 35% of the sample. Whereas countries with no PPP investment in the ICT sector over the analysis period account for 80%. The AfDB indicator measuring the percentage of telephone subscriptions and Internet users in the group of countries with PPPs in the ICT sector from 2012 to 2017 is estimated on average at 10.43 out of 100, while that of countries with no PPP investment is on average 9.49 out of 100. For the World Bank indicator measuring the number of fixed-line telephone subscriptions, it is estimated at an average of 18.74 out of 100 for countries with PPP investments, versus 15.40 out of 100 for countries without PPP investments over the analysis period.

Figure 3.3: Distribution of countries with PPP investment in ICT sector



Note: The left-hand figure shows on the map the countries with and without PPP investments in the ICT sector. The right-hand figure shows the repair as a percentage of countries with or without PPP investment in the ICT sector

A direct comparison of the average performance of indicators in ICT sector (**Table 3.3**) could lead us to overestimate the effect of PPPs on fixed-line telephone subscriptions and telecom infrastructure development. Conversely, this direct comparison could also lead us to underestimate the effect of PPPs on the level of access to basic drinking water service or access to an improved water source and sanitation facilities (**Table 3.2**). Directly comparing the performance of PPPs on the effect of roads could also mislead us into either overestimating the effect on road quality or underestimating the effect on the level of road development (**Table 3.1**).

However, the effect of not making PPP investments cannot be directly observed in countries that have not made PPP investments. To eliminate any bias and better understand the impact of PPP investments on infrastructure quality and coverage, a group of comparator countries with the same characteristics as the group of countries with PPPs needs to be created. The aim of the chapter is to create, for each sector, a group of countries with the same characteristics as those that have made PPP investments in the same sector, to assess the real impact of PPP investments on the different outputs selected.

3.3.2. Methodology

The aim of this chapter is to reduce bias in the estimation of the effect of sectoral PPP investments on infrastructure quality or coverage. To do this, we first motivate the choice of methodology. In randomized controlled methods, a randomly assigned intervention is used to divide the individuals studied into two groups: one that has undergone the intervention (known as the treatment group) and another that has not (known as the control group). Given the randomization, all individuals in each of the two groups have the same probability of receiving the treatment. In other words, the individuals studied have the same probability of belonging to one of the two groups (treated or control). The individuals in the two groups are statistically identical in terms of observable and unobservable characteristics. In this case, the treatment effect can be directly measured by the difference in results between the two groups (treatment and control).

In the case of observational studies, such as this one, randomization is impossible. For this study, for example, the intervention is the decision to invest in a PPP. Indeed, the decision to invest in a PPP in a country is not random, given all that these types of long-term contracts entail. Indeed, there are several factors that lead to the decision to invest in a PPP in a country or sector, rather than in another country or sector. These may include macroeconomic conditions, governance factors, market conditions (Hamani and al., 2012). In other words, countries do not have the same probability of receiving PPP investments because they are systematically different and don't offer the same opportunities to the private sector. Thus, a direct comparison of infrastructure quality or coverage rates between countries with PPPs versus countries without PPP investments can lead to biased conclusions about the real effect of PPPs.

To address the situation of non-randomization of PPP investments in a country or sector, we propose to use a quasi-experimental approach where the intervention is assigned to a group through self-selection (individuals choose treatment or control groups) or administrative selection (policymakers, civil servants, etc.) (White and Sabarwal, 2014). The aim is to identify a comparison group that is as identical as possible to the group that received the intervention. In our case, the control group is made up of countries that have not made PPP investments in the three (03) sectors studied, but with the same probability of doing so. The difference in results between the treatment group and the control group provides an estimate of the net effect or impact of PPP investments. As a reminder, the results analyzed are infrastructure quality and coverage rates, for the three sectors: Road, Water, and ICT.

Several methods can be used to identify the control group. Before listing the different methods, it is important to note that, based on the literature, two approaches are generally used to measure the impact of interventions: experimental and quasi-experimental. In our case, as explained above, we are not interested in the experimental approach, also known as randomized controlled trial. The quasi-experimental or non-randomized approach applies to situations where it is difficult to randomize the two groups (control and treatment). Quasi-experimental evaluation can be carried out using several techniques: double difference; regression on discontinuity; instrumental variable and matching score.

Double difference method: this is a method for assessing the causal effect of an intervention or treatment by comparing changes in outcomes over time between a treatment group (having undergone the intervention) and a control group (not having undergone the intervention). It's a simple method to use with panel data (Khandker, 2009). One of the method's limitations is the difficulty of verifying the basic hypothesis. Indeed, according to Bozio (2014), in the absence of treatment, the two groups studied should follow parallel trajectories over time. Also, this method requires pre- and post-intervention data, which makes it somewhat difficult to apply given the availability of data, especially in the field of infrastructure in Africa.

Regression on discontinuity (RDD): this is a method used to determine causal effects when treatment assignment is determined by a predefined eligibility threshold or a predefined cut-off point on a continuous variable, enabling the results of units on either side of the threshold to be compared. Its first use dates to the research work of

Thistlethwaite and Campbell (1960). The method is essentially based on the assumption that individuals near and around the eligibility threshold are statistically comparable, differing only in their participation in treatment. The method is relatively easy to apply compared to other econometric approaches. However, it requires precise data around the eligibility threshold. In addition, its fundamental hypothesis can be difficult to test. These limitations make it difficult to apply to our study.

The instrumental variable method: this consists of identifying a variable that delimits the two groups (treatment and control) to estimate the causal effect of the intervention. It makes it possible to estimate the probability of participation in a treatment through a variable exogenous to the outcome indicators (Cling and al., 2009). The main assumption is to find a variable that is statistically correlated with the treatment variable but not directly correlated with the outcomes analyzed. According to Givord (2014), the method has limitations, and its challenge lies in identifying relevant instrumental variables. In our case, it was not possible to find a variable correlated with PPP investments and not linked to outcomes (infrastructure quality and coverage).

The matching method: The matching method is used to estimate causal effects by balancing observable covariates between intervention and non-intervention groups, thus reducing the selection bias inherent in observational studies. It was proposed and introduced by Rubin (1974) in educational economics. It is generally used in the ex-post evaluation of intervention results. The basic principle of the method is to create a control group comparable to the treatment group using a propensity score, which is the probability that an individual will receive the treatment according to his or her observable characteristics.

In our study, we focused on the latter method: propensity score matching. One of the advantages of this method is that it reduces selection bias by balancing observable covariates between treatment and control groups. In addition to the method's advantages, it is widely used in the literature as part of quasi-experimental evaluations (Givord, P. 2014; Gertler and al. 2011; Maatala, N.; 2018). To create a counterfactual, we will first determine the characteristics explaining treatment assignment. In other words, for each sector we will look at the determinants of PPP investment. Secondly, for each sector, we identify a group of countries that have not made PPP investments in the sector but have the same probability of receiving them, using propensity score matching (PSM). Thirdly, when the control group is created, we compare the results between the two groups (treatment and control). As a reminder, the outcomes are quality and level of infrastructure coverage.

3.3.2.1. Processing assignment

A good match would be for each country in the treatment group to be matched with a country in the control group with the same observable characteristics. The greater the number of observable characteristics, the more difficult the matching procedure will be. In this case, it is advisable to calculate a propensity score, which is defined as the probability of a country being in the treatment group, given its observable characteristics. In our study, the propensity score is estimated by logit regression. It is advisable to use as many characteristics as possible to estimate the probability. However, only those characteristics that are not influenced by the treatment should be considered (Caliendo and al., 2008).

In this way, we have determined the characteristics that explain the assignment to the model to be studied. The characteristics are chosen based on their potential to influence the probability of a country belonging to the treated group and on the outcomes (coverage rate (Water and ICT) and road (quality level) to respect the conditional independence hypothesis. To analyze the real effect of PPPs on the 2 outcomes (coverage and/or quality), the factors that will be analyzed are exogenous variables, notably the determinants of PPP investments: budget deficit, public debt, public aid, inflation, foreign exchange reserves, population, GDP per capita, corruption index, country risk, rule of law. In addition to these characteristics, the following factor will also be considered: the adoption of a specific PPP law. This characteristic is a dummy variable taking the value 0 if the country has no specific PPP law, and 1 if it does. The adoption of a PPP law is a major element of the PPP legal framework. However, several countries have implemented PPP projects without waiting for the adoption of a specific PPP law. PPP legislation can be a decisive factor in a country's decision to use PPPs, and for the private sector to invest in a country. Another factor worth analyzing is the public partner's PPP capabilities. Indeed, these capabilities should be part of the government's motivation to enter a contract with the private partner. Unfortunately, many countries enter PPP contracts even though their PPP capabilities are lacking in several respects. In our study, these capabilities are measured at three levels: PPP project preparation, procurement, and PPP management during the contractual phase.

3.3.2.2. Propensity score evaluation and quality assessment

The second step consists of estimating propensity scores corresponding to the probability of a country benefiting from a PPP investment in one of the three sectors (Water, ICT and Roads). These propensity scores are estimated using a Logit model containing the explanatory variables for a country's probability of benefiting from a sectoral PPP. These variables were chosen based on the tests carried out in the first stage of our approach.

Once the propensity scores have been estimated, it is necessary to assess their quality. A good propensity score is a balancing tool: it should make it possible to balance the distribution of selected variables in the two groups (treatment and control). With a quality propensity score, significant differences between the groups (treatment and control) at baseline should no longer persist, for each of the variables used in the construction of the score (Lecocq and al., 2014). Classical distribution comparison tests will therefore be performed to assess the significance of the differences).

In addition to assessing the quality of the propensity scores, the existence of common support between the two groups (treatment and control) will be verified. This check ensures that each country benefiting from a sector PPP investment in the treatment group has at least one country with the same characteristics in the control group. The first is based on a comparison of the minimum and maximum propensity scores of the two groups, while the second is based on a comparison of the distribution (trimming).

3.3.2.3. Matching

Once the propensity scores have been estimated, their quality confirmed and the common support zone determined, we proceed to the third stage of our approach: matching. There are various matching estimators for finding the country or countries with propensity scores close to those of countries with PPP investments, the main ones of

which are used in our study to confirm the robustness of our results. This is the nearest neighbor method. This estimator matches a country that has made a PPP investment in a given sector with another country in the control group on the basis of the nearest propensity score. Kernel matching assigns greater weight to countries in the control group whose propensity scores are close to that of the country in the treatment group. Finally, radius matching imposes a threshold or maximum distance between propensity scores.

Finally, for each sector, we analyze the results (output): on the coverage rate (Water, ICT) and quality level (Roads) in the treated group versus the matched control group, to measure the average treatment effect (ATT) as a function of propensity scores. The final ATT estimator for the implementation of a sectoral PPP investment is obtained as the average of the deviations of the situation of countries having implemented PPP investments and that of their counterfactuals, estimated as follows:

$$\Delta ATT = E(Y_{i1} - Y_{i0} / T_i = 1) = E(Y_{i1} / T_i = 1) - E(Y_{i0} / T_i = 1) \quad (1)$$

T_i and the treatment variable taking the value 1 if a country has made a PPP investment in a given sector, and 0 otherwise. Y_{i1} and Y_{i0} and the level of infrastructure coverage (Water and ICT) or infrastructure quality (Road) of a country i , conditional on whether it has made a sectoral PPP investment, respectively.

3.4. Evaluation results by sector

This section presents the results of the evaluation of the real effect of PPP investments on the selected indicators. For each sector, Road, Water, and ICT, we will present the impact of PPP investments on road quality, water access rates and telephone and internet subscriptions, respectively. Results are presented by sector of activity.

ICT sector

After years of PPP investments in the ICT sector in SSA, it would be interesting to know how the level of Internet and telephony access in countries that have made PPP investments compares with those that have not. Have PPPs had a positive effect on access to ICT infrastructure? To answer this question, we present the results of our approach. To compare the level of ICT infrastructure development in countries that have implemented PPPs with that of countries that have not, we first had to find countries that are comparable in terms of their characteristics. These characteristics were chosen based on their ability to influence the probability of countries belonging to the group of countries with PPP investments.

First, it is essential to know the difference between countries that have received PPP investment in ICT and those that have not. **Table 3.4** shows the test results for both groups of countries, for the different variables used in this chapter. We performed t-tests to assess the significance of the difference between the means of the two groups (countries with ICT PPPs and countries without ICT PPPs). The results show that countries with ICT PPP investments are more likely to be more populous and wealthier in terms of GDP. This confirms the importance of market conditions as measured by GDP and population size. The results also show that countries that have made PPP investments

are not likely to have the best macroeconomic conditions. Indeed, foreign exchange reserves and the money supply are lower in these countries than in those without PPP investments. However, inflation is better controlled in countries with PPP investments. In addition, countries with PPP investments are less likely to be fiscally constrained. In fact, these countries have lower fiscal deficits and hold more natural resources as a percentage of exports. Countries with PPPs have received less development aid. However, this last variable is not significant. Finally, regarding good governance, the results show that PPP countries are less likely to have high-quality institutions. Indeed, factors such as rule of law, control of corruption, government efficiency and voice accountability perform less well compared to countries without PPP investments in the ICT sector. The same applies to the regulatory quality factor, which is not significant.

Table 3.4: Descriptive statistics conditional on concluding PPP (ICT)

	No PPP mean	PPP mean	Ho: diff = 0 Differences	Ha: diff < 0 Pr (T < t)	Ha: diff! = 0 Pr (T > t)	Ha: diff > 0 Pr (T > t)
Real GDP	71208.23	120171.8	-48963.5	0.0209	0.0419	0.9791
Population	18.28053	33.44415	-15.1636	0.0003	0.0005	0.9997
GDP per capita	4625.995	5185.529	-559.534	0.2117	0.4234	0.7883
Money Supply	37.54618	27.48991	10.05628	0.9999	0.0002	0.0001
Inflation	5.556173	7.654314	-2.09814	0.0119	0.0238	0.9881
Fiscal Balance	-3.848758	-2.654229	-1.19453	0.0043	0.0086	0.9957
Public Debt	45.72233	45.24966	.4726634	0.5566	0.8868	0.4434
ODA per capita	76.4225	70.0384	6.384093	0.7347	0.5307	0.2653
Natural Resources	11.48113	14.20326	-2.72212	0.0272	0.0543	0.9728
Control of Corruption	-.5257201	-.7012154	.1754953	0.9799	0.0403	0.0201
Rule of Law	-.5397874	-.6799727	.1401854	0.9653	0.0695	0.0347
Regulatory Quality	-.5566077	-.6455178	.0889102	0.8852	0.2296	0.1148
Government effectiveness	-.6321427	-.7978116	.1656689	0.9791	0.0418	0.0209
Voice accountability	-.3482382	-.5904581	.2422199	0.9955	0.0090	0.0045
Political Stability	-.3707486	-.7284285	.3576799	0.9993	0.0014	0.0007
International Reserve	4.191475	3.526869	.6646054	0.9950	0.0101	0.0050

Sources: Authors' calculation.

Note: The table presents descriptive statistics comparing PPP countries to countries without PPP investment in the ICT sector. It also presents the results of the t-tests for the selection of control variables.

In the results of our empirical analysis, we first present overall results that do not include a control on public sector PPP capabilities, nor on the PPP legal framework.

Model 1: no controlling for PPP capabilities and legal framework

Standard propensity score modelling begins with the estimation of the conditional probability of receiving a treatment, in our case the realization of a PPP investment. As mentioned above, we used Logit regression to estimate the conditional probability of making a PPP investment. As a reminder, the choice of control variables was conditioned by the results of the tests of significance of the mean of the differences presented in **Table 3.4**.

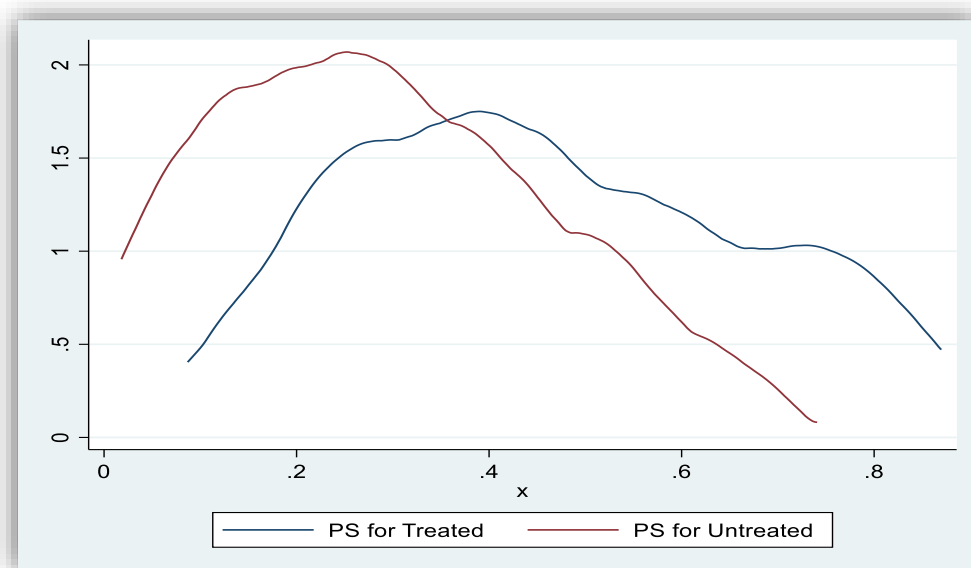
The **Table 3.23** in the appendix presents the results of the logit regression. Based on the results obtained, the first observation is the limited number of significant PPP determinants. Indeed, none of the business environment variables is significant. Yet it is in this sector that the greatest number of countries have made PPP investments. This may be due to the high profitability of projects in this sector, which compensates for certain policy-induced distortions (Hammami and al., 2006). This finding is confirmed by the "Population" variable, which is positive and significant. Another variable that measures

market conditions is GDP. However, despite its positive sign, it is not significant. In terms of budgetary constraints, we note that the probability of PPPs being implemented in countries with less budgetary constraints is relatively high. It should be remembered that PPPs in the ICT sector are generally user-pay PPPs, and the impact on public finances is less significant than that of public-pay PPPs. Furthermore, as far as macroeconomic conditions are concerned, countries with less money supply and fewer reserves of good fortune are more likely to make PPP investments. These results are in line with those of Hammami and al. (2006) on the determinants of PPPs in infrastructure. Indeed, countries with a controlled money supply reflecting stable and credible macroeconomic conditions are more likely to attract private investment.

At this stage, we have ensured that the level of overlap is acceptable, since for any given Propensity Score value, we have sufficient frequencies of treated and untreated units. This confirms the robustness of the approach and allows us to continue the evaluation, as the degree of overlap is sufficient to guarantee reliable estimation results, as we can see in **Figure 3.4**

Figure 3.4. The "common support" shows that the "non-support" units are only 12 out of 240, indicating a high degree of overlap within this data set.

Figure 3.4: Overlapping check using the Propensity Score (ICT)



Source: Author's estimation

Note: The figure shows the existence of a common support based on the propensity score obtained for the treated group (countries with PPP investments in ICT) and the untreated group (countries without PPP investments in the ICT sector)

The main objective of this section is to examine the effect of PPP investments on the coverage rate of ICT infrastructures. The results of this examination are presented in **Table 3.5**. We first note that the differences are positive and significant at a confidence level of 1%. We have also carried out a robustness test using the radius matching method, and we also note that the estimates provide very close results that are positive and significant. Thus, for the indicator: fixed-line telephone subscriptions, the difference with respect to the control group is positive. Using the neighbor matching method, we can say

that, on average, PPPs have enabled 7.56 more inhabitants out of 100 to have access to telephone subscriptions, compared with countries that have not invested in PPPs. This shows the positive effect of PPPs on ICT infrastructure coverage rates. A similar picture emerges when using the AfDB's AIDI sector indicator. However, the proportions are lower. This is due to the difference in the methodology used to compile the two indicators. In fact, for the neighbor matching method, PPPs enabled ICT infrastructure development to be 3.67 out of 100 higher than in countries without PPP investment.

Table 3.5: Model 1 Estimated ATE of PPP investments (ICT)

Fixed telephone subscriptions						
	PPP	No PPP	Difference	S.E.	T-stat	p-value
ICT Unmatched	18.7352	15.398	3.3372	1.9584	1.70	0.000
ATT-neighbor matching	18.7352	11.1674	7.5678	3.2668	2.32	0.001
ATT-radius matching	18.6590	10.6257	8.0332	2.6625	3.02	0.000

AIDI ICT						
	PPP	No PPP	Difference	S.E.	T-stat	p-value
ICT Unmatched	10.4254	9.4915	.9338	1.3624	0.69	0.000
ATT-neighbor matching	10.4254	6.7495	3.6759	2.5403	1.45	0.011
ATT-radius matching	10.5529	6.4357	4.1172	1.9216	2.14	0.001

Sources: Authors' calculation.

Note: The table shows Average Treatment Effect (ATE) on PPP investment on Fixed telephone subscriptions and sectoral AIDI for ICT using neighbor matching and radius matching methods with no control on variables.

With the overlaps verified and confirmed, we were able to estimate the ATTs using different methods. Model 1 allows us to use exogenous variables that are unaffected by the treatment. However, neglecting the legal framework, the capacity of the public partner or the geographical area could lead to a biased estimate of the effect of PPP investments. Thus, the second model differs from the present model through the control of the legal framework measured by the PPP law.

Model 2: controlling for the legal framework (PPP law)

In this model, the dummy PPP variable measuring the existence or non-existence of a PPP law will be added to the variables selected based on the significance of their difference. A PPP law is an important element of the governance of PPPs specially the legal framework. It can be an important element for a private partner before coming to invest in a country. It sets out the PPP institutional framework, the scope of application, the organization of procurement, the approach to dispute settlement, and so on. Logit regression was also used to estimate the conditional probability of making a PPP investment. **Table 3.23** in the appendix presents the results of the logit regression.

As in Model 1, the main finding remains the limited number of PPP determinants that are significant. In fact, there are only three significant variables, and they retain the same signs as in Model 1, as can be seen in **Table 3.23**. In addition to these variables, it should be noted that the new "PPP law" control variable is negative and significant. Thus, a PPP law does not increase the probability of achieving a PPP in the ICT sector. As mentioned above, the business environment, including the legal framework, is not a determining factor for PPPs in the ICT sector. This is due to the profitability of the sector (Hammami and al., 2006). In fact, only 2 of the 14 countries had specific PPP legislation before

launching their first PPP investment in the ICT sector. What's more, 18 countries have a PPP law, but have not yet made a PPP investment in the ICT sector.

For this model also, we have ensured that the level of overlap is acceptable. The degree of overlap is sufficient to guarantee reliable estimation results, as the "unsupported" units are only 6 out of 240, confirming a high degree of overlap within this data set.

The results of the estimation of the effect of PPP investments on the coverage rate of ICT infrastructures considering the PPP law are presented in .

Table 3.6. We first note that all differences are positive and significant at a confidence level below 1%. We also note that, controlling for the PPP law, all differences (regardless of the outcome indicator selected) remain positive, but are slightly up on the initial model. The increase is greater for the World Bank's WDI indicator (0.75) than for the AfDB's AIDI indicator (0.2). This suggests that the adoption of a specific PPP law has an indirect and positive effect on the rate of access to telephony and the Internet.

Table 3.6: Model 2 Estimated ATE of PPP investments (ICT)

Fixed telephone subscriptions						
	PPP	No PPP	Difference	S.E.	T-stat	p-value
ICT Unmatched	18.7352	15.398	3.3372	1.9584	1.70	0.000
ATT-neighbor matching	18.7352	10.4232	8.3120	3.0447	2.73	0.000
ATT-radius matching	18.6718	10.3606	8.3111	2.7321	3.04	0.000

AIDI ICT						
	PPP	No PPP	Difference	S.E.	T-stat	p-value
ICT Unmatched	10.4254	9.4915	.9338	1.3624	0.69	0.000
ATT-neighbor matching	10.4254	6.6004	3.8250	2.3178	1.65	0.006
ATT-radius matching	10.4579	6.2464	4.2115	1.9981	2.11	0.001

Sources: Authors' calculation.

Note: The table shows Average Treatment Effect (ATE) on PPP investment on Fixed telephone subscriptions and sectoral AIDI for ICT using neighbor matching and radius matching methods with control for the legal framework.

With the overlaps verified and confirmed, we were able to estimate the ATTs using different methods. Model 2 used the existence of a PPP law as a determinant of a PPP. We will now analyze the effect of public authorities' PPP capabilities on the two outcome indicators.

Model 3: controlling for the state's PPP capabilities

In this third model, we focus on another aspect of the governance of PPPs: the PPP capabilities of public authorities. These PPP capabilities will be measured by assessing three major stages in the PPP project cycle. These are preparation, procurement, and contract management. Each of these three stages will be measured by a variable corresponding to a score awarded during the World Bank's evaluations of the said stages. Logit regression was also used to estimate the conditional probability of making a PPP investment. **Table 3.23** in the appendix presents the results of the Logit regression.

As in the first two models, the main finding remains the limited number of significant PPP determinants, and the significant variables retain the same signs as in the previous

models. None of the three new variables measuring the state's PPP capabilities is significant, despite their positive sign. In fact, these three variables are linked to the existence of a PPP regulatory framework. However, these countries have started investing in the sector without really putting in place a PPP framework. It's also worth noting that many of these PPP projects in the sector are private initiatives or spontaneous bids. These types of projects are generally prepared by the partner, and the public authority's role in preparation is generally very limited. Lastly, these private-initiative projects are rarely put out to open tender. They are generally awarded to the bidder by direct agreement. However, their insignificance does not mean that they have no influence on the effect of PPPs. In fact, the increased capacity of the state can have an impact on other determining variables in our model. For example, preparation with better analysis of the budgetary sustainability of projects can have a positive impact on the budget deficit, or good preparation can improve the social acceptability of the project and have a positive impact on market conditions through an increase in users.

The degree of overlap is sufficient to guarantee reliable estimation results, as the "non-support" units are only 11 out of 240, confirming a high degree of overlap within this data set.

The results of the estimation of the effect of PPP investments on the coverage rate of ICT infrastructures considering the PPP capabilities of the contracting authority are presented in **Table 3.7**. We first note that all differences are positive and significant at a confidence level of 1%. We also note that with the contracting authority's PPP capabilities, all differences (regardless of the outcome indicator selected) remain positive and are slightly up on the initial model. The variation is greater for the World Bank's WDI indicator (1.99) than the AfDB's AIDI indicator (0.7). This suggests that the contracting authority's PPP capabilities have an indirect and positive effect on the rate of access to telephony and the Internet.

Table 3.7: Model 3 Estimated ATE of PPP investments (ICT)

Fixed telephone subscriptions						
	PPP	No PPP	Difference	S.E.	T-stat	p-value
ICT Unmatched	18.7352	15.398	3.3372	1.9584	1.70	0.000
ATT-neighbor matching	18.7352	9.1834	9.5518	2.7505	3.47	0.000
ATT-radius matching	19.2311	10.5458	8.6852	2.2829	3.80	0.000
AIDI ICT						
	PPP	No PPP	Difference	S.E.	T-stat	p-value
ICT Unmatched	10.4254	9.4915	.9338	1.3624	0.69	0.000
ATT-neighbor matching	10.4254	6.0785	4.3469	2.3570	1.84	0.010
ATT-radius matching	10.4579	6.5445	4.3225	1.5753	2.74	0.002

Sources: Authors' calculation.

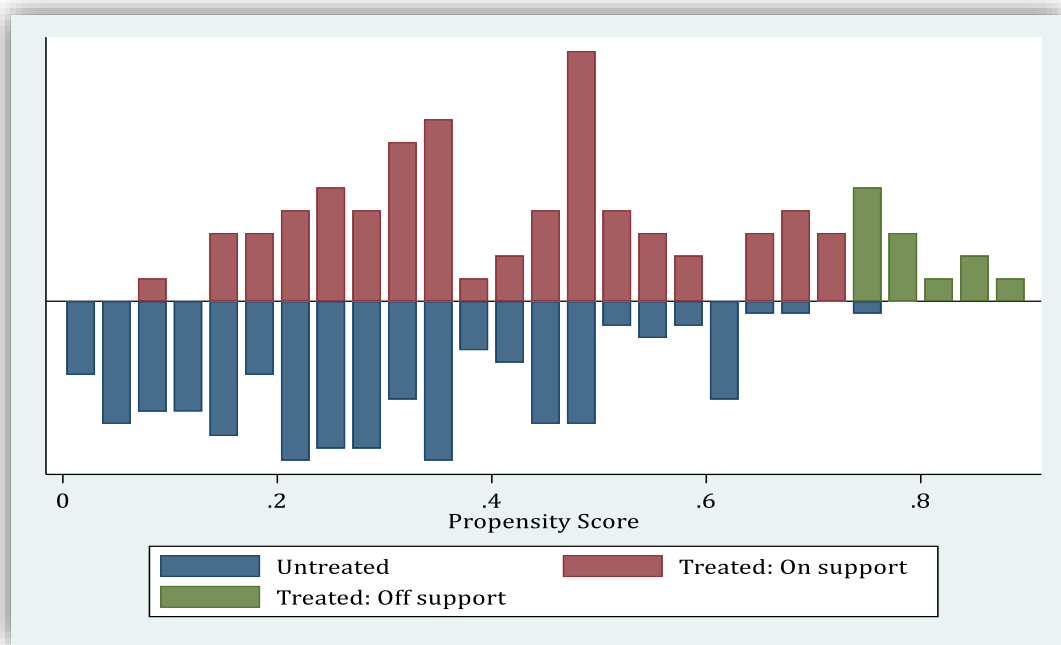
Note: The table shows Average Treatment Effect (ATE) on PPP investment on Fixed telephone subscriptions and sectoral AIDI for ICT using neighbor matching and radius matching methods with control for the country's PPP capabilities.

Post estimation and sensitivity test for ICT models

To ensure the robustness of our results, we check the Propensity Score Matching (PSM) balancing **Table 3.24** in the appendix shows the main balancing results. The t-test column shows that no difference in covariate means that was significant before the match continued to be significant after the match. This confirms that balancing holds for each control variable. In the second section of **Table 3.24**, which presents some balancing indices, we see a sharp reduction in mean (from 34.5 pre-match to 4.6 post-match) and median (from 32.9 pre-match to 3.7) bias, confirming that the matching procedure has successfully balanced treated and untreated units.

According to Benedetto and al. (2018), standardized biases (also known as standardized mean difference) are recommended to assess the balance of covariates between 2 groups. The standardized mean difference (SMD) compares the difference in means in units of the pooled standard deviation (Austin, 2009). A value higher than 0.10 (10% in case it is reported as percentage) is commonly considered index of residual imbalance. The lack of balance can indicate the need to add higher order or non-linear terms. Graphical diagnostics can be helpful for getting a quick assessment of the covariate balance in the presence of many covariates. The first step is to examine the distribution of the PS in the original and matched groups and the PS overlapping using mirrored histogram (**Figure 3.5**), while a Love plot of the standardized differences of means (**Figure 3.6**) gives us a quick overview of whether balance is adequate. The graphics confirm the achievement of good balancing, although very small differences still appear.

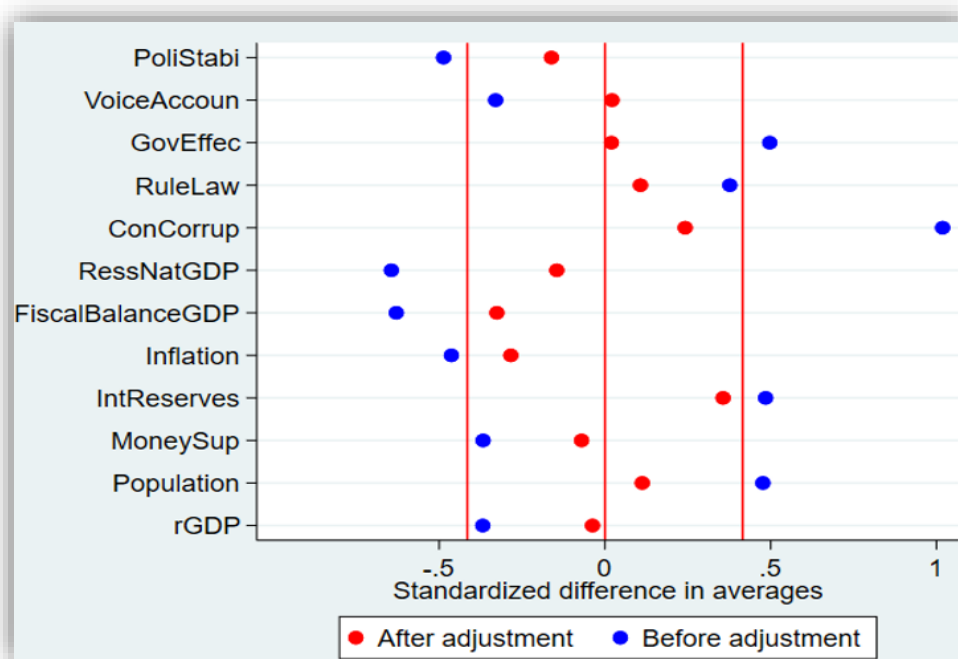
Figure 3.5: Propensity Score post matching balancing (ICT)



Sources: Authors' calculation.

Note: The figure shows the estimated balance between countries that have received PPP investments and countries with the same characteristics that have not received PPP investments in the ICT sector

Figure 3.6: Love Plot of SMD (ICT)



Note: Love plot of selected covariates, after (red circles) and before (blue circles) PSM analysis, the very narrow width of the red lines around the red points of the plot suggests that the variables have been well-balanced after matching.

Finally, to test the sensitivity of our results, we drew inspiration from the Rosenbaum bounds approach (2002). This method uses a "gamma" parameter to measure the degree of deviation from random treatment assignment. Gamma is the ratio between the propensity scores of treated and untreated individuals, which is equal to 1 in the normalization framework. We therefore assume that our gamma equals 1. Next, we assume the existence of an unobservable confounding factor generating an increase in the Gamma ratio: the greater this increase, the greater the deviation from randomization. Consequently, the test simulates higher Gamma values and explores the extent to which the ATT p-value remains significant. If the p-value (see "sig+" column) in **Table 3.25** in the appendix remains low even when Gamma increases significantly, this means that our matching results are robust. On the contrary, if we lose significance by a small amount compared to randomization, it means that the results are not robust. In our case, we lose significance at 5% (or 10%) by a 76% (or 95%) deviation from randomization induced by an unobservable confounding factor. We therefore conclude that our matching results are robust to unobservable confounders.

Water Sector

After years of PPP investments in SSA, it would be interesting to know how the rate of access to water in countries with PPP investments compares with that in countries without investments in the sector. The results presented in this section will attempt to answer these questions. **Table 3.8** presents the results of the mean difference t-tests between the two treated and untreated groups. This test was carried out on all the variables indicated as being determinants of PPP investments. Thus, we note that countries with PPP investments are more likely to have better market conditions, notably a larger population size and a higher income level measured by GDP. Macroeconomic

conditions are not significant for PPP investments in the water sector. Countries with PPP investments are less likely to receive development aid. Finally, regarding good governance, the results show that countries with PPP achievements are more likely to have quality institutions. Indeed, factors such as the rule of law, the quality of regulation and the effectiveness of government and voice accountability perform better in these countries than in countries without PPP investments in the water sector.

Table 3.8: Descriptive statistics conditional on concluding PPP (Water)

	No PPP mean	PPP mean	Ho: diff = 0 Differences	Ha: diff < 0 Pr (T < t)	Ha: diff! = 0 Pr (T > t)	Ha: diff > 0 Pr (T > t)
Real GDP	63582.84	140764.8	-77182	0.0000	0.0001	1.0000
Population	20.75139	27.42688	-6.675483	0.0342	0.0684	0.9658
GDP per capita	4348.088	5307.943	-959.8544	0.0492	0.0983	0.9508
Money Supply	32.57021	31.49584	1.074361	0.6746	0.6508	0.3254
Inflation	6.881758	8.094807	-1.213049	0.0727	0.1453	0.9273
Fiscal Balance	-2.03207	-3.08658	1.054507	0.8827	0.2346	0.1173
International Reserve	4.247073	3.836256	.4108171	0.9353	0.1295	0.0647
Public Debt	44.06428	43.89639	.1678937	0.5181	0.9638	0.4819
ODA per capita	94.06301	56.21589	37.84712	0.9996	0.0008	0.0004
Natural Resources	13.4591	12.30255	1.156558	0.7988	0.4024	0.2012
Control of Corruption	-.5919512	-.5457545	-.0461967	0.2675	0.5349	0.7325
Rule of Law	-.652025	-.4594895	-.1925356	0.0033	0.0065	0.9967
Regulatory Quality	-.6399681	-.4272758	-.2126923	0.0006	0.0013	0.9994
Govern. effectiveness	-.7364844	-.5298221	-.2066622	0.0020	0.0039	0.9980
Voice accountability	-.4922417	-.2912434	-.2009983	0.0070	0.0140	0.9930
Political Stability	-.4882284	-.4691315	-.0190969	0.4276	0.8553	0.5724

Sources: Authors' calculation.

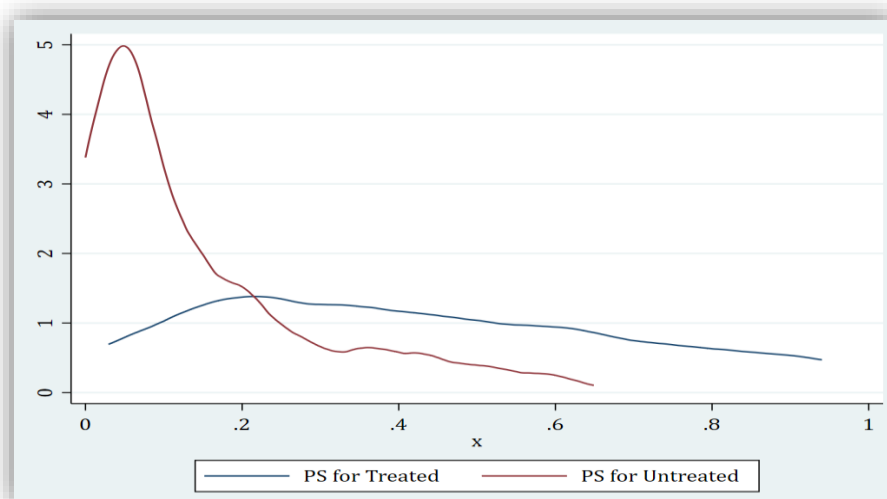
Note: The table presents descriptive statistics comparing PPP countries to countries without PPP investment in the water sector. It also presents the results of the t-tests for the selection of control variables

Model 1: no controlling for PPP capabilities and legal framework

Table 3.26 in the appendix presents the results of the logit regression. Based on the results obtained, the first observation is the significance of the variables linked to market conditions. Population and GDP are positive and significant at 0.1% and 10% respectively. Another factor that strongly increases the likelihood of PPPs in the water sector is the rule of law. In line with the literature on the determinants of PPPs, a strong rule of law combined with favorable market conditions increases the prevalence of PPP investments in the water sector (Hammami, 2006). However, the quality of regulation reduces the likelihood of PPPs in the water sector. According to Auriol (2021), this is to be expected. Indeed, regulating quality is a challenge in public services, particularly water, as quality is multidimensional, not objectively measurable, and difficult to measure. Thus, such a condition may reduce the interest of the private partner in a PPP. Other variables linked to macroeconomic conditions and budgetary constraints were not considered in the model, given their non-significance.

Before proceeding to the next steps in our approach, we ensured that the overlap was acceptable to guarantee reliable results (Figure 3.7). Indeed, the "common support" shows that "non-support" units number only 19 out of 440, indicating a high degree of overlap within this data set.

Figure 3.7: Overlapping check using the Propensity Score (Water)



Source: Author's estimation

Note: The figure shows the common support based on the propensity score obtained for the treated group (countries with PPP investments in the water sector) and the untreated group (countries without PPP investments in the water sector)

Table 3.9 presents the results of the effect of PPP investments on the level of access to water. We first note that the differences are positive and significant at a confidence level below 1%. We also note that the differences range from 1% to 7.9%. Using the neighbor matching method, we can say that, on average, PPPs have improved access to water for 1.16% more people than countries without PPP investments. This figure rises to 7.90% using the kernel matching method. This shows that PPPs have a positive effect on the rate of access to water.

Table 3.9: Model 1 Estimated ATE of PPP investments (Water)

	Water access rate for 100 inhbt					
	PPP	No PPP	Difference	S.E.	T-stat	p-value
ICT Unmatched	64.2449	64.3976	-.15264	1.9304	-0.08	0.001
ATT-neighbor matching	59.3904	58.2318	1.1586	2.9143	0.40	0.001
ATT-kernel matching	64.2449	56.3451	7.8998	4.1452	1.91	0.002

Source: Author's estimation

Note: The table shows Average Treatment Effect (ATE) on PPP investment on water access rate using neighbor matching and Kernel matching methods with no control on variables.

Model 1 allows us to use exogenous variables that are unaffected by the treatment. However, neglecting the PPP legal framework or the PPP capacity of the public partner area could lead to a biased estimate of the effect of PPP investments. Thus, the second model differs from the present model through the control of the legal framework measured by the PPP law.

Model 2: controlling for the legal framework (PPP law)

In this section, we will analyze the effect of the PPP law on our model. It should be remembered that many PPPs in the water sector were implemented long before countries adopted specific PPP laws. On the face of it, countries did not wait for a specific PPP law

before embarking on this type of procurement. A Logit regression was also used to estimate the conditional probability of making a PPP investment. **Table 3.26** in the appendix presents the results of the logit regression.

Controlling for the PPP law had no impact on the regression results compared with the results of the model without control. Indeed, the significance of the variables, as well as their sign, remained identical to model 1. However, it is important to emphasize the non-significance of the "PPP Law" variable, despite its positive sign. Thus, the PPP legal framework measured by the adoption of a PPP law does not increase the probability of a country making a PPP investment in the water sector. In fact, 21 countries had a PPP law, without having made any investments in the country. Also, of the 8 countries with PPP investments, only two had a PPP law.

Despite the non-significance of the "PPP Law" variable, we have ensured that the level of overlap is acceptable. Indeed, the "common support" table shows that "non-support" units number only 24 out of 440, indicating a high level of overlap within this data set.

The results of the estimation of the effect of PPP investments on the rate of access to water, considering the PPP law, are presented in **Table 3.10**. There was no significant difference between the two estimation methods. This means that the adoption of a specific PPP law had no effect on the rate of access to water.

Table 3.10: Model 2 Estimated ATE of PPP investments (Water)

	Water access rate for 100 inhbt					
	PPP	No PPP	Difference	S.E.	T-stat	p-value
ICT Unmatched	64.2449	64.3976	-.15264	1.9304	-0.08	0.001
ATT-neighbor matching	59.4417	61.0493	-1.6075	3.1120	-0.52	0.172
ATT-kernel matching	64.2449	60.0686	4.1763	4.5453	0.92	0.209

Sources: Authors' calculation.

Note: The table shows Average Treatment Effect (ATE) on PPP investment on water access rate using neighbor matching and Kernel matching methods with control for the legal framework

Model 2 used the existence of a PPP law as a determinant of a PPP. We will now analyze the effect of public authorities' PPP capabilities on the outcome indicator.

Model 3: controlling for the state's PPP capabilities

In this model, we focus on the state's PPP capabilities as a control variable. A clear PPP regulatory framework indicating the different stages of a PPP and the entities responsible can help attract more private investment into PPPs. However, the literature has shown that quality regulation can act as a brake on infrastructure investment in the sector. **Table 3.26** in the appendix presents the results of the logit regression.

The addition of variables measuring the government's PPP capacity had no impact on the regression results compared with the results of the model without controls, particularly in terms of the signs and significance of the variables. Also, the three variables added simultaneously are all negative and non-significant, except for the variable measuring the quality of project preparation, which is the only one that is negative and significant. When added separately, only the variables measuring the quality of contract

preparation and management are negative and significant. The variable measuring contracting quality is not significant, despite its negative sign. These results are in line with the literature in the water sector (Auriol, 2022). The three variables assess the best practices of states during the different phases of implementation of their PPP project. These best practices are a set of rules aimed at achieving value for money through improved transparency and quality. However, the quality of regulation reduces the likelihood of PPPs in the water sector. This may explain the negative sign of the contract preparation and management variables.

We also ensured that the level of overlap was acceptable. Indeed, the "common support" table shows that the "non-support" units are only 48 out of 440, which proves a good level of overlap.

The results of the estimation of the effect of PPP investments on the rate of access to water, considering the PPP capacities of the State, are presented in **Table 3.11**. We note that with the addition of these three control variables measuring the state's PPP capabilities, the differences are not significant for either method. This means that improving the state's PPP capacity had no effect on the rate of access to water.

Table 3.11: Model 3 Estimated ATE of PPP investments (Water)

	Water access rate for 100 inhbt					
	PPP	No PPP	Difference	S.E.	T-stat	p-value
ICT Unmatched	64.2449	64.3976	-.15264	1.9304	-0.08	0.001
ATT-neighbor matching	59.7113	66.4369	-6.7255	3.4485	-1.95	0.152
ATT-kernel matching	64.2449	59.7088	4.5361	8.2604	0.55	0.104

Sources: Authors' calculation.

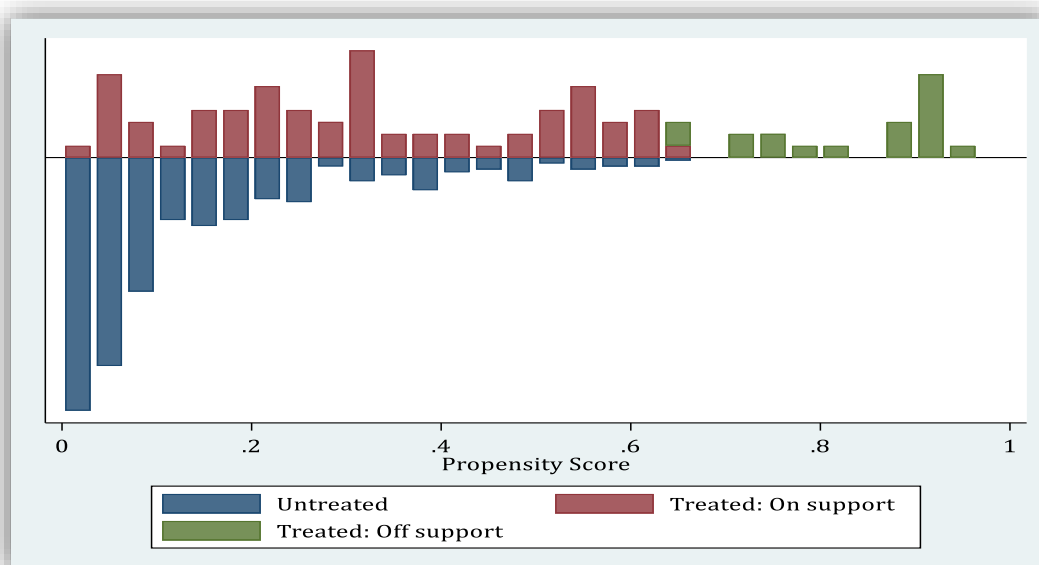
Note: The table shows Average Treatment Effect (ATE) on PPP investment on water access rate using neighbor matching and Kernel matching methods with control for the country's PPP capabilities.

Post estimation and sensitivity test for Water models

To ensure the robustness of our results, a Propensity Score Matching (PSM) balancing test was carried out. **Table 3.27** in the appendix shows the main balancing results. The t-test column shows that no difference in covariate means that was significant before the match continued to be significant after the match. Furthermore, the balancing indices show a strong reduction in mean (from 34.2 pre-match to 4.7 post-match) and median (from 36.4 pre-match to 5) bias, confirming that the matching procedure successfully balanced treated and untreated units.

Graphical diagnostics are also used for getting a quick assessment of the covariate balance. We first examine the distribution of the PS in the original and matched groups and the PS overlapping using mirrored histogram (**Figure 3.8**) and a Love plot of the standardized differences of means (**Figure 3.9**) to have a quick overview of whether balance is adequate. The graphics confirm the achievement of good balancing, although very small differences still appear.

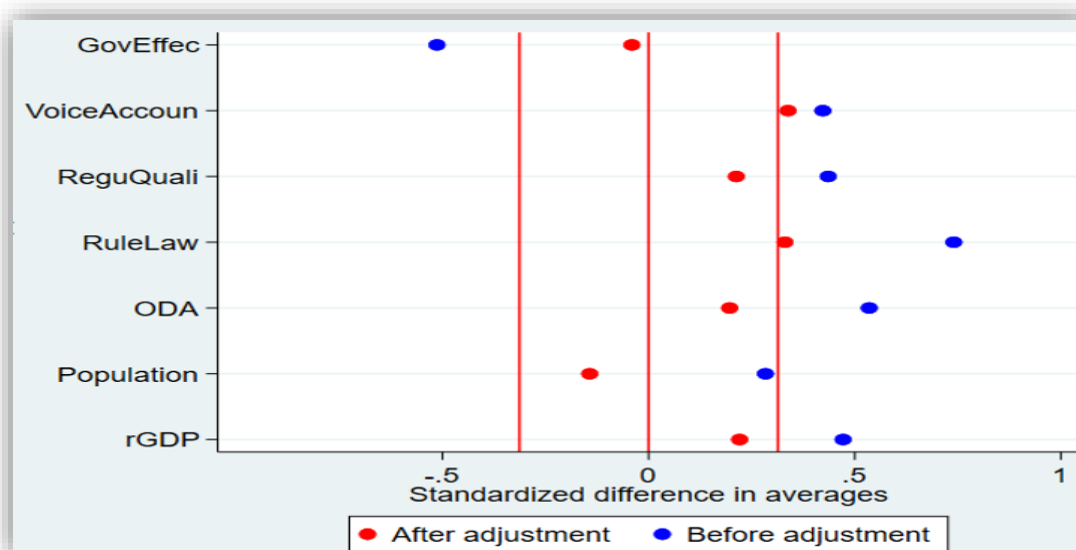
Figure 3.8: Propensity Score post matching balancing (Water)



Source: Author's estimation

Note: The figure shows the balance after estimation between countries that have received PPP investments and countries with the same characteristics that have not received PPP investments in the water sector

Figure 3.9: Love Plot of SMD (Water)



Source: Author's estimation

Note: Love plot of selected covariates, after (red circles) and before (blue circles) PSM analysis, the very narrow width of the red lines around the red points of the plot suggests that the variables have been well-balanced after matching.

Finally, a robustness test of the results was carried out using the Rosenbaum bounds approach (2002). The test results in **Table 3.28** show that we lose significance at 5% (or 10%) by a 31% (or 44%) deviation from randomization induced by an unobservable confounding factor. We can therefore conclude that our matching results are robust to unobservable confounders.

Road sector

After years of PPP investments in SSA, it would be interesting to know how the quality of roads in countries that have made PPP investments in roads compares with other SSA countries that have not. Have PPPs had a positive effect on road quality? To answer these questions, we present the results of our approach.

Table 3.12 shows the test results for the two groups of countries, for the different variables used in this chapter. We performed t-tests to assess the significance of the difference between the means of the two groups of countries (with PPP and without PPP). The results show that countries that have received PPP investment in the Road Transport sector are more likely to be more populous and wealthier in terms of GDP. This confirms the importance of market conditions for the transport sector as measured by GDP and population size. The results also show that countries that have made PPP investments are likely to have better control over their inflation. In addition, countries with PPP investments are more likely to receive development aid and have better control of corruption. However, countries with PPP investments are less likely to own natural resources. Finally, PPP investments are more likely to be made in countries with less stringent fiscal policies. The other determinants of PPPs in the roads sector are not significant.

Table 3.12 : Descriptive statistics conditional on concluding PPP (Road)

	No PPP mean	PPP mean	Ho: diff = 0 Differences	Ha: diff < 0 Pr (T < t)	Ha: diff! =0 Pr (T > t)	Ha: diff > 0 Pr (T > t)
Real GDP	48612.85	300979.2	-252366.3	0.0000	0.0000	1.0000
Population	18.32726	51.32083	-32.99357	0.0000	0.0000	1.0000
GDP per Capita	4761.123	4776.066	-14.94317	0.4930	0.9860	0.5070
Money Supply	32.93552	38.39122	-5.455703	0.0517	0.1035	0.9483
International Reserves	3.991085	3.917168	.0739173	0.5906	0.8189	0.4094
Inflation	6.835415	4.776247	2.059168	0.9645	0.0711	0.0355
Fiscal Balance	-3.151513	-3.580299	.4287852	0.7632	0.4736	0.2368
Public Debt	44.45928	43.11749	1.34179	0.6313	0.7375	0.3687
ODA per capita	82.3679	51.29283	31.07507	0.9896	0.0208	0.0104
Natural Resources	13.64649	8.186693	5.459801	0.9986	0.0028	0.0014
Control of Corruption	3.255687	2.991153	.2645335	0.9904	0.0191	0.0096
Fiscal Policy	3.80557	3.486524	.3190457	0.9946	0.0107	0.0054
Rule of law	-.5768251	-.712592	.1357669	0.9204	0.1592	0.0796
Regulatory quality	-.5863229	-.586692	.0003692	0.5016	0.9968	0.4984
Govern. effectiveness	-.6961117	-.6626727	-.033439	0.3703	0.7405	0.6297
Voice accountability	-.4613632	-.3217652	-.139598	0.1128	0.2257	0.8872
Political stability	-.4469082	-.7354942	.2885859	0.9799	0.0403	0.0201

Sources: Authors' calculation.

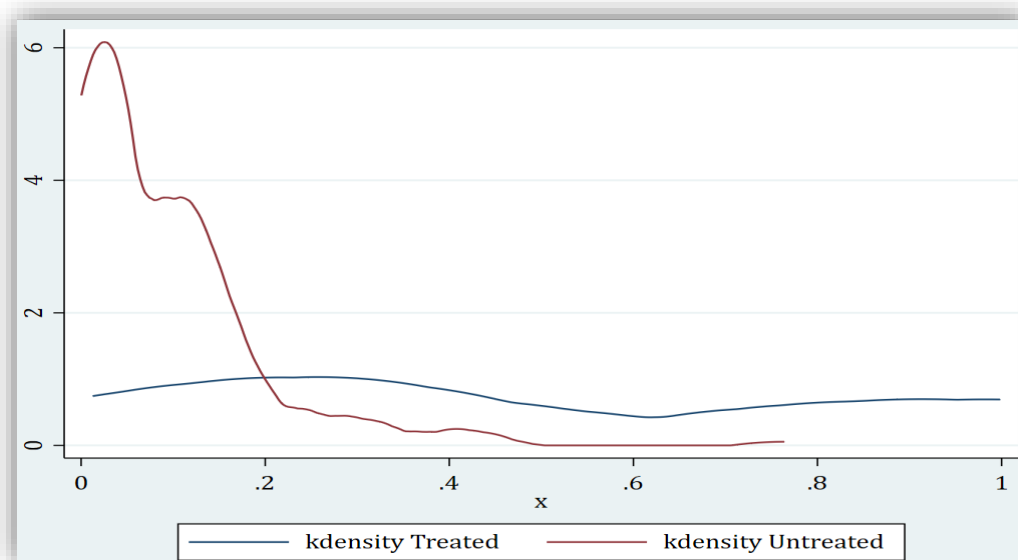
Note: The table presents descriptive statistics comparing PPP countries with countries without PPP investment in the road sector. It also presents the results of the t-tests for the selection of control variables

Model 1: no controlling for PPP capabilities and legal framework

Table 3.29 in the appendix presents the results of the logit regression. Based on the results obtained, the first observation is the significance of variable linked to market conditions. GDP is positive and significant at 5% respectively. Another factor that strongly increases the likelihood of PPPs in the road sector is low inflation. Indeed, low inflation is a sign of macroeconomic stability, allowing for better anticipation of the costs of road infrastructure projects over the duration of the contract. Additionally, low inflation helps ensure the predictability of cash flows, which primarily depend on revenues from tolls or staggered payments by contracting authorities. More interestingly, we find that the small size of natural resources as a percentage of GDP increases the likelihood of realizing PPPs in the road sector. When natural resources are insufficient to finance infrastructure projects, states systematically turn to the private sector to fill the financing gaps (Estache and al., 2004).

As with the other sectors, we ensured that the overlap was acceptable to guarantee reliable results. Indeed, the "common support» shows that "non-support" units number only 25 out of 280, indicating a high degree of overlap within this data set.

Figure 3.10: Overlapping check using the Propensity Score (Road)



Source: Author's estimation

Note: The figure shows the common support based on the propensity score obtained for the treated group (countries with PPP investments in the road sector) and the untreated group (countries without PPP investments in the road sector)

Table 3.13 presents the results of the effect of PPP investments on road quality. We first note that the differences are negative but not significant. We also note that the differences are -0.16 and -0.26 respectively for the neighbor and radius matching methods. Based on the results, even if the difference remains small, we cannot say that PPPs have impact on road quality. This result may be due to the very limited number of PPP investments made during the analysis period compared to traditional investments.

Table 3.13: Model 1 Estimated ATE of PPP investments (Road)

	Road Quality (WEF)					
	PPP	No PPP	Difference	S.E.	T-stat	p-value
ICT Unmatched	3.40738	3.32030	.08707	.13422	0.65	0.000
ATT-neighbor matching	3.23285	3.38919	-.15633	.21436	-0.73	0.899
ATT-radius matching	3.2308	3.49268	-.26188	.19043	-1.38	0.089

Sources: Authors' calculation.

Note: The table shows Average Treatment Effect (ATE) on PPP investment on road quality using neighbor matching and Kernel matching methods with no control on variables.

Model 2: controlling for the legal framework (PPP law)

In this model, we add to the initial model a new variable controlling the effect of governance proxied by the adoption of a PPP law. Logit regression was also used to estimate the conditional probability of making a PPP investment. **Table 3.29** in the appendix presents the results of the logit regression. The first finding is that the same variables as in the model are significant and retain the same signs. In addition to these variables, it should be noted that the new control variable "PPP law" is not significant. Thus, a PPP law has no effect on the probability of implementing a PPP in the road sector. In fact, PPPs in the road and water sectors were implemented long before countries had PPP laws. Côte d'Ivoire, Senegal, and South Africa are the countries that have implemented the most PPPs in this sector, and they did before the adoption of a PPP law.

The degree of overlap of this model is sufficient to guarantee reliable estimation results. Indeed, the "non-support" units number is only 25 out of 280, confirming a high degree of overlap within this dataset.

The results of the estimation of the effect of PPP investments on road quality considering the PPP law are presented in **Table 3.14**. We note that the differences are negative and not significant, as in the initial model.

Table 3.14: Model 2 Estimated ATE of PPP investments (Road)

	Road Quality (WEF)					
	PPP	No PPP	Difference	S.E.	T-stat	p-value
ICT Unmatched	3.40738	3.32030	.08707	.13422	0.65	0.000
ATT-neighbor matching	3.40738	3.4816	-.0742	.27739	-0.27	0.646
ATT-radius matching	3.24708	3.46082	-.2137	.18233	-1.17	0.212

Sources: Authors' calculation.

Note: The table shows Average Treatment Effect (ATE) on PPP investment on road quality using neighbor matching and Kernel matching methods with control for the legal framework.

Model 3: controlling for the state's PPP capabilities

In this third model, we looked at the PPP capabilities of public authorities as a determinant. Logit regression was also used to estimate the conditional probability of making a PPP investment. **Table 3.29** in the appendix presents the results of the logit regression. As in the first two models, market conditions (specially the GDP) are an important factor in increasing the probability of PPP investment in the road transport sector. The same is true of controlled inflation and limited natural resources. Regarding the government's PPP capabilities, measured by the variables: level of project preparation and PPP contract management, they are significant and negative. This reduces the

probability of a country implementing a PPP in the road sector. This negative sign can be explained by the fact that projects prepared by the public sector fail to attract the interest of private partners. There may be a few explanations for this, including the length of time it takes to complete the studies, the quality of the studies, poor market sounding, inadequate identification, or allocation of risks, etc. Regarding the capacity of states related to contract management, it is closely linked to the level of project preparation. Indeed, it often happens that PPP projects are subject to renegotiation due to poor preparation. These contract renegotiations harm the relationship between the private and public sectors and discourage private partners. Concerning procurement-related capacities, they increase the likelihood of realizing PPPs. This is likely since a significant portion of PPP projects in the road sector is carried out through unsolicited bids, which requires very little from the Country's preparation capacities, as they are often concluded through direct procurement. According to the ALSF survey (2024), 69% of the surveyed states use direct procurement. Given the limited technical capacities of states, this type of procurement can favor the private sector.

The degree of overlap is sufficient to guarantee reliable estimation results, the "non-support" units number is 23 out of 280, confirming a high degree of overlap within this data set.

The results of the estimation of the effect of PPP investments on road quality considering the PPP law are presented in **Table 3.15**. Unfortunately, the results obtained are not significant. However, even though the contribution is less significant than that of the PPP law, it is important to highlight the positive contribution of PPP capacities in improving road quality. Indeed, strengthening state capacities during the preparation, procurement, and management of contracts has a direct positive impact on the quality of road infrastructure.

Table 3.15: Model 3 Estimated ATE of PPP investments (Road)

	Road Quality (WEF)					
	PPP	No PPP	Difference	S.E.	T-stat	p-value
ICT Unmatched	3.40738	3.32030	.08707	.13422	0.65	0.000
ATT-neighbor matching	3.40738	3.4821	-.0747	.29601	-0.25	0.761
ATT-radius matching	3.17954	3.43007	-.25005	.19316	-1.30	0.132

Sources: Authors' calculation.

Note: The table shows Average Treatment Effect (ATE) on PPP investment on road quality using neighbor matching and Kernel matching methods with control for the country's PPP capabilities

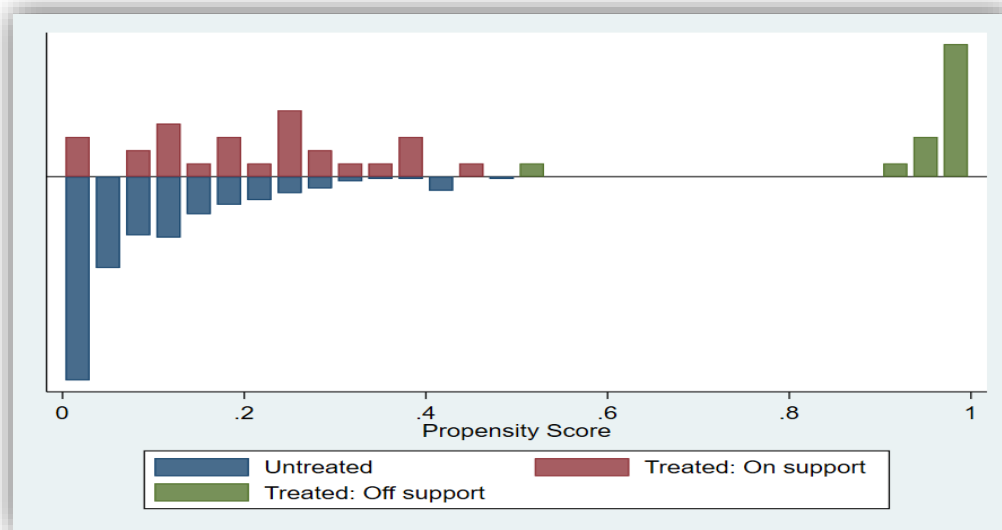
Post estimation and sensitivity test for Road models

To ensure the robustness of our results, a Propensity Score Matching (PSM) balancing test was carried out. **Table 3.30** in the appendix shows the main results of the balancing. The t-test column shows that no difference in covariate means that was significant before the match continued to be significant after the match. In addition, the balancing indices show a strong reduction in mean (from 61.2 pre-match to 10.2 post-match) and median (from 48.3 pre-match to 8) bias, confirming that the matching procedure successfully balanced treated and untreated units.

Graphical diagnostics are also used for getting a quick assessment of the covariate balance. We first examine the distribution of the PS in the original and matched groups

and the PS overlapping using mirrored histogram (**Figure 3.11**) and a Love plot of the standardized differences of means (**Figure 3.12**) to have a quick overview of whether balance is adequate. The graphics confirm the achievement of good balancing, although very small differences still appear.

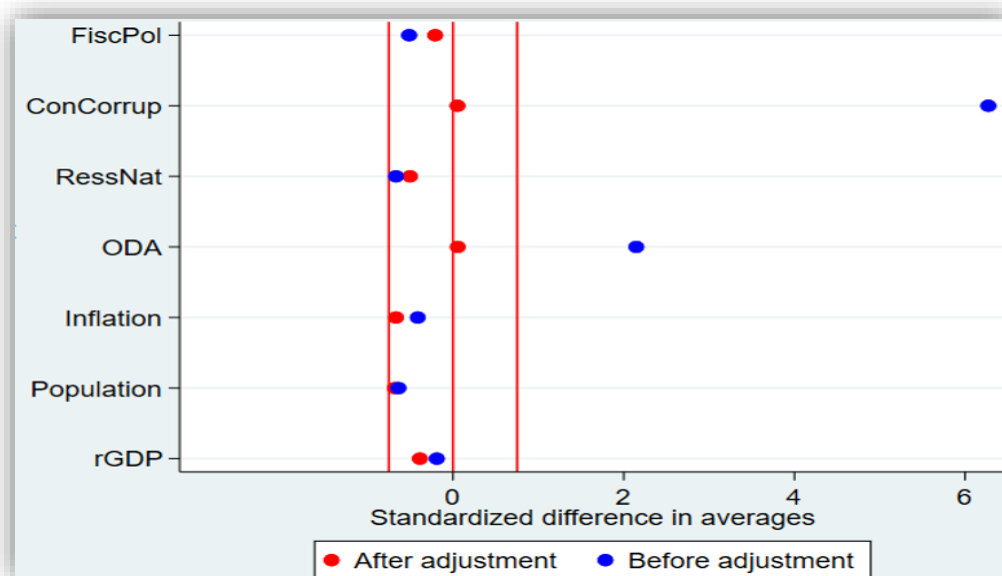
Figure 3.11: Propensity Score post matching balancing (Road)



Source: Author's estimation

Note: The figure shows the estimated balance between countries that have received PPP investments and countries with the same characteristics that have not received PPP investment in the roads sector

Figure 3.12: Love Plot of SMD (Road)



Note: Love plot of selected covariates, after (red circles) and before (blue circles) PSM analysis, the very narrow width of the red lines around the red points suggests that the variables have been well-balanced after matching.

A robustness test of the results was performed using the Rosenbaum bounds approach (2002). The results of the test in **Table 3.31** show that we do not lose significance in

relation to randomization induced by an unobservable confounding factor. We can therefore conclude that our matching results are robust to unobservable confounders.

3.5. Robustness Analysis by Sector

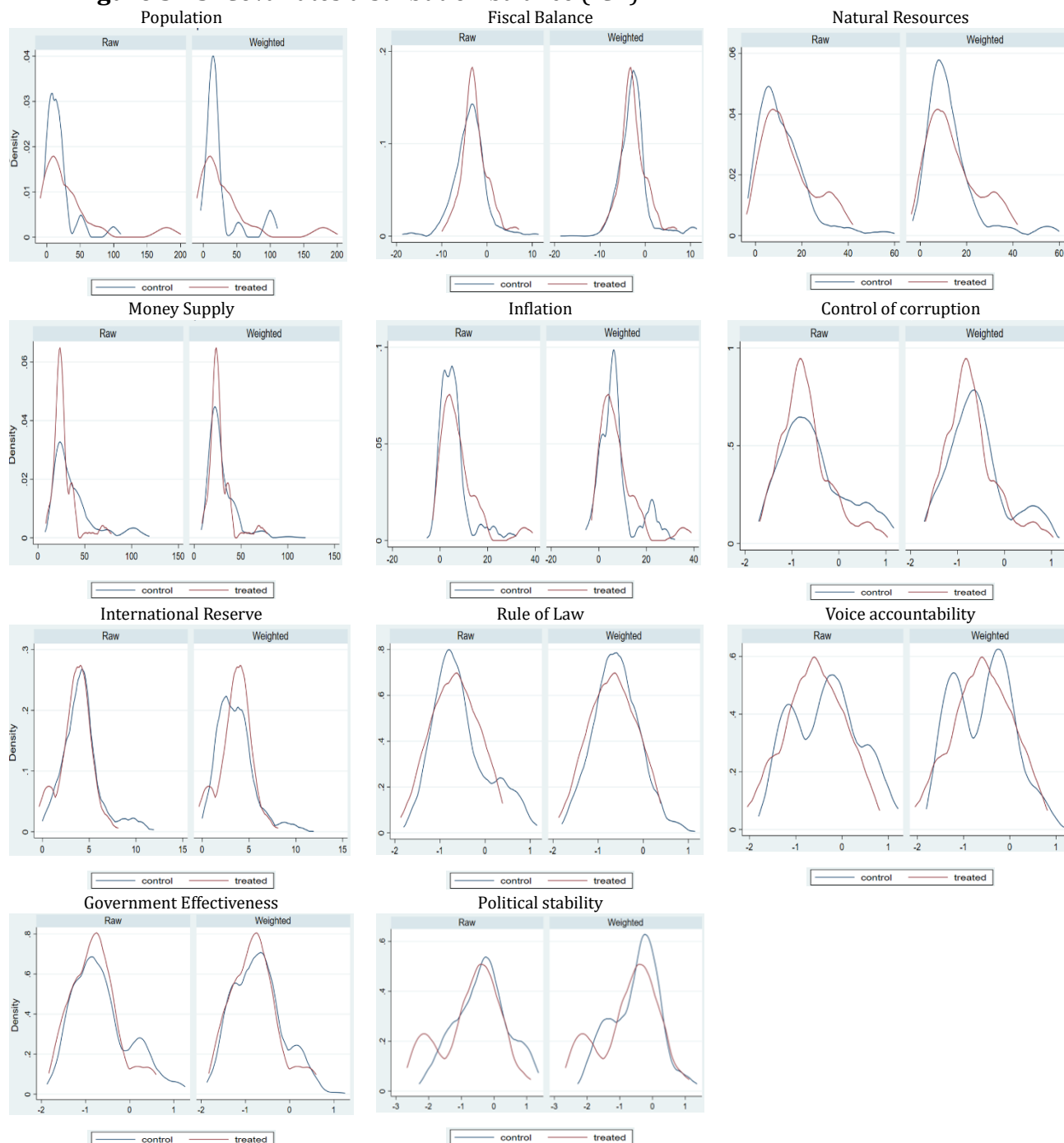
3.5.1. ICT Sector

IPW Estimation

We will investigate the IPW approach, popularized in economics by Hirano and al. (2003), as an alternative to PSM. The observed differences between countries that implemented PPPs and those that did not can lead to biased estimates of treatment effects (Agostino, 1998). Compared to matching, IPW has the advantage of retaining the entire sample for analysis, provided the common support assumption holds, whereas PSM excludes individuals who cannot be matched.

The methodological approach involves several steps. First, we estimate the propensity score using a Logit regression that measures the probability of a country engaging in a PPP investment in the ICT sector based on observed characteristics. Once the propensity score is estimated, we calculate the weights. Each country receives an inverse weighting based on the probability of engaging in a PPP investment. More specifically, for treated countries, the weight is the inverse of the propensity score, i.e., $(PS)^{-1}$, while for countries without PPP investments, the weight is $(1-PS)^{-1}$. The inverse weighting reduces the importance of countries that had a high probability of executing a current PPP based on observable characteristics and increases the importance of countries that had a low probability of executing a PPP but did so based on observable characteristics (Lecocq and al., 2014). After estimating and applying the weights, we ensured covariate balance between the two groups of countries (with and without PPP investments) by comparing covariate distributions before and after weighting. **Figure 3.13** below shows a good balance for all covariates before and after applying the weights.

Figure 3.13: Covariates distribution balance (ICT)



Note: Density function showing the distribution balance for different covariable used to estimate the PS. It shows balance plot before and after weighting. The blue line represents countries without PPP and red, countries with PPP

Given that the PSM results remained positive and significant, regardless of the two control variables (PPP Law and PPP Capacity), we opted to limit the IPW estimation to the initial model, i.e., the model without control variables. The IPW results are like those obtained through the PSM approach. Indeed, with PSM, PPPs helped improve fixed-line telephone and internet subscriptions by 3.6% to 4.1%, depending on the estimation method. Using IPW, the results show a significant 4.08% increase in subscriptions due to PPP investments.

Table 3.16: IPW method estimations Results (ICT)

AIDI ICT				
	Difference	S.E.	T-stat	p-value
Average treatment effect on treaties (ATET)	4.084338	.848162	4.82	0.000
Pomean	6.341093	.571985	11.09	0.000

Note: The table shows the results of the IPW estimation and the level of significance.

Placebo Effect

To test the difference between countries that implemented PPPs and those that did not, we conducted a "placebo effect" test. This test determines whether PPP investments truly contribute to improved access to fixed-line telephony and internet or if the increase in subscriptions is due to data bias or mere coincidence. We introduce a new dummy variable to measure the placebo effect. Naturally, we expect the effect of the fake variable to be close to zero and not significant. The variable of interest is the binary PPP investment indicator, and we include the same explanatory variables, such as PPP determinants. **Table 3.17** shows that the placebo test results are not significant, confirming the positive and significant contribution of PPPs to fixed-line telephony and internet access.

Table 3.17: Placebo Effect Test Results (ICT)

IPW				
	Difference	S.E.	T-stat	p-value
Average treatment effect - Placebo	-1.67373	1.20980	-1.38	0.168
Average treatment effect - Initial Model	4.28138	.857447	4.99	0.000

Note: The table presents the significance of the placebo variable on subscription levels for fixed-line telephony and internet. It shows a significant effect in the initial model, unlike the placebo effect.

Heterogeneity Test

Given the disparities between countries at the institutional and economic levels, we performed heterogeneity tests to determine whether the effect of PPP investments on access to fixed-line telephony and the internet varies depending on the quality of institutions and economic development. In other words, we used the "testpram" command (below) in Stata to test whether global interactions between treatment and these variables (institutional quality and economic development) are significant.

- (1) 1.Treat#c.ControlOfCorruption = 0
 - (2) 1. Treat#c.RuleOfLaw = 0
 - (3) 1. Treat#c.PoliticalStability= 0
 - (4) 1. Treat#c.GovEffectiveness= 0
 - (5) 1. Treat#c.VoiceAccountability= 0
- F(5, 234) = 0.07
Prob > F = 0.7974

The results show that the p-value from the F-test allows us to reject the hypothesis that institutional quality affects the relationship between PPP investments and access to fixed-line telephony and the internet. These results confirm earlier findings that PPP interventions in the ICT sector are driven by profitability rather than institutional quality.

Furthermore, we tested whether the effect of PPP investments on access to fixed-line telephony and the internet varies depending on the economic development of countries.

$$(1) \text{ 1.Treat\#c.RealGDP} = 0$$

$$F(1, 236) = 49.32$$

$$\text{Prob} > F = 0.0000$$

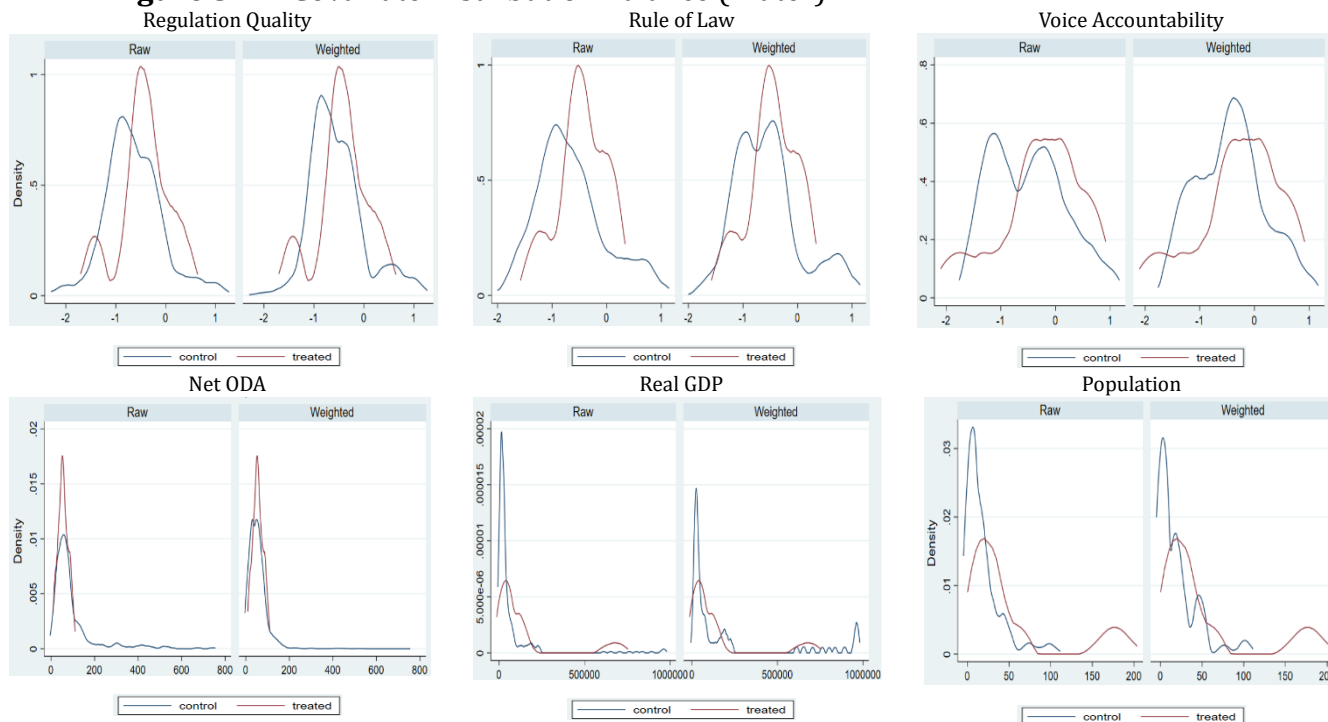
The results show that the effects of PPP investments on access to fixed-line telephony and the internet are conditioned by the level of economic development, consistent with the initial results

3.5.2. Water Sector

IPW Estimation

For the water sector, we also applied an alternative estimation approach: Inverse Probability Weighting (IPW). We first estimated the propensity score using a Logit regression that measured the probability of a country undertaking a PPP investment in the water sector based on its observed characteristics. Once the propensity score was estimated, we calculated the weights. After applying the weights, we ensured the covariates were balanced between the two groups of countries (those with and without PPP investments) by comparing the distributions of covariates before and after weighting. **Figure 3.14** shows a good balance before and after applying the weighting for all covariates.

Figure 3.14: Covariate Distribution Balance (Water)



Note: Density function showing the distribution balance for different covariable used to estimate the PS. It shows balance plot before and after weighting. The blue line represents countries without PPP and red, countries with PPP.

We estimated the initial model without control variables (PPP Law and PPP capacity) using the IPW approach. The IPW results are like those obtained with the Propensity

Score Matching (PSM) approach. In the PSM approach, PPPs were found to improve water access by 1.15% to 7.89%, depending on the estimation method. With the IPW approach, the results show a significant increase of 5.33% in the number of people with access to water due to PPP investments.

Table 3.18: IPW Estimation Results (Water)

Water access rate for 100 inhbs				
	Difference	S.E.	T-stat	p-value
Average treatment effect on treaties (ATET)	5.331495	2.711359	1.97	0.049
Pomean	48.78543	1.648194	29.60	0.000

Note: The table presents the IPW estimation results and the level of significance.

Placebo Effect

To test the difference between countries that implemented PPP investments and those that did not, we conducted a "placebo effect" test. A new fictitious variable was introduced to measure the placebo effect. As in the ICT sector, the variable of interest remains the binary variable for PPP investments, and we introduced the same explanatory variables, such as the determinants of PPPs. **Table 3.19** shows that the results of the placebo test are not significant, which confirms the positive and significant contribution of PPPs to water access.

Table 3.19: Placebo Effect Test Results (Water)

IPW				
	Difference	S.E.	T-stat	p-value
Average treatment effect - Placebo	-.5039679	2.156052	-.23	0.815
Average treatment effect - Initial Model	7.51343	1.89232	-3.97	0.000

Note: The table presents the results of the placebo variable's significance on water coverage. It shows a significant effect of the initial model, unlike the placebo effect.

Heterogeneity Test

Given the disparities that may exist between countries in terms of institutional and economic levels, we conducted heterogeneity tests to determine if the effect of PPP investments on water access varies depending on institutional quality and the country's level of economic development. Using the Stata command *testpram*, we tested the significance of global interactions between the treatment and variables (institutional quality and economic development).

- (1) 1.Treat#c.RegulatoryQuality = 0
 - (2) 1. Treat#c.RuleOfLaw = 0
 - (3) 1. Treat#c.GovEffectiveness= 0
 - (4) 1. Treat#c.VoiceAccountability= 0
- F(4, 436) = 6.62
Prob > F = 0.0104

Based on the results obtained, the p-value of the F-test does not allow us to reject the hypothesis that institutional quality affects the relationship between PPP investments and water access. These results confirm earlier findings. Indeed, the rule of law is a crucial

factor in the likelihood of achieving a PPP in this sector. However, regulatory quality reduces the likelihood of PPPs in the water sector. According to the literature, regulatory quality is a challenge in public services, especially water, because quality is multidimensional, not objectively measurable, and hard to assess.

Furthermore, we tested whether the effect of PPP investments on water access rates varies depending on the level of economic development of the countries.

$$\begin{aligned} (1) \quad & 1.\text{Treat}\#c.\text{RealGDP} = 0 \\ & F(1, 436) = 37.09 \\ \text{Prob} > F &= 0.0000 \end{aligned}$$

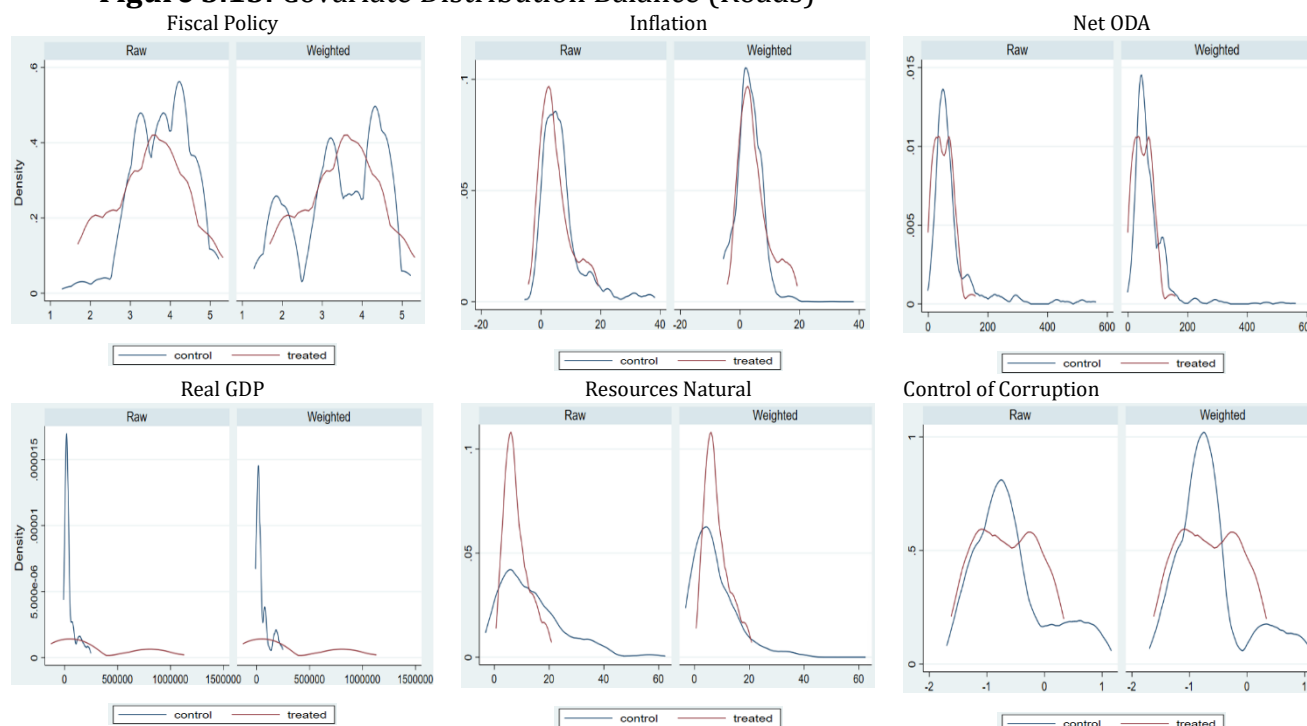
Unsurprisingly, and consistent with previous results, the findings show that the effects of PPP investments on water access rates are conditioned by the country's level of economic development.

3.5.3. Road Sector

IPW Estimation

For the estimation using the IPW approach, as with the previous sectors, we estimated the propensity score using a Logit regression that measures the probability of a country undertaking a PPP investment in the road sector based on its observed characteristics. Once the propensity score was estimated, we calculated the weights. After estimating and applying the weights, we ensured the balance of covariates between the two groups of countries (with PPP investments and without PPP investments) by comparing the distributions of the covariates before and after weighting. **Figure 3.15** shows a good balance before and after weighting for all covariates.

Figure 3.15: Covariate Distribution Balance (Roads)



Note: Density function showing the distribution balance for different covariable used to estimate the PS. It shows balance plot before and after weighting. The blue line represents countries without PPP and red, countries with PPP.

We estimated the initial model without the control variables (PPP law and PPP capacities) using the IPW approach. The IPW results are like those obtained through the PSM approach. In fact, in the PSM approach, the effect of PPPs on road quality was not significant, which is confirmed by the result obtained through the IPW approach. This result can be explained by the very modest share of PPPs in the road sector compared to traditional investments.

Table 3.20: IPW Estimation Results (Roads)

Road quality				
	Difference	S.E.	T-stat	p-value
Average treatment effect on treaties (ATET)	-.0169752	.1427877	-0.12	0.905
Pomean	3.451919	.0569158	67.42	0.000

Note: The table presents the results of the IPW estimation and the level of significance.

Placebo Effect and Heterogeneity Test

To test the placebo effect, a new fictitious variable was introduced. As in the first two sectors (ICT and Water), the variable of interest remains the binary variable indicating the realization of PPP investments. We introduced the same explanatory variables, such as the determinants of PPPs. **Table 3.21** shows that the placebo test results are not significant, confirming that if there was any effect of PPPs on road quality, it would not be due to a simple coincidence.

Table 3.21: Results of the Placebo Effect (Road)

IPW				
	Difference	S.E.	T-stat	p-value
Average treatment effect - Placebo	-.1754371	.1179087	-1.49	0.138
Average treatment effect - Initial Model	-.1316549	.1297348	-1.01	0.311

Note: The table presents the significance results of the fictitious "placebo" variable on road quality. It shows a non-significant effect in both models (initial and placebo effect).

Furthermore, due to the non-significant results obtained in both approaches (PSM and IPW), heterogeneity tests are not relevant to perform.

3.5.4. GMM Estimation for the three sectors

Empirical Model and Estimation Procedure

In this section, we will proceed with the estimation using the generalized method of moments (GMM) for the three sectors: ICT, Water, and Road. The objective is to confirm our previously obtained results by measuring the effect of PPP investments on our three sectoral outputs (telephone and internet subscriptions, access to water, and road quality). Our approach is inspired by previous studies (Calderón and al., 2004; Straub, 2008) that examined the causal effect between infrastructure investments and growth. Our model has been adapted to account for sectoral outputs. The empirical model for each sector is presented as follows:

$$y_{it} = \alpha_i + \beta_0 y_{it-1} + \beta_1 PPP_{it} + \beta_3 X_{it} + e_{it}$$

with $i = 1, \dots, 40$

$t = 2012, \dots, 2017$ for ICT sector

$t = 2007, \dots, 2017$ for Water sector

$t = 2011, \dots, 2017$ for Road sector

y_{it} represents the sectoral output; PPP_{it} represents the PPP investments; X_{it} is a vector of control variables; and e_{it} is the error term.

Estimation Procedure

It is often noted that static panel data suffer from the issue of variable endogeneity. In our model, it is highly likely that PPP investments are endogenous due to feedback loops between the level of infrastructure development and PPP investment. Indeed, countries with high growth tend to have better infrastructure and attract more investments. In this context, dynamic modeling, which corrects for endogeneity, is more effective when there is strong persistence in the data (Mehmood and al., 2018).

Lagged values of the endogenous variable (sectoral PPP investments) are used as instruments, provided they are not correlated with the error term. The instruments must be correlated with PPP investments but not with the error term (exogeneity condition). Sargan/Hansen tests will also be conducted to test the validity of lagged variables as instruments.

To estimate our model, the literature suggests the GMM: first-difference GMM (Arellano and Bond, 1991) and system GMM (Arellano and Bover, 1995; Blundell and Bond, 1998). Given that country-specific differences are considered significant, first-difference GMM can correct these effects by transforming the model into differences. We opt for first-difference GMM. This approach estimates the first differences of the model to eliminate country-specific effects, using lagged values of the variables as instruments.

Prior to estimation, we conducted unit root tests on the model variables to study their stationarity, followed by the Hausman specification test and the error autocorrelation test.

Estimation and Interpretation of Results

For the ICT sector, the results of our GMM model estimation show that population, GDP, and money supply have a positive and significant impact on the access rate to fixed-line telephony and the internet, while other variables have no significant effect. These findings align with the initially obtained results. Regarding our variable of interest, our results confirm that PPP investments have a positive and significant impact on the access rate to mobile telephony and the internet.

In the water sector, we observe, as in previous estimations, that the effect of population and GDP on access to water is positive and significant. Additionally, the effect of the Voice Accountability variable is positive and significant. Meanwhile, other control variables are not significant. Finally, the results confirm that PPP investments in the water sector have a positive and significant impact on access to water.

Lastly, in the road sector, we note that GDP has a positive and significant effect on road quality, while the other variables are not significant. Unlike the results obtained from the PSM and IPW methods, PPP investments have a positive and significant effect on road quality. This supports the hypothesis of endogeneity between PPPs and the level of development in countries and indirectly the development level of road infrastructure. The difference in results may be explained by several factors related to assumptions, data, and bias correction mechanisms inherent to each estimation method. The GMM method is particularly effective in addressing endogeneity when PPPs are correlated with errors. Additionally, it is possible that countries with PPP road projects have unobservable characteristics that influence both the decision to adopt PPPs and road quality. The GMM methodology addresses this endogeneity by using instruments (lagged variables) to obtain more precise estimates. In contrast, PSM and IPW approaches primarily focus on correcting observable selection biases. Furthermore, as road quality evolves slowly and is influenced by past investments, the GMM approach is well-suited to this temporal dynamic, while IPW and PSM approaches are generally more static.

Finally, for all three sectors, we observed no autocorrelation. The Arellano-Bond tests for AR(1) and AR(2) do not reject the null hypothesis of no autocorrelation in the first differences. This indicates that the errors are not correlated over time, which is an important condition for the validity of GMM estimators. Moreover, the results of the Sargan and Hansen tests do not reject the null hypothesis of instrument validity. This means that the chosen instruments are relevant and exogenous, i.e., they are correlated

with the endogenous variable but not with the error term. The Hansen difference tests also confirm the exogeneity of the instruments used for the levels of the dependent variable.

Table 3.22: Estimation of PPPs Effect on the 3 Outputs (GMM)

ICT sector		Water Sector		Road Sector	
fixed-line telephone and Internet subscriptions		Water access rate		Quality of road	
Variables	Coef. (p-value)	Variables	Coef. (p-value)	Variables	Coef. (p-value)
L.Aidi_ICT	0.700** (0.104)	L2.Aidi_Water	0.531** (0.126)	L.WEF_Road	0.847** (0.169)
PPP	0.0279** (0.00869)	L3.Aidi_Water	0.529** (0.130)	PPP	12.79** (4.527)
rGDP	3.799** (0.999)	PPP	2.186** (2.316)	L.PPP	-21.04** (6.286)
Population	0.119** (0.0282)	rGDP	4.365** (2.047)	L2.PPP	8.280** (2.914)
NaturalRessources	0.180 (0.130)	Population	3.673* (2.110)	rGDP	1.144** (0.486)
Inflation	0.401 (0.456)	ODA	-0.00123 (0.00206)	L.rGDP	-1.520** (0.479)
MoneySupply	0.263** (0.0654)	RegulatoryQuality	1.255 (0.945)	L2.rGDP	0.420 (0.631)
Constant	-49.17** (11.85)	VoiceAccountability	1.507** (0.694)	Population	-0.0190 (0.0427)
		Constant	36.61** (15.90)	ODA	6.88e-06 (0.000332)
				Inflation	-0.000757 (0.00511)
				NaturalResources	-0.0202 (0.0181)
				FiscalPolicy	-0.124 (0.144)
				L.FiscalPolicy	0.188 (0.141)
				L2.FiscalPolicy	-0.101 (0.0774)
				ControlCorruption	0.0964 (0.215)
				Constant	0.308 (0.590)
Observations	200	Observations	320	Observations	200
Number of id	40	Number of id	40	Number of id	40
AR(1)	0.373	AR(1)	0.192	AR(1)	0.010
AR(2)	0.630	AR(2)	0.335	AR(2)	0.745
Sargan	0.588	Sargan	0.285	Sargan	0.363
Hansen	0.692	Hansen	0.225	Hansen	0.597

Source: Author's estimation

Note: The table presents the GMM estimation results for the three sectors. The explanatory variables are selected based on the significance test results conducted in Section 3. The asterisks indicate the level of significance of the t statistics based on the following * p<0.05, ** p<0.01, *** p<0.00

3.6. Summary of Results

ICT Sector

- PPPs have a positive effect on ICT infrastructure coverage rates when there are no controlling variables
- PPP Law decreases the probability of achieving a PPP in the ICT sector

- PPPs still have a positive effect on ICT infrastructure coverage rates when PPP Law is considered. This shows PPP law has an indirect positive effect on the rate of access to telephony and the Internet.
- The 3 variables (Preparation, Procurement, Contract Management) measuring the state's PPP capabilities have no significant effect on the probability of achieving PPP in ICT sector.
- PPPs have a positive effect on ICT infrastructure coverage rates when PPP capabilities are considered. This shows PPP capabilities have an indirect and positive effect on the rate of access to telephony and the Internet.

Robustness analysis

- **IPW Estimation:** with the PSM approach, PPPs helped improve fixed-line telephone and internet subscriptions by 3.6% to 4.1%, depending on the estimation method. Using IPW, the results show a significant 4.08% increase in subscriptions due to PPP investments.
- **Placebo Effect:** the placebo test results are not significant, confirming the positive and significant contribution of PPPs to fixed-line telephony and internet access.
- **Heterogeneity test:** The results show that the effects of PPP investments on access to fixed-line telephony and the internet are conditioned by the level of economic development, consistent with the initial results
- **GMM:** results confirm that PPP investments have a positive and significant impact on the access rate to mobile telephony and the internet.

Water sector

- PPPs have a positive effect on the rate of access to water. When there are no controlling variables
- PPP Law has no significant effect on the probability of achieving a PPP in the Water sector
- PPPs have no significant effect on Water coverage rate when PPP Law is considered.
- The variables Contract Management has a negative effect on the probability of achieving a PPP in the water sector while the 2 other variables are not significant.
- The 3 variables (Preparation, Procurement, Contract Management) measuring the state's PPP capabilities have no significant effect on water coverage rate.

Robustness analysis:

- **IPW Estimation:** with PSM approach, PPPs were found to improve water access by 1.15% to 7.89%, depending on the estimation method. With the IPW approach, the results show a significant increase of 5.33% in the number of people with access to water due to PPP investments.
- **Placebo Effect:** the placebo test results are not significant, confirming the positive and significant contribution of PPPs to water access.
- **Heterogeneity test:** The results show that the effects of PPP investments on water access rates are conditioned by the country's level of economic development.
- **GMM:** the results confirm that PPP investments in the water sector have a positive and significant impact on access to water

Road Sector

- PPPs have no significant effect on the quality of road when there are no controlling variables
- PPP Law has no significant effect on the probability of achieving a PPP in road sector
- PPPs have no significant effect on road quality when PPP Law is considered.
- The variables Preparation and Contract Management has a negative effect on the probability of achieving a PPP in the road sector while Procurement has a positive effect.
- The 3 variables (Preparation, Procurement, Contract Management) measuring the state's PPP capabilities have no significant effect on road quality

Robustness analysis

- **IPW Estimation:** The effect of PPPs on road quality was not significant, which is confirmed by the result obtained through the IPW approach.
- **Placebo Effect and heterogeneity test:** due to the non-significant results obtained in both approaches (PSM and IPW), heterogeneity tests are not relevant to perform
- **GMM:** Unlike the results obtained from the PSM and IPW methods, PPP investments have a positive and significant effect on road quality.

3.7. Conclusion

Several studies have been carried out on the performance of infrastructure projects involving the private sector. However, in many cases, these studies have been limited to case studies evaluating the pre- and post-project situations. Other studies have assessed the performance of projects in specific sectors, such as ports, roads, electricity and so on. These studies generally evaluate the performance of a set of projects from one or more countries in each sector. Performance is assessed in terms of indicators such as cost overruns, completion times, quality of service or number of subscriptions, etc. What's more, these projects generally involve private-sector participation in infrastructure, rather than PPPs. In view of the current state of private-sector involvement in infrastructure, we wanted to break new ground by assessing the performance of PPPs in certain sectors (water, ICT, and road). In the absence of a before-and-after analysis, we opted for a comparative evaluation between countries. What's more, instead of project-specific indicators, we designed development indicators linked to each sector. Furthermore, the results were analyzed under the influence of the PPP governance framework. Indeed, the PPP governance framework includes, among other things, the legal framework and the institutional framework. For the former, we used the adoption of a PPP law, and for the latter, the capacities of the PPP actors responsible for implementing and managing PPPs

The difficulty with this new approach to PPP performance benchmarking lies in the lack of randomization of PPP investments across countries. To overcome this difficulty, we have used a quasi-experimental approach. Two groups of countries are created: i) a first group of countries, called the treated group, with PPP investment in one sector (Water, ICT and Road) and ii) a second group of countries with no PPP investment in these sectors (one sector at a time), called the control group. For the Water and ICT sectors, the result is the level of coverage or rate of access to water and the number of fixed-line telephone and Internet subscriptions. For the road sub-sector, the outcome is the quality of road infrastructure. The evaluation involved analyzing the effect of PPP investments on these outcomes, for each sector.

Our approach is based on a three-stage process: the first stage consists in determining the factors explaining the assignment to the model to be studied. The characteristics are chosen based on their potential to influence the probability of a country belonging to the treated group and on the outcomes (coverage rate (Water and ICT) and road quality level). To analyze the real effect of PPPs on the 2 outcomes (coverage and/or quality), the factors retained are exogenous variables, notably PPP investment determinants. In addition to these characteristics, the following factors were considered: the adoption of a specific PPP law and the PPP capabilities of the public partner: PPP project preparation, procurement, and PPP management during the contractual phase. The second step in our approach was to estimate propensity scores corresponding to the probability of a country benefiting from a PPP investment in each sector (Water, ICT and Roads). These propensity scores were estimated using a Logit model containing the explanatory variables for a country's probability of benefiting from a sectoral PPP. Having estimated the propensity scores, we then proceeded to analyze the results (output) for each sector: the coverage rate (Water, ICT) and quality level (Roads) in the treated group versus the matched control group, to measure the effect of PPP investments in each sector. The data used in this chapter come mainly from the World Bank's database on private participation in

infrastructure (PPI database). It covers PPP investments in the various sectors selected: water, ICT, and road transport. As a reminder, the World Bank's PPI database lists all projects involving private sector participation. This chapter focuses solely on PPP investments that meet the PPP knowledgeLap definition of a PPP.

The results obtained in the ICT sector show that the probability of making a PPP is linked to market conditions dictated by population size. The business environment is not significant enough to influence the probability of countries making a PPP investment, which is explained by the high profitability in the sector, which offsets policy-induced distortions. In other words, regulation in this sector is either insignificant or significant and negative. As is the case for the "PPP law" variable, which is negative and significant. As for the state's PPP capabilities, they have no significant effect on the probability of implementing a PPP. It is important to point out that these factors may not be significant or negative in relation to the probability of implementing a PPP but may have an indirect effect on the execution and management of PPP projects. Apart from these investment determinants, the results show that countries with PPPs had a higher ICT infrastructure coverage rate than countries without PPP investments in this sector. In other words, PPP investments led to an increase in the number of telephone and Internet subscriptions. This coverage rate increases further if we consider the adoption of a PPP law in the country, and improve government capacities in the evaluation, procurement, and management of PPP projects.

The probability of implementing a PPP in the water sector increases with market conditions. Indeed, real GDP and population size are decisive factors in the likelihood of a PPP in the water sector. The rule of law is also an essential factor in the likelihood of achieving a PPP in the sector. However, the quality of regulation reduces the likelihood of PPPs in the water sector. According to the literature, regulating quality is a challenge in public services, particularly water, because quality is multidimensional, not objectively measurable, and difficult to measure. The adoption of a PPP law has had no significant effect on the likelihood of PPP investment in the sector. This can be explained by the fact that almost all countries had already implemented PPPs long before the adoption of a specific PPP law. Regarding countries' PPP capabilities, the level of preparation decreases the probability of implementing PPPs in the sector. This negative sign can be explained by the fact that projects prepared by the public sector are not sufficiently attractive to private partners (long lead times, quality of studies, poor market sounding, inadequate risk identification or allocation). As for the effect of PPPs on the rate of access to water, the results show that countries with PPPs have a better coverage rate than countries without PPP investments. However, neither the adoption of a specific PPP law, nor the improvement of PPP player capacities had a significant effect on the coverage rate.

In the road sector, market conditions, as measured by GDP, greatly increase the likelihood of a PPP in the road sector. Limited natural resources and controlled inflation are positively linked to the likelihood of a PPP in the roads sector. The adoption of a PPP law had no significant effect on the likelihood of PPP investment in the road sector. This can be explained by the fact that the countries that invested most in PPP roads did so before the adoption of a specific PPP law (Côte d'Ivoire, Senegal, and South Africa). In terms of countries' PPP capabilities, the level of preparation and contract management decrease the probability of implementing PPPs in the sector. However, capabilities related to procurement increases the probability of implementing PPPs. This can be explained by

the fact that projects prepared by the public sector are not sufficiently attractive to the private sector (long lead times, low quality of studies, poor market sounding, inadequate identification, or allocation of risks, etc.) and unbalanced contract drafting during preparation has a direct negative impact on contract management. As for the effect of PPPs on road quality, the results are not significant. This could be due to the limited number of PPP contracts in the road sector compared to traditional financing. However, the adoption of a PPP-specific law and improvement of PPP player capabilities indirectly improved road quality.

The various robustness tests conducted using alternative approaches such as IPW and GMM confirm the results obtained in the two sectors: Water and ICT. However, for the road sector, the GMM approach concluded that PPPs made a positive and significant contribution to quality of roads. Additionally, the placebo effect estimation confirms that the effect of PPPs was not due to mere coincidence.

We cannot conclude without mentioning a few limitations of the analysis, some of which are associated with the nature of the indicators used. Indeed, the indicator on road quality is based on respondents' self-perception of the quality of road infrastructure, which leaves much to the subjectivity of the indicator that will need to be considered when interpreting the results. In addition, data measuring PPP capacity are published in 2018, whereas the analysis period ends in 2017. However, these surveys take time to finalize and publish. Finally, this study could be extended to other sectors of activity, notably in the electricity sector, with Energy production as a result, or in ports, with container traffic as a result, etc.

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Appendices

Table 3.23: Determinants of ICT PPP using logit regression

	Model (1)	Model (2)	Model (A)	Model (B)	Model (C)	Model (3)
Treat						
RealGDP	-0.166 (-0.88)	-0.321 (-1.68)	-0.201 (-1.05)	-0.181 (-0.95)	-0.206 (-1.07)	-0.220 (-1.14)
Population	0.0158* (2.08)	0.0226** (2.93)	0.0188* (2.36)	0.0151* (1.98)	0.0172* (2.24)	0.0182* (2.24)
MoneySup	-0.0377** (-2.77)	-0.0513** (-3.25)	-0.0323* (-2.24)	-0.0383** (-2.72)	-0.0421** (-2.91)	-0.0370* (-2.28)
IntReserves	-0.245* (-2.49)	-0.245* (-2.45)	-0.263** (-2.62)	-0.252* (-2.55)	-0.260** (-2.61)	-0.269** (-2.67)
Inflation	0.0235 (0.97)	0.0175 (0.70)	0.0264 (1.08)	0.0249 (1.02)	0.0278 (1.13)	0.0286 (1.17)
FiscalBala~P	0.163** (2.93)	0.113 (1.95)	0.162** (2.88)	0.166** (2.96)	0.156** (2.79)	0.160** (2.81)
RessNatGDP	0.0102 (0.59)	0.0274 (1.43)	0.0113 (0.65)	0.00904 (0.52)	0.00955 (0.55)	0.00994 (0.57)
Concorrup	-0.429 (-0.69)	-0.859 (-1.29)	-0.377 (-0.59)	-0.513 (-0.81)	-0.425 (-0.68)	-0.432 (-0.67)
Rulelaw	1.285 (1.36)	1.396 (1.42)	1.338 (1.40)	1.355 (1.42)	1.090 (1.13)	1.240 (1.25)
Goveffec	0.0679 (0.08)	0.466 (0.53)	-0.220 (-0.25)	0.0535 (0.06)	0.266 (0.30)	-0.0140 (-0.01)
Voicaccoun	0.0652 (0.17)	0.250 (0.64)	-0.160 (-0.37)	-0.0123 (-0.03)	-0.0242 (-0.06)	-0.173 (-0.40)
Polistabi	-0.130 (-0.38)	-0.0636 (-0.18)	-0.00296 (-0.01)	-0.103 (-0.30)	-0.0511 (-0.15)	0.0125 (0.04)
PPP_Law		-1.509*** (-3.90)				
Preparation			0.0155 (1.13)			0.0103 (0.67)
Procurement				0.0103 (0.72)		0.00492 (0.32)
ContraMgmt					0.0166 (1.13)	0.00974 (0.57)
_cons	3.634 (1.70)	5.874** (2.67)	2.919 (1.32)	3.262 (1.48)	3.319 (1.55)	2.796 (1.24)
N	240	240	240	240	240	240

Note: The table reports the estimation results of the logit regression for PPP investments in ICT sector. Clustered standard errors by country are presented between brackets. The 1%, 5%, and 10% significance levels are represented by ***, **, and *, respectively. Model (1) is the model without control on variables. Model (2) is the model with control on PPP Law. Model (3) is the model with control on country's capabilities added simultaneously. models (A), (B) and (C) refer to model (3) with the addition one by one of the variables measuring county capabilities

Table 3.24: ICT Model bias reduction after matching

Variable	Unmatched Matched	Mean		%reduct		t-test		V(T) / V(C)
		Treated	Control	%bias	bias	t	p> t	
ReaGDP	U	1.2e+05	71208	25.7		2.05	0.042	2.76*
	M	80419	95236	-7.8	69.7	-0.53	0.594	0.81
Population	U	33.444	18.281	42.5		3.50	0.001	4.74*
	M	24.121	23.903	0.6	98.6	0.04	0.965	1.66*
MoneySup	U	27.49	37.546	-54.9		-3.77	0.000	0.31*
	M	29.008	31.29	-12.5	77.3	-0.90	0.370	0.55*
IntReserves	U	3.5269	4.1915	-36.3		-2.59	0.010	0.63*
	M	3.6694	3.8631	-10.6	70.9	-0.67	0.506	0.59*
Inflation	U	7.6543	5.5562	29.6		2.27	0.024	1.69*
	M	7.3525	7.1751	2.5	91.5	0.13	0.896	0.78
FiscalBalanceGDP	U	-2.6542	-3.8488	37.0		2.65	0.009	0.66
	M	-3.0903	-2.4402	-20.1	45.6	-1.00	0.317	0.26*
RessNatGDP	U	14.203	11.481	26.0		1.93	0.054	1.10
	M	12.822	12.05	7.4	71.6	0.49	0.626	1.03
Concorrup	U	-.70122	-.52572	-28.8		-2.06	0.040	0.63*
	M	-.61812	-.64387	4.2	85.3	0.28	0.782	0.79
Rulelaw	U	-.67997	-.53979	-25.4		-1.82	0.069	0.69
	M	-.59887	-.59786	-0.2	99.3	-0.01	0.991	0.72
Goveffec	U	-.79781	-.63214	-28.6		-2.05	0.042	0.66
	M	-.72218	-.72237	0.0	99.9	0.00	0.998	0.62*
Voicaccoun	U	-.59046	-.34824	-36.2		-2.63	0.009	0.81
	M	-.50431	-.49614	-1.2	96.6	-0.08	0.939	0.86
Polistabi	U	-.72843	-.37075	-42.9		-3.23	0.001	1.25
	M	-.55725	-.52768	-3.6	91.7	-0.24	0.812	1.02

* if variance ratio outside [0.65; 1.54] for U and [0.63; 1.60] for M

Sample	Ps R2	LR chi2	p>chi2	MeanBias	MedBias	B	R	%Var
Unmatched	0.148	46.09	0.000	34.5	32.9	95.0*	0.76	50
Matched	0.023	4.49	0.973	5.9	3.9	35.2*	0.29*	42

* if B>25%, R outside [0.5; 2]

Note: The table shows for PPP investments in the ICT sector, the percentage reduction in bias before and after matching for each variable as well as the significance of the reduction.

Table 3.25: Sensitivity Test of the impact of PPP on ICT coverage

Rosenbaum bounds for delta (N = 84 matched pairs)						
Gamma	sig+	sig-	t-hat+	t-hat-	CI+	CI-
1	.000084	.000084	7.25835	7.25835	3.77682	11.1774
1.01	.000099	.000072	7.2247	7.32165	3.7	11.238
1.02	.000115	.000061	7.13862	7.4	3.6	11.3
1.03	.000134	.000052	7.02735	7.55	3.53938	11.4
1.04	.000155	.000045	6.995	7.61235	3.475	11.5247
1.05	.000179	.000038	6.95	7.7	3.44665	11.6
1.06	.000207	.000032	6.83862	7.7247	3.37156	11.6403
1.07	.000237	.000027	6.75544	7.775	3.30653	11.7386
1.08	.000272	.000023	6.66801	7.92101	3.22735	11.821
1.09	.000311	.00002	6.61006	7.95212	3.17712	11.8839
1.1	.000354	.000017	6.52999	7.99624	3.1168	11.9886
1.11	.000402	.000014	6.4747	8.07461	3.05197	12.0271
1.12	.000456	.000012	6.375	8.18465	2.9747	12.1
1.13	.000515	.00001	6.3247	8.22566	2.85	12.2386
1.14	.000581	8.9e-06	6.29317	8.2997	2.8	12.3101
1.15	.000654	7.5e-06	6.23968	8.39656	2.75267	12.4497
1.16	.000734	6.4e-06	6.16801	8.45889	2.70164	12.55
<OMITTED>						
1.74	.047058	4.1e-10	3.44665	11.6	-.6	16.1757
1.75	.049124	3.5e-10	3.4	11.6021	-.6253	16.2054
1.76	.051247	2.9e-10	3.37156	11.6403	-.675	16.2257
1.77	.053429	2.5e-10	3.35	11.7247	-.699999	16.2721
1.78	.055669	2.1e-10	3.3	11.7494	-.725301	16.3143
1.79	.057968	1.8e-10	3.2747	11.7886	-.745	16.3596
1.8	.060326	1.5e-10	3.2	11.8383	-.767883	16.4247
1.81	.062743	1.3e-10	3.18652	11.8772	-.811379	16.471
1.82	.06522	1.1e-10	3.1349	11.9247	-.846094	16.5039
1.83	.067757	9.0e-11	3.1168	11.9886	-.95	16.55
1.84	.070353	7.6e-11	3.08	12.0057	-1.00683	16.5747
1.85	.073008	6.4e-11	3.05	12.05	-1.02759	16.6247
1.86	.075723	5.4e-11	3	12.0633	-1.1003	16.6574
1.87	.078498	4.6e-11	2.94317	12.1247	-1.14609	16.7153
1.88	.081332	3.9e-11	2.9	12.2094	-1.19767	16.8
1.89	.084226	3.3e-11	2.84	12.2494	-1.22031	16.8293
1.9	.087178	2.8e-11	2.8247	12.2847	-1.25	16.8801
1.91	.09019	2.3e-11	2.79931	12.3772	-1.2753	16.9554
1.92	.093261	2.0e-11	2.75267	12.4497	-1.28199	16.9974
1.93	.09639	1.7e-11	2.73153	12.5021	-1.3	17.0789
1.94	.099577	1.4e-11	2.70164	12.55	-1.36032	17.2247
1.95	.102822	1.2e-11	2.6747	12.6574	-1.375	17.265
1.96	.106124	1.0e-11	2.62241	12.7021	-1.45	17.3571
1.97	.109484	8.4e-12	2.57156	12.725	-1.48033	17.3923
1.98	.1129	7.1e-12	2.52735	12.775	-1.58199	17.4104
1.99	.116372	6.0e-12	2.5	12.8057	-1.6	17.4543
2	.1199	5.1e-12	2.4747	12.8912	-1.6253	17.5074

* gamma - log odds of differential assignment due to unobserved factors
 sig+ - upper bound significance level
 sig- - lower bound significance level
 t-hat+ - upper bound Hodges-Lehmann point estimate
 t-hat- - lower bound Hodges-Lehmann point estimate
 CI+ - upper bound confidence interval (a= .95)

Note: The table presents the results of the PPP investment sensitivity test on the rate of access to ICT infrastructure through a test of the robustness of the match with respect to the possible presence of an unobservable selection, using the Rosenbaum test.

Table 3.26: Determinants of Water PPP using logit regression

	Model (1)	Model (2)	Model (A)	Model (B)	Model (C)	Model (3)
Treat						
ReaGDP	0.00000359 (1.82)	0.00000295 (1.52)	0.00000343 (1.93)	0.00000365 (1.83)	0.00000510* (2.49)	0.00000400* (2.13)
Population	0.173*** (5.43)	0.180*** (5.49)	0.283*** (6.90)	0.179*** (5.49)	0.163*** (5.10)	0.278*** (6.54)
netODAp~2017	-0.00533 (-1.47)	-0.00596 (-1.61)	-0.00427 (-1.14)	-0.00452 (-1.30)	-0.00568 (-1.44)	-0.00412 (-1.06)
Rulelaw	2.754*** (3.39)	2.780*** (3.42)	2.550** (2.79)	2.197* (2.53)	2.623** (3.25)	2.297* (2.36)
Reguquali	-1.532* (-2.21)	-1.751* (-2.51)	-0.558 (-0.69)	-1.091 (-1.45)	-0.310 (-0.38)	0.144 (0.15)
Goveffec	-0.265 (-0.34)	-0.0929 (-0.12)	0.0522 (0.06)	-0.181 (-0.23)	-1.159 (-1.35)	-0.314 (-0.31)
Voicaccoun	0.00500 (0.01)	0.0794 (0.20)	0.607 (1.31)	0.325 (0.72)	0.0941 (0.25)	0.695 (1.44)
PPP_Law		-0.579 (-1.65)				
Preparation			-0.0913*** (-6.01)			-0.0868*** (-5.60)
Procurement				-0.0249 (-1.72)		-0.00783 (-0.48)
ContraMgmt					-0.0410** (-2.83)	-0.0194 (-1.28)
_cons	-2.668*** (-4.98)	-2.462*** (-4.46)	0.719 (1.02)	-1.382 (-1.55)	-0.408 (-0.43)	1.980 (1.78)
N	440	440	440	440	440	440

t statistics in parentheses

* p<0.05, ** p<0.01, *** p<0.001

Note: The table reports the estimation results of the logit regression for PPP investments in Water sector. Clustered standard errors by country are presented between brackets. The 1%, 5%, and 10% significance levels are represented by ***, **, and *, respectively. Model (1) is the model without control on variables. Model (2) is the model with control on PPP Law. Model (3) is the model with control on country's capabilities added simultaneously. models (A), (B) and (C) refer to model (3) with the addition one by one of the variables measuring country capabilities

Table 3.27: Water Model bias reduction after matching

Variable	Unmatched Matched	Mean		%bias	%reduct bias	t-test		V(T) / V(C)
		Treated	Control			t	p> t	
Rgdpna	U	1.4e+05	63583	42.9		4.02	0.000	1.97*
	M	61920	74939	-7.2	83.1	-1.09	0.279	0.25*
Population	U	27.427	20.751	25.5		1.83	0.068	0.24*
	M	23.593	24.2	-2.3	90.9	-0.21	0.831	0.50*
netODAperK2017	U	56.216	94.063	-50.1		-3.38	0.001	0.05*
	M	61.309	62.634	-1.8	96.5	-0.18	0.854	0.13*
Rulelaw	U	-.45949	-.65203	36.0		2.73	0.007	0.47*
	M	-.56702	-.54531	-4.1	88.7	-0.29	0.770	0.54*
Reguquali	U	-.42728	-.63997	39.8		3.24	0.001	0.80
	M	-.55649	-.50605	-9.4	76.3	-0.68	0.497	0.85
Goveffec	U	-.52982	-.73648	36.7		2.90	0.004	0.65*
	M	-.68099	-.64615	-6.2	83.1	-0.49	0.624	0.61*
Voicaccoun	U	-.29124	-.49224	28.7		2.47	0.014	1.16
	M	-.45917	-.4537	-0.8	97.3	-0.05	0.956	1.55

* if variance ratio outside [0.66; 1.53] for U and [0.63; 1.59] for M

Sample	Ps R2	LR chi2	p>chi2	MeanBias	MedBias	B	R	%Var
Unmatched	0.272	119.78	0.000	34.2	36.4	74.0*	0.09*	75
Matched	0.027	5.60	0.692	4.7	5.0	24.4	0.04*	75

* if B>25%, R outside [0.5; 2]

Note: the table shows for PPP investments in the Water sector, the reduction in percentage bias before and after matching for each variable as well as the significance of the reduction

Table 3.28: Sensitivity Test of the impact of PPP on Water coverage

Rosenbaum bounds for delta (N = 88 matched pairs)						
Gamma	sig+	sig-	t-hat+	t-hat-	CI+	CI-
1	.003252	.003252	8.02926	8.02926	2.01394	13.4986
1.01	.003673	.002874	7.9424	8.14179	1.91873	13.5574
1.02	.004137	.002539	7.81181	8.27554	1.85528	13.6555
1.03	.004646	.002242	7.61	8.40055	1.75466	13.7264
1.04	.005204	.001979	7.49769	8.54693	1.67027	13.7942
1.05	.005814	.001746	7.36771	8.63745	1.53778	13.8849
1.06	.006478	.001539	7.25923	8.80471	1.36535	13.9318
1.07	.007201	.001357	7.09917	8.87022	1.30773	14.0085
1.08	.007984	.001196	6.93121	8.99361	1.23802	14.107
1.09	.008832	.001053	6.80076	9.09732	1.19822	14.1686
1.1	.009748	.000927	6.71886	9.24852	1.12675	14.2441
1.11	.010735	.000816	6.62346	9.31968	1.02774	14.2866
1.12	.011797	.000718	6.50362	9.40155	.920331	14.3462
1.13	.012936	.000631	6.42273	9.49001	.797283	14.392
1.14	.014157	.000555	6.30064	9.6078	.626319	14.466
1.15	.015461	.000488	6.19544	9.69989	.543075	14.5325
1.16	.016854	.000428	6.10411	9.80643	.457851	14.5838
1.17	.018337	.000376	6.0375	9.90984	.407963	14.667
1.18	.019914	.00033	5.94344	10.0074	.27943	14.7211
1.19	.021588	.00029	5.83446	10.0848	.216677	14.7985
1.2	.023362	.000254	5.73094	10.1446	.102149	14.859
1.21	.025238	.000223	5.56158	10.1864	-.013406	14.9109
1.22	.02722	.000196	5.46885	10.2498	-.08936	14.9445
1.23	.029311	.000171	5.43778	10.3143	-.177904	15.0334
1.24	.031513	.00015	5.38034	10.379	-.2229	15.088
1.25	.033828	.000132	5.29925	10.4528	-.332289	15.119
1.26	.036258	.000115	5.23263	10.6638	-.455178	15.165
1.27	.038807	.000101	5.1408	10.6907	-.582744	15.2296
1.28	.041475	.000088	4.99703	10.7701	-.705851	15.2893
1.29	.044265	.000077	4.89157	10.8321	-.7844	15.3381
1.3	.047179	.000068	4.75587	10.9086	-.888662	15.3702
1.31	.050218	.000059	4.6876	10.9728	-.910373	15.453
1.32	.053383	.000052	4.61197	11.0973	-.937714	15.5264
1.33	.056677	.000045	4.49451	11.1934	-.999599	15.5688
<OMITTED>						
1.97	.474519	6.2e-09	.216677	14.7985	-4.0746	19.1278
1.98	.482264	5.4e-09	.185652	14.8142	-4.11198	19.1957
1.99	.489976	4.7e-09	.091433	14.8834	-4.14448	19.2721
2	.497653	4.0e-09	.039603	14.9075	-4.16619	19.2849

* gamma - log odds of differential assignment due to unobserved factors
 sig+ - upper bound significance level
 sig- - lower bound significance level
 t-hat+ - upper bound Hodges-Lehmann point estimate
 t-hat- - lower bound Hodges-Lehmann point estimate
 CI+ - upper bound confidence interval (a= .95)
 CI- - lower bound confidence interval (a= .95)

Note: The table presents the results of the sensitivity test of PPP investments on the rate of access to Water through a test of the robustness of the match with respect to the possible presence of an unobservable selection, using the Rosenbaum test

Table 3.29: Determinants of road PPP using logit regression.

	Model (1)	Model (2)	Model (A)	Model (B)	Model (C)	Model (3)
Treat						
ReaGDP	0.00000824*	0.00000846*	0.0000103**	0.00000758*	0.0000101**	0.0000144**
	(2.36)	(2.34)	(2.89)	(2.08)	(3.05)	(3.14)
Population	0.00906	0.00964	0.00135	0.00725	0.00316	-0.0378
	(0.54)	(0.56)	(0.08)	(0.42)	(0.19)	(-1.64)
Inflation	-0.224**	-0.220**	-0.233***	-0.251**	-0.207**	-0.226**
	(-3.17)	(-3.13)	(-3.38)	(-3.18)	(-3.09)	(-2.88)
netODAp~2017	-0.00191	-0.00149	-0.00179	-0.00264	-0.00246	-0.00414
	(-0.47)	(-0.37)	(-0.46)	(-0.58)	(-0.60)	(-0.85)
ResNatGDP	-0.0771*	-0.0791*	-0.104**	-0.0573	-0.0806*	-0.0895*
	(-2.22)	(-2.21)	(-2.69)	(-1.58)	(-2.33)	(-2.04)
TrasPAccCorr	-0.629	-0.777	-0.683	-0.553	-1.041	-0.875
	(-0.98)	(-1.18)	(-1.02)	(-0.88)	(-1.63)	(-1.43)
FiscPol	-0.352	-0.284	-0.190	-0.560	0.0541	-0.200
	(-0.72)	(-0.57)	(-0.38)	(-1.13)	(0.11)	(-0.42)
Polistabi	-0.416	-0.431	-0.502	-0.445	-0.150	-0.346
	(-1.09)	(-1.13)	(-1.28)	(-1.16)	(-0.34)	(-0.74)
PPP_Law		0.435				
		(0.88)				
Preparation			-0.0348*			-0.0452*
			(-2.17)			(-1.96)
Procurement				0.0406		0.132**
				(1.86)		(3.00)
ContraMgmt					-0.0554*	-0.0999*
					(-2.30)	(-2.29)
_cons	2.194	2.194	3.519**	0.476	4.976**	2.804
	(1.96)	(1.95)	(2.65)	(0.34)	(2.95)	(1.62)
N	280	280	280	280	280	280

Note: The table reports the estimation results of the logit regression for PPP investments in Road's sector. Clustered standard errors by country are presented between brackets. The 1%, 5%, and 10% significance levels are represented by ***, **, and *, respectively. Model (1) is the model without control on variables. Model (2) is the model with control on PPP Law. Model (3) is the model with control on country's capabilities added simultaneously. models (A), (B) and (C) refer to model (3) with the addition one by one of the variables measuring country capabilities

Table 3.30: Road model bias reduction after matching

Variable	Unmatched Matched	Mean		%reduct		t-test		V(T)/ V(C)
		Treated	Control	%bias	bias	t	p> t	
RealGDP	U	3.0e+05	48613	96.0		10.02	0.000	41.68*
	M	50105	93046	-16.3	83.0	-2.17	0.038	0.10*
Population	U	3.47	2.0433	108.5		5.53	0.000	0.31*
	M	2.9682	3.0363	-5.2	95.2	-0.21	0.834	0.05*
Inflation	U	4.7762	6.8354	-33.5		-1.81	0.071	0.52*
	M	3.9536	4.2458	-4.8	85.8	-0.18	0.856	2.04
netODAperK2017	U	51.293	82.368	-48.3		-2.32	0.021	0.13*
	M	66.769	71.913	-8.0	83.4	-0.26	0.794	0.08*
RessNatGDP	U	8.1867	13.646	-62.4		-3.02	0.003	0.14*
	M	7.8082	7.8096	-0.0	100.0	-0.00	0.999	0.46
ContCorruption	U	2.9912	3.2557	-40.7		-2.36	0.019	0.84
	M	3.201	3.3252	-19.1	53.1	-0.57	0.575	1.29
FiscPolicy	U	3.4865	3.8056	-38.9		-2.57	0.011	1.69
	M	4.0049	4.1507	-17.8	54.3	-0.53	0.598	1.50

* if variance ratio outside [0.54; 1.86] for U and [0.36; 2.76] for M

Sample	Ps R2	LR chi2	p>chi2	MeanBias	MedBias	B	R	%Var
Unmatched	0.545	128.89	0.000	61.2	48.3	207.6*	0.64	71
Matched	0.376	17.73	0.013	10.2	8.0	165.9*	0.30*	43

* if B>25%, R outside [0.5; 2]

Note: The table shows for PPP investments in the road sector, the percentage reduction in bias before and after matching for each variable as well as the significance of the reduction

Table 3.31: Sensitivity Test of the impact of PPP on road quality

Rosenbaum bounds for delta (N = 42 matched pairs)						
Gamma	sig+	sig-	t-hat+	t-hat-	CI+	CI-
1	.000588	.000588	-.4925	-.4925	-.8875	-.22
1.01	.000532	.000648	-.495	-.49	-.895	-.215
1.02	.000482	.000714	-.497499	-.485144	-.9	-.21
1.03	.000436	.000784	-.5	-.475	-.9	-.2075
1.04	.000395	.00086	-.5	-.475	-.9	-.205
1.05	.000358	.000942	-.51	-.47	-.9075	-.2
1.06	.000324	.001029	-.515	-.47	-.91	-.195
1.07	.000293	.001123	-.52	-.465	-.914375	-.19
1.08	.000266	.001223	-.525	-.46	-.92	-.19
1.09	.00024	.00133	-.5275	-.455	-.93	-.19
1.1	.000218	.001444	-.532188	-.45	-.93	-.19
1.11	.000197	.001566	-.534375	-.4475	-.9375	-.1875
1.12	.000178	.001695	-.54	-.445	-.94327	-.1775
<OMITTED>						
1.78	2.4e-07	.041786	-.7975	-.280769	-1.22	.145
1.79	2.2e-07	.043034	-.7975	-.280001	-1.225	.150625
1.8	2.0e-07	.044304	-.7975	-.28	-1.23	.16
1.81	1.8e-07	.045595	-.801538	-.28	-1.23	.1725
1.82	1.6e-07	.046907	-.8025	-.2775	-1.23	.175625
1.83	1.5e-07	.048241	-.805	-.275	-1.23	.175625
1.84	1.3e-07	.049596	-.812499	-.2725	-1.23	.1775
1.85	1.2e-07	.050973	-.814375	-.270769	-1.23077	.18
1.86	1.1e-07	.052371	-.819375	-.265	-1.235	.1875
1.87	9.9e-08	.05379	-.82	-.26	-1.2375	.19
1.88	9.0e-08	.05523	-.820833	-.26	-1.24	.19
1.89	8.1e-08	.056692	-.8275	-.2575	-1.24	.19
1.9	7.3e-08	.058174	-.8275	-.2525	-1.245	.193334
1.91	6.6e-08	.059678	-.8275	-.2475	-1.245	.1975
1.92	6.0e-08	.061202	-.8275	-.245001	-1.2475	.200625
1.93	5.4e-08	.062747	-.83	-.245	-1.25	.205625
1.94	4.9e-08	.064313	-.834375	-.245	-1.255	.2125
1.95	4.5e-08	.0659	-.844375	-.2425	-1.26	.2125
1.96	4.0e-08	.067507	-.850769	-.241875	-1.2625	.2125
1.97	3.6e-08	.069135	-.850769	-.24	-1.2675	.216667
1.98	3.3e-08	.070782	-.850769	-.235	-1.2725	.2175
1.99	3.0e-08	.07245	-.8525	-.235	-1.2725	.2175
2	2.7e-08	.074139	-.857052	-.23	-1.275	.226666

* gamma - log odds of differential assignment due to unobserved factors
 sig+ - upper bound significance level
 sig- - lower bound significance level
 t-hat+ - upper bound Hodges-Lehmann point estimate
 t-hat- - lower bound Hodges-Lehmann point estimate
 CI+ - upper bound confidence interval (a= .95)
 CI- - lower bound confidence interval (a= .95)

Note: The table presents the results of the sensitivity test of PPP investments on road quality through a test of the robustness of the match with respect to the possible presence of an unobservable selection, using the Rosenbaum test

3.A List of countries

Countries	
Angola	Malawi
Benin	Mali
Burkina Faso	Mauritania
Botswana	Mauritius
Cape Verde	Mozambique
Burundi	Namibia
Cameroon	Niger
Chad	Nigeria
Comoros	Rwanda
Congo, Dem, Rep,	São Tomé and Príncipe
Congo, Rep,	Senegal
Côte d'Ivoire	Seychelles
Ethiopia	Sierra Leone
Gabon	South Africa
Gambia, The	Sudan
Ghana	Tanzania
Guinea	Togo
Kenya	Uganda
Liberia	Zambia
Madagascar	Zimbabwe

3.B List of variables and sources

Variables Name	Unit	Variables definition	Sources
RegionGeo		Geographic region	Sahel and West Africa Club
RegionEco		Economic region	InOnAfrica
ConCorrup	Estimate of governance (ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance)	<i>Reflects perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests.</i>	The World Governance Indicators, 2020
RuleLaw	Estimate of governance (ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance)	<i>Reflects perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence.</i>	The World Governance Indicators, 2020
ReguQuali	Estimate of governance (ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance)	<i>Reflects perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development.</i>	The World Governance Indicators, 2020
GovEffec	Estimate of governance (ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance)	<i>Reflects perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies.</i>	The World Governance Indicators, 2020
VoicNaccoun	Estimate of governance (ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance)	<i>Reflects perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media.</i>	The World Governance Indicators, 2020
PoliStabili	Estimate of governance (ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance)	<i>Political Stability and Absence of Violence/Terrorism measures perceptions of the likelihood of political instability and/or politically motivated violence, including terrorism.</i>	The World Governance Indicators, 2020
Preparation	Scores range between 0 and 100. Higher scores signify that an economy's regulatory framework is in greater compliance with internationally recognized good practices in Preparation of projects	<i>Assesses the regulatory frameworks and recognized good practices that govern PPP procurement in terms of assessments and fiscal treatment of PPP</i>	Procuring Infrastructure PPP, 2018
Procurement	Scores range between 0 and 100. Higher scores signify that an economy's regulatory framework is in greater compliance with internationally recognized good practices in Procurement of Projects	<i>Assesses the regulatory frameworks and recognized good practices that govern PPP procurement in terms of interactions between the procuring authority and bidders</i>	Procuring Infrastructure PPP, 2018
Mgmt Contract	Scores range between 0 and 100. Higher scores signify that an economy's regulatory framework is in greater compliance with internationally recognized good practices in Contract Management of Projects	<i>Assesses the regulatory frameworks and recognized good practices that govern PPP procurement in terms of renegotiation or modification of the PPP contract and termination of PPP contract</i>	Procuring Infrastructure PPP, 2018
Rgdpna	in mil. 2017 US\$	<i>Real GDP at constant 2017 national prices</i>	Penn World Table version 10
Population	in million	<i>Total Population</i>	Penn World Table version 10
GdpK	2017 US\$	<i>Real GDP at constant 2017 national prices / Total Population</i>	Author estimates
MassMonetai	% of GDP	<i>Broad Money</i>	World Bank, WDI
ReserChan	in months of imports	<i>Total reserves in months of imports</i>	World Bank, WDI
Inflation	annual variation %	<i>Inflation, consumer prices (annual %)</i>	World Bank, WDI
Fiscal Balance %GDP	% of GDP	<i>Difference between revenue and total expenditure using IMF GFSM 2001</i>	IMF
Public Debt%GDP	% of GDP	<i>All liabilities that require future payment of interest and/or principal by the debtor or creditor</i>	IMF
net ODA perK \$2017	International \$ 2017	<i>Net ODA received per capita</i>	World Bank, WDI
RessNat%GDP	% of GDP	<i>Total natural resources rents</i>	World Bank, WDI
\$Total_ippp_m	in millions of constant 2017 international \$	<i>Sum of the PPP investments of the different sectors</i>	Private Participation to Infrastructure
\$Total_kppp_m	in millions of constant 2017 international \$	<i>Sum of depreciated PPP capital stock since the 1st PPP investment in a given country</i>	Author estimates
Primary sector	5 different sectors	<i>Sector that receives the investment</i>	Private Participation to Infrastructure
Subsector	7 different subsectors	<i>Sub-Sector that receives the investment</i>	Private Participation to Infrastructure

ipp_m\$courr	in millions of currents US\$	<i>PPP investments of the different sectors</i>	Private Participation to Infrastructure
\$ipp_m	in millions of constant 2017international \$	<i>PPP investment since the 1st PPP investment in a given country</i>	Private Participation to Infrastructure
\$kppp_m	in millions of constant 2017international \$	<i>PPP capital stock (constructed based on "ipp_m\$")</i>	Author estimates
AIDI_Output			
AIDI_Water	0 - 100 best	<i>Improved water source (% population with access) and improved sanitation facilities (% population with access)</i>	African Development Bank
AIDI_Telecom	0 - 100 best	<i>Total Phone subscriptions per 100 inhbt, number of internet users per 100 inhbt,</i>	African Development Bank
Physical Output			
ICT	0 - 100	<i>Fixed telephone subscriptions (per 100 people)</i>	World Bank, WDI
Water	% of population	<i>People using at least basic drinking water services</i>	World Bank, WDI
WEF output			
WEF_Roads	1-7 best	<i>Quality of roads</i>	The Global Competitiveness Index Historical Dataset © 2007-2017 World Economic Forum Version 20180717
PPP adj		<i>Factor adjustment</i>	PWT10

3.C Sector analysis of infrastructure investments

The role of infrastructure investment as a driver of development is well established. That's why infrastructure investment has been growing steadily in Africa. According to the ICA report (2017), total commitments to African infrastructure increased from \$66.9 billion in 2016 to \$81.6 billion in 2017. This level of commitments is the highest since 2010. However, based on infrastructure development indicators measured by quantity, quality and access rates, Sub-Saharan African countries lag countries in other regions of the world. In this section of the chapter, we will provide a portrait of infrastructure in the three sectors (Road Transport, Water, and ICT), present the trend in public and PPP investment in these sectors, and analyze the performance of these investments on the various indicators of coverage or quality.

Road sector

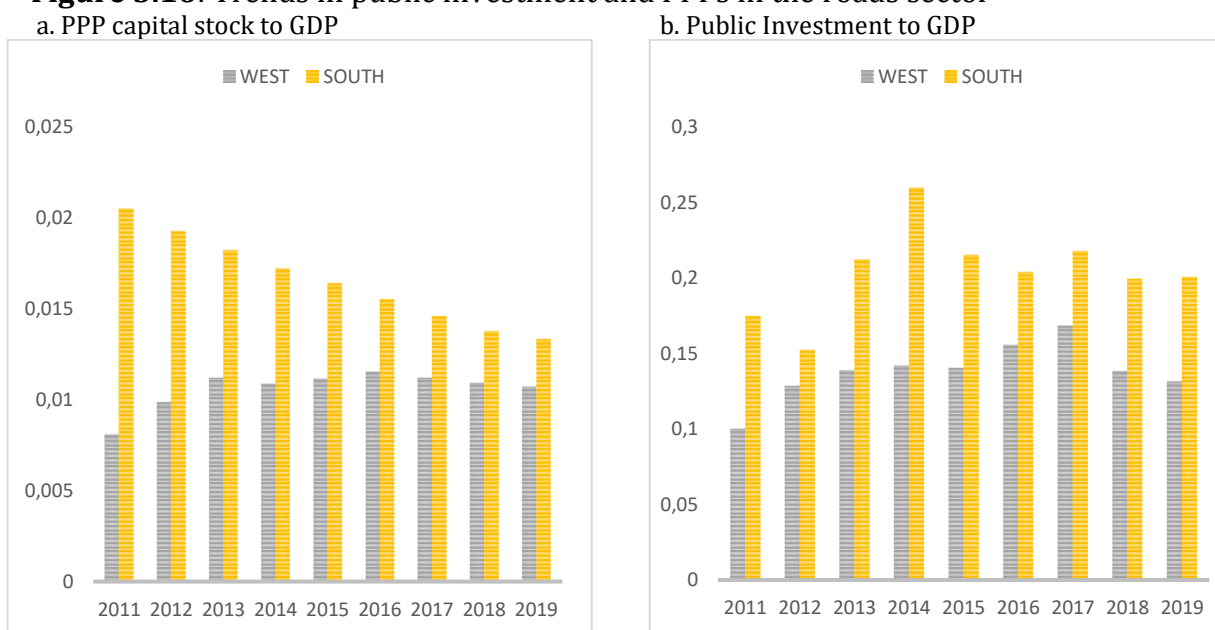
Sector diagnosis: The transport sector is an important factor for integration in Sub-Saharan Africa (SSA). For landlocked countries in the various regions of SSA, transport remains vital to maintain links with the rest of the world and ensure access to international trade, especially in a context of ratification of the African Continental Free Trade Area (AfCFTA). According to the Master Plan of the Economic Community of West African Countries (2019), between 60,000 and 100,000 km of regional roads were needed in Africa in 2008. In 2013, the continent's road network covered a total length of 31,423 km, coupled with 45,832 km of access roads. The density of the network per 100km² is 7km, compared with 12km in Latin America and 18km in Asia. These figures give an idea of how far the continent lags other regions of the world. In addition to its very limited density, the African road network presents several challenges. The continent's road network is mainly made up of national roads, which are not always practicable and offer very limited fluidity and safety. Added to these challenges is the very low level of road maintenance, even though several African countries have succeeded in setting up road maintenance funds. However, despite the widespread imposition of fuel taxes to finance road maintenance, the level of these taxes varies considerably from country to country (Gwilliam and al., 2008). They can range from a symbolic US\$0.03 to US\$0.16 per liter. Collecting these resources presents a challenge for countries because of tax evasion (as in Tanzania) or delays in transferring collected revenues (Rwanda). In other countries, due to the low level of fuel taxes, maintenance fund resources are over 75% dependent on budget allocations (Benin, Gabon, Zambia).

Investment trends: This section deals only with investments in countries that made PPP investments in roads during the analysis period. This explains the absence of the Central and Eastern regions from the figures. In terms of public investment, of the two regions with PPP projects in the roads sector, the Southern region leads, followed by the Western region. Public investment in the Southern region averaged 20.38% of GDP, compared with 13.81% in the Western region. In the Southern region, the highest public investment in relation to GDP was achieved in 2014 (around 26% of GDP), thanks to countries like South Africa and Zambia, which invested a lot in the Energy and Transport sectors. As for the Western region, although it has lower public investment than the Southern region, overall, there is an upward trend in public investment, with a peak in 2017 of over 16% of GDP. This increase is mainly attributable to investments in three

countries in particular: Côte d'Ivoire, Nigeria, and Senegal. These three countries mainly invested in the following three sectors: Transport, Energy, and ICT.

Regarding PPP investment in the road sector, we looked at the stock of PPP capital in this sector over the analysis period. The trends obtained show a very low PPP capital stock relative to GDP for both regions. Although the efforts deployed are considerable in relation to the size of the region's economies, they remain very low. On average, the Southern region has a PPP capital stock to GDP ratio of 1.65%, while in the Western region it is 1.06%. These figures remain below the average for road spending in Africa, which is estimated at around 2% of GDP (Gwilliam and al., 2008). Although the Southern region has a better PPP capital stock than the Western region, it should be noted that the trend is downwards, from a peak of over 2% of GDP in 2011 to a low of 1.3% in 2019. This downward trend can be explained by the absence of recent PPP investment in the sector. However, the picture is different in the Western region, with an upward trend in PPP capital stock justified by the PPP investments made by Côte d'Ivoire, Nigeria, and Senegal from 2011 to 2017 with the construction of new freeways. As a reminder, the PPP projects considered are exclusively those listed in the PPI database and that meet the definition of a PPP according to Knowledge Hub.⁵

Figure 3.16: Trends in public investment and PPPs in the roads sector



Source: author's estimate based on PPI and IMF data

Note: The figure on the left shows the evolution of the PPP capital stock in relation to GDP for the two regions that have made PPP investments for the roads sector. The figure on the right shows the evolution of the stock of public capital in relation to GDP, for the two regions that have made PPP investments.

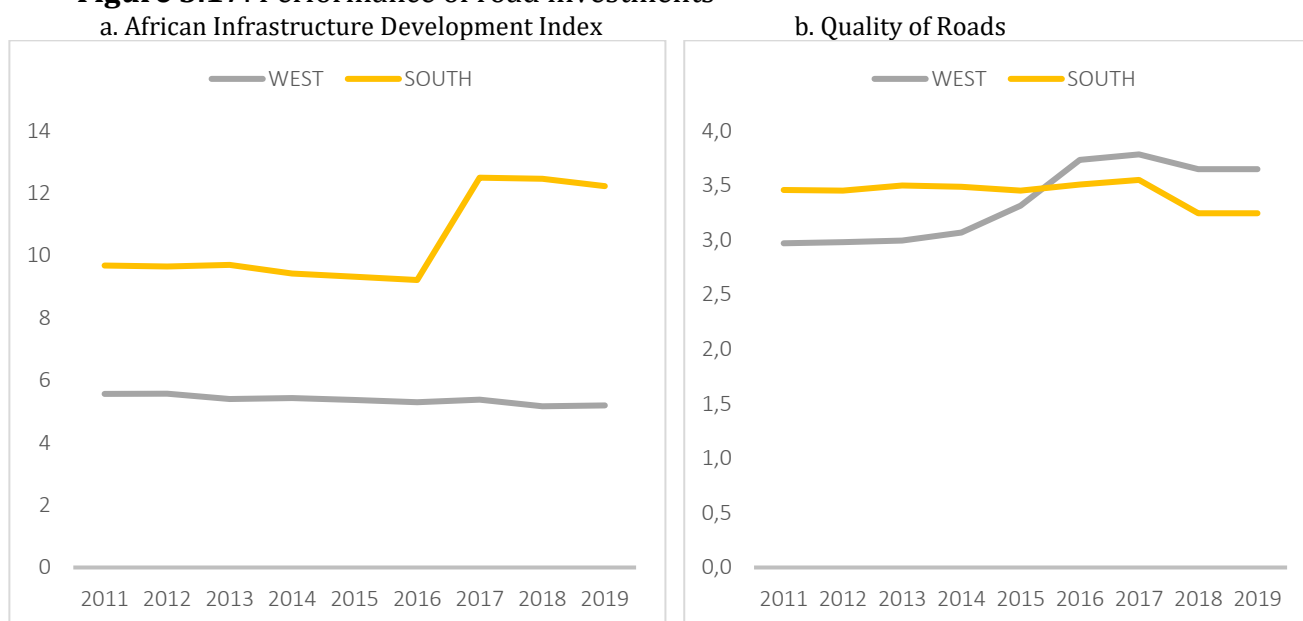
Investment performance: the performance of the road transport system is determined by its efficiency, which can be measured by several indicators, notably cost, safety and comfort (quality). As mentioned above, in the road transport sector, the study focused only on the quality indicator taken from the World Economic Forum database due to challenges related to the nature and the collection of road density measures. However, for this section, road investment performance is also measured using the African

⁵ The BRT projects in Ghana and Nigeria are not listed in the database. The Dakar BRT was completed after 2017, so it is excluded from our analysis.

Development Bank's AIDI sector indicator which indirectly measures road density. The data on road quality reported by the World Economic Forum (WEF) primarily comes from the Global Competitiveness Report survey. This survey is conducted among business leaders and economic experts in each country and relies on qualitative perceptions, as well as quantitative indicators provided by government agencies or the World Bank. However, the opinion survey remains the main source.

In addition to these two indicators, it is important to highlight the safety challenges presented by the road network. The composition of the road network in SSA is mainly made up of national roads, which limits traffic density. As a result, the condition and dimensions of national roads are conducive to accidents of all kinds. Indeed, according to the United Nations (2021), Sub-Saharan Africa is the region of the world proportionally most affected by road accidents, with a mortality rate of 27/100,000 inhabitants, which is three times higher than the European average of 9/100,000. This ratio is above the world average of 18/100,000. However, this indicator is not considered in our study. Only the performance of countries that have implemented PPPs during the analysis period is considered.

Figure 3.17: Performance of road investments



Source: author's estimate based on WEF and AfDB data

Note: The figure on the left shows the performance of road investments measured by AIDI, for the two regions that have made PPP investments in the sector. The figure on the right shows the performance of road investments as measured by the Road Quality Indicator for the two regions that have made PPP investments in the sector

According to the performance measured by AIDI, countries in the Southern region have the best performance with an average indicator of 10.46 over the analysis period, followed by countries in the Western region with an average indicator of 5.38. The relationship between investments (public and PPP) is not perfect. However, it is important to note that from 2011 to 2017, the downward trend in the AIDI indicator for countries in the Southern region can be partly explained by the drop in public investment over the same period. Furthermore, the trends observed do not allow us to establish a relationship between the AIDI indicator and PPP investments, for both the Southern and Western regions. For countries in the Western region, it shows a constant trend in AIDI.

However, for countries in the Southern region, we see a slight drop in AIDI from 9.68 in 2011 to 9.21 in 2016, with a jump from 2017 to 2019 reaching a maximum of 12.50. This could be explained in part by the rise in public investment.

Measured by the WEF indicator, infrastructure quality between the two regions is on a par: an average of 3.4 for countries in the SOUTH region and 3.3 for countries in the WEST region. The difference between the two indicators (AIDI and WEF) can be explained by the methodology used to establish them. The WEF indicator is based on a survey. For the WEF indicator, we can see that for countries in the WEST region, it followed an upward trend from 2011 to 2017, rising from 2.97 to 3.98. We can thus see that there is a positive relationship between the quality of road infrastructure and public investment, especially PPP, over the period 2011 to 2017. Although there are some trends emerging by region, there is considerable disparity between the countries studied. Differences in road quality between countries are a function of both economic and geographical conditions, as well as the influence of the institutional model and funding flows as indicated by certain studies, notably Gwilliam and al., (2008).

ICT sector

Sector diagnosis: ICT infrastructures will be analyzed according to the indicators selected. In fact, the two performance indicators selected are: fixed-line telephone subscriptions and the number of Internet users. As far as the Internet is concerned, it is important to note that SSA countries have made considerable progress since the 2000s, thanks to the deployment of over 300 undersea fiber optic cables required for almost all international telecommunications (Internet and messaging, telephone calls, etc.). However, SSA lags other developing regions (Cariolle and Goujon, 2019; World Bank, 2016). This deficit in wired physical infrastructure and its under-utilization is highlighted by several studies (Bates, 2014; Schuman and Kende, 2013). However, mobile telephony and the Internet can help to bridge this gap, as they require less infrastructure (ITU, 2016).

Despite the efforts made in recent years, the level of Internet penetration remains very low in some regions of SSA, according to data on broadband access, which may be due to insufficient coverage of the telecom's infrastructure. In addition to SSA's territorial fragmentation, the high number of landlocked states makes infrastructure coverage difficult. Beyond the state of the infrastructure, other factors may also explain this low level of penetration: regulation or monopolies (Akue-Kpakpo, 2013). The digital ecosystem in SSA is made up of several stakeholders: states, regional Internet governance forums, the Smart Africa Alliance (Towela and Tesfaye, 2015). However, the bulk of investment in the field is provided by the private sector (Williams and al., 2011).

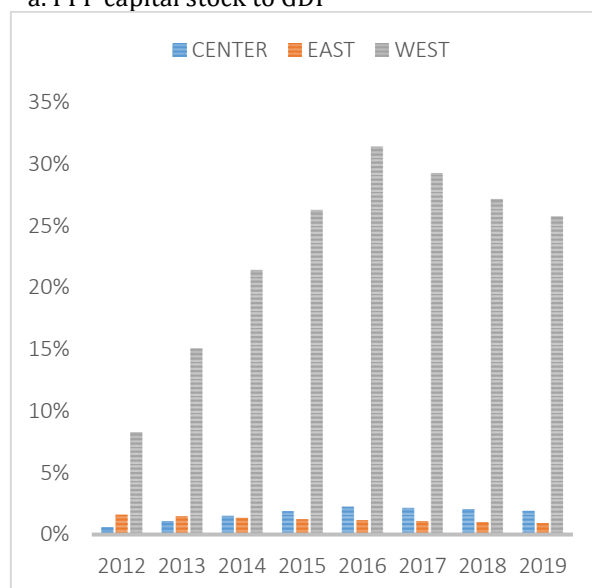
To improve Internet penetration, one of the challenges facing the sector is to improve the political and regulatory environment. In the WEST region, for example, some countries have not yet incorporated specific provisions on the resale of excess capacity or access to or use of alternative infrastructures into their telecommunications legislative and regulatory frameworks (ECOWAS Master Plan, 2019). The cost of broadband access is a challenge that stems from the low level of competition in certain regions of SSA, notably the Western and Central regions. This low level of competition is compounded by the cost of energy and the size of the economy and the ICT market.

Investment trends: in this section, the analysis of investment trends will focus on just three regions: Central, Eastern, and Western. The absence of the Southern region is explained by the non-implementation of PPP projects over the period 2012 to 2017. In terms of public investment relative to GDP, we can see that countries in the Western region have done better than those in the Central and Eastern regions. In fact, over the period 2012 to 2019, countries in the Central region achieved an average total investment equivalent to 40.15% of their GDP, followed by countries in the Eastern region with an average investment of 18.70% of their GDP. Finally, the countries in the Central region had an average total investment of 8.40% of their GDP. This difference in public investment is mainly since the Western region had to invest more than the other two regions. It is also explained by the relatively small size of certain countries in the Western region included in the database, notably Liberia, The Gambia, and Cape Verde. It's important to note that while there is no clear trend for the Western region, this is not the case for the Eastern and Central regions. Indeed, for the Central region, we note a decline in public investment, from an average total of over 14% of the GDP of the countries in the region in 2012 to an average total of less than 6% of regional GDP.

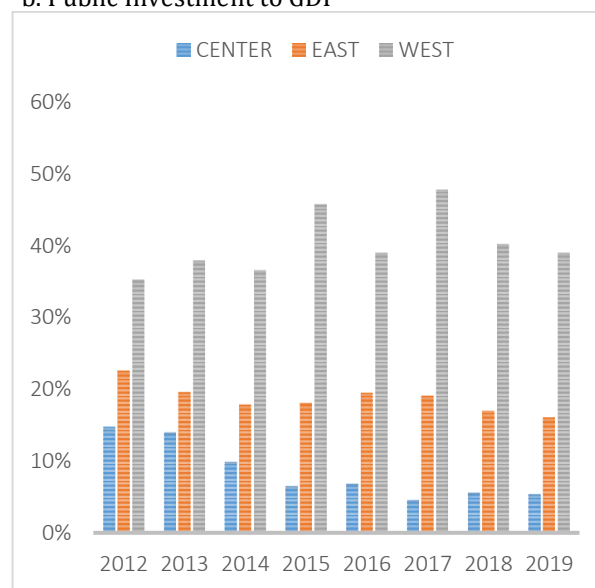
When it comes to the capital stock of PPP investments in the ICT sector, it's the same story: the Western region is well ahead, followed by the Central and Eastern regions. In fact, over the 2012-2019 analysis period, countries in the Western region with PPP investments totaled on average more than 23% of their GDP in PPP capital stock in the ICT sector. They are followed by countries in the Central region with an average total of 1.67% of GDP, and then come the countries in the Eastern region with a total of just 1.22% of GDP. The high level of PPP capital stock compared with other regions can be explained by the large PPP investments made by ECOWAS countries since 2010. PPP capital stock in the Western region is on an upward trend from 2012 (8.30%) to 2019 (25.74%), peaking in 2016 at 31.40% of the region's GDP. In the EAST region, PPP capital stock is lower than in the Western region and has been on a downward trend from 2012 (1.60%) to 2019 (0.92%). For the Central region, even if the capital stock remains modest compared with the Western region, the stock has been on an upward trend from 2012 (0.61%) to 2019(1.90%) with a peak in 2017 equivalent to 2.1%.

Figure 3.18: Trends in public investment and PPPs in the ICT sector

a. PPP capital stock to GDP



b. Public Investment to GDP



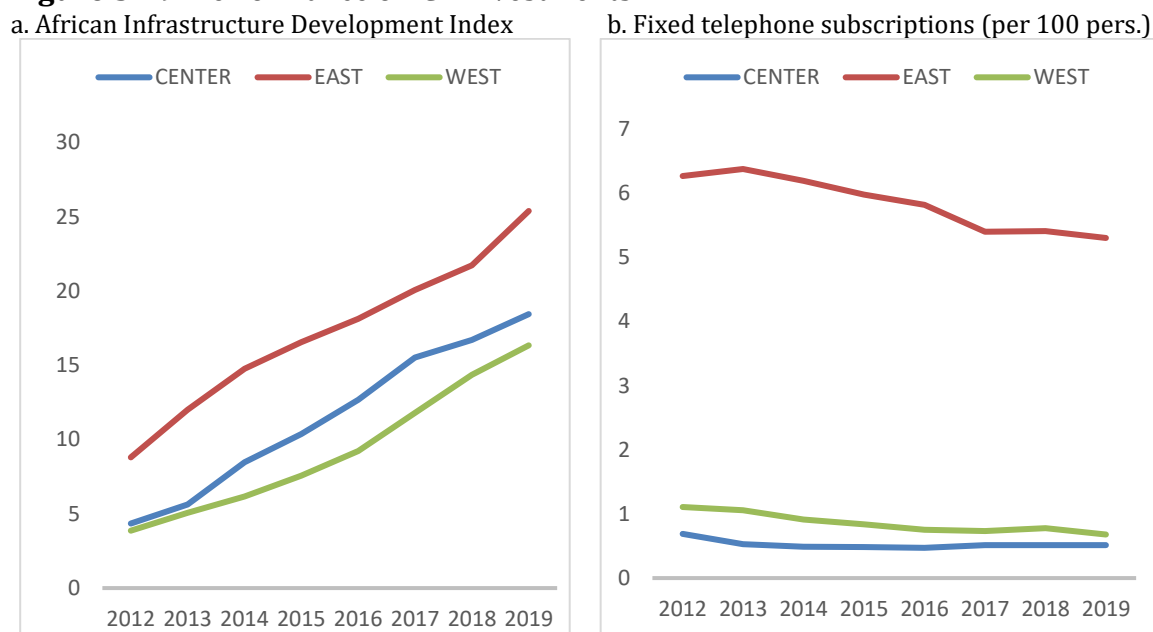
Source: author's estimate based on PPI and IMF data

Note: The figure on the left shows the evolution of the PPP capital stock in relation to GDP for the ICT sector for the three regions that have made PPP investments. The figure on the right shows the evolution of the stock of public capital in relation to GDP, for the three regions that have made PPP investments

Investment performance: the trends in **Figure 3.19** (right) confirm that most people in the various regions of SSA, notably the Eastern and Western, regions, have access to voice and data services via wireless or mobile networks rather than cable (fixed) platforms. Indeed, **Figure 3.19** (Left) shows a downward trend in the indicator measuring fixed-line subscriptions per 100 inhabitants. For the Southern region, the data show that after a slight rise in 2013, from (6.27 in 2012 to 6.38 in 2013) fixed-line subscriptions, the level continued to fall until 2019 reaching 5.30. The same is true of the Western region, although the decline is less marked. The level of fixed-line subscriptions in this region fell from 1.11 in 2012 to 0.68 in 2019. For the Central region, the downward trend is less visible, showing that mobile penetration has been less pronounced than in the other two regions. However, with a subscription level of 0.69 in 2012, it fell slightly by 0.18 points in 2012 reaching 0.51. In summary, the reduction in fixed-line subscriptions was most marked in the Western region, with a 39% drop over the analysis period, followed by the Central region with a 26% drop, and finally the Eastern region with a 15% drop.

The AIDI indicator in **Figure 3.19** measures telephone subscriptions and Internet users per 100 inhabitants. The figures show an upward trend for all three regions. In absolute terms, this upward trend is dominated by the Eastern region, where the sectoral AIDI has risen from 8.80 in 2012 to 25.39 in 2019. It is followed by the Central region, with AIDI rising from 4.35 in 2012 to 18.44 in 2019. Finally comes the Western region, where AIDI has risen from 3.87 in 2012 to 16.34 in 2019. However, the variation over the analysis period was more marked in the Central and Western regions, where it was 324% and 323% respectively. In the Eastern region also, the change in AIDI was very significant, with an increase of 188%. These trends show the large number of Internet users in the Eastern region, driven by the Seychelles and Uganda.

Figure 3.19: Performance of ICT investments



Source: author's estimate based on World Bank and AfDB data.

Note: The figure on the left shows the performance of ICT investments measured by AIDI, for the three regions that have made PPP investments in the sector. The figure on the right shows the performance of ICT investments measured by the number of telephony subscriptions for the three regions that have made PPP investments in the sector

Water Sector

Sector diagnosis: access to drinking water and sanitation services is one of the main challenges facing SSA countries. Of the approximately 768 million people not using water points around 344 million people live in Africa (AfDB, 2015⁶). The situation is the same for sanitation infrastructure. Indeed, of the 2.5 billion people in the world living without sanitation infrastructure, almost a quarter, or 612 million people, are in Africa (WHO and UNICEF, 2013). The Millennium Development Goals (MDGs) called for 75% of the population to have access to improved food services by 2015. Unfortunately, this target has not been reached by all SSA countries. However, efforts have been made to improve the sector's infrastructure and, by extension, access to water. Considerable funding has been devoted to setting up monitoring and evaluation systems in several SSA countries. Monitoring progress in infrastructure sectors such as water distribution has been an important effect towards achieving the MDGs (Banerjee and al., 2008). Despite the efforts made, it is important to note that there has been a deterioration in the level of coverage of public water distribution services, particularly in urban areas. According to Banerjee and al. (2008), based on AICD DHS/MICS data, 39% of the urban population is connected to a piped water distribution network, compared with 50% in the early 1990s. This deterioration in urban coverage can be explained by rapid population growth and galloping urbanization, which water utilities have been unable to keep pace with. However, in some countries, such as Ethiopia and Côte d'Ivoire, dazzling progress has been made in improving access to water in urban areas. With a view to achieving the

⁶ Given that the period of analysis on access to water extends from 2012 to 2017, these more recent data from 2023 were not relevant in our context.

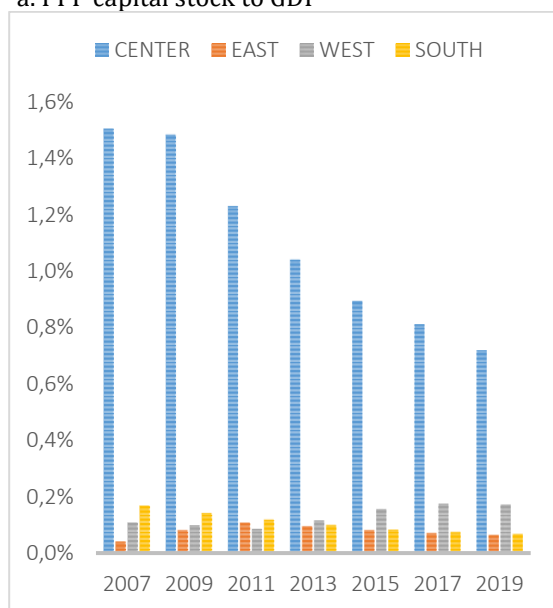
MDGs and, above all, creating commercially oriented public services, SSA countries have introduced several reforms aimed at mobilizing more resources to finance the water sector, as well as improving management of the sector, notably through private-sector participation. However, these reforms have failed to attract large-scale private investment, prompting countries to strengthen the governance of state-owned companies.

Investment trends: Of the three sectors covered by this study, it is only in the water sector that PPP investments have been made in the four regions over the analysis period. **Figure 3.20** shows that the Central region has the largest stock of PPP capital. This capital stock is mainly made up of Gabon PPP investments made before the analysis period began in 2007. These PPP investments represent an average of 1.1% of GDP over the period 2007 to 2017. After the Central region comes the Western region, whose PPP capital stock in the water sector was estimated at an average of 0.13% of the GDP of countries with PPP investments. In this region, investments were mainly made by Senegal, Ghana, and Niger. Right after the West region comes the Southern region with South Africa and Mozambique, whose PPP capital stock is estimated at slightly less than that of the Western region, namely 0.11% of the GDP of these two countries. In last place, we have the Eastern region with the smallest capital stock, estimated at 0.08% of the GDP of Sudan and Tanzania, the two countries that have implemented PPPs in the sector. Despite being the region with the lowest capital stock, it is the region that has seen the greatest growth in PPP capital stock (57%), just after the Western region with growth of 59% (0.11% of GDP in 2007 to 0.17% of GDP in 2010); followed by the Central region (a drop of over 52%) and finally the Southern region with a drop of over 60%.

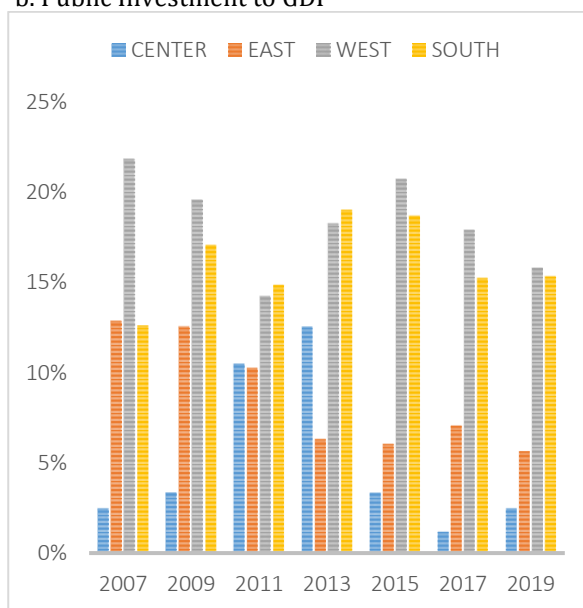
The trend in public investment in the various regions analyzed above is not as clear-cut as that of PPP capital stocks. However, it is generally agreed that the Western and Southern regions had the highest levels of public investment in relation to GDP, with averages of 17.85% and 16.39% respectively. Next come the countries of the Eastern region, where public investment represented 8.6% of GDP, and finally the Central region with 5.2% of GDP. After a downward trend in public investment from 2007 to 2015 in the Southern region, it was not until 2016 that the region saw an increase in public investment, with projects undertaken by Kenya, Seychelles, Tanzania, and Uganda. This upward trend will continue into 2017. The same trend can be observed in the Western region, but this time, the downward trend is of shorter duration, from 2007 to 2011, and then increases until 2015, with rising investment mainly in Senegal, Liberia, and Togo. After 2015, public investment as a percentage of GDP continued its downward trend. The Central region saw the longest upward trend in public investment as a proportion of GDP from 2007 to 2013, coinciding with rising investment in infrastructure projects in the Republic of Congo, Sao Tomé and Príncipe, and Gabon.

Figure 3.20: Trends in public investment and PPPs in the Water sector

a. PPP capital stock to GDP



b. Public Investment to GDP



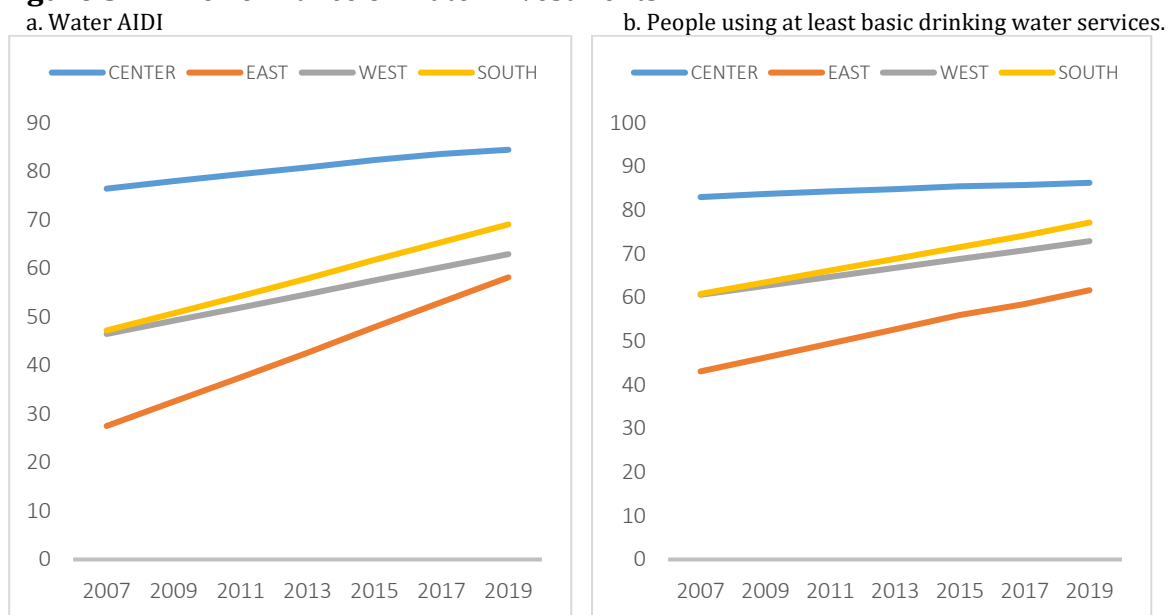
Source: author's estimate based on PPI and IMF data

Note: The figure on the left shows the evolution of the PPP capital stock in relation to GDP for the four regions that have made PPP investments for the water sector. The figure on the right shows the evolution of the stock of public capital in relation to GDP, for the four regions that have made PPP investments

Investment performance: the MDG of providing access to improved water supply services for 75% of the population by 2015 has been achieved by only half of the 8 countries with PPP investments. These countries are: South Africa (91.85%), Gabon (85.47%), Ghana (79.42%) and Senegal (78.24%). Although South Africa comes first in terms of coverage rate with 91.85%, if we look at the regional averages for countries with PPP investments (**Figure 3.21**), it's the Central region that leads the way in terms of coverage rate, with an average of 84.76%, followed by the Southern and Western regions with 68.88% and 66.76% respectively. Finally, the Eastern region comes in with 52.54%. Looking at investment trends, it is only in the Western region that we find a positive relationship between PPP investments and the coverage rate. For the other regions, the relationship between PPP capital stock and coverage rate is not obvious. This could lead us to say that it is more public or purely private investments (in the case of privatizations) that could mainly explain the rise in the coverage rate.

The trend presented in **Figure 3.21 (left)** showing the percentage of people with access to an improved water source or sanitation facility shows the same trends as the **Figure 3.21 (right)**, with a few differences in proportions. The trends dominated by the Central region (80.76% average over the analysis horizon), followed by the Southern (68.88%), Western (66.76%) and Eastern (52.54%) regions are confirmed. Although the Eastern region has seen the weakest trend in terms of progress from 2007 to 2019, it remains the region with the greatest progress, with a rate of change of over 111%. This can also be explained by its low coverage rate in 2007 (27.51%), more specifically that of Tanzania (17.82%). It is followed by the Southern region, with a variation of over 46%. Next comes the Western region, with a variation of over 35%, and finally the Central region, with a variation of over 10% over the analysis period.

Figure 3.21: Performance of Water investments



Source: author's estimate based on World Bank, WEF and AfDB data.

Note: The figure on the left shows the performance of investments in the water sector as measured by AIDI for the four regions that have made PPP investments in the sector. The figure on the right shows the performance of investments in the water sector as measured by access to basic sanitation services for the four regions that have made PPP investments in the sector

General Conclusion

Public-Private Partnerships (PPPs) have become an increasingly popular tool for financing and managing infrastructure and public services in many countries, particularly in sub-Saharan Africa. By their very nature, PPPs make it possible to combine public and private resources to improve service delivery, reduce financing shortfalls and accelerate infrastructure development. However, their effectiveness is the subject of debate. While many benefits are attributed to PPPs, there is also evidence and criticism pointing to their inefficiencies. There are several reasons why there is no consensus on their actual performance. One reason is the diversity of methodologies used to assess performance. Studies on PPP performance use a variety of methodologies, ranging from quantitative analyses, such as cost-benefit analyses, to qualitative analyses based on case studies and stakeholder perceptions. This diversity makes it difficult to compare results directly. In addition, the performance criteria used may differ from one sector to another. Several studies use economic criteria: cost reduction, on-time delivery, and financial risk management. However, results vary according to context and sector. The geographical and sectoral scope of PPP projects can have an impact on PPP performance. Most studies focus on specific regions, mainly in Europe, North America, and Asia, leaving PPP performance in regions such as Africa less explored. Finally, there may be a selection bias in the projects analyzed, often the most successful or those that have failed notably, creating an unrepresentative view of overall PPP performance.

Given such a context surrounding the evaluation of PPP performance, our thesis has attempted to fill the literature gap while considering the sources of divergence in PPP performance. Thus, to overcome the challenge in terms of geographical and sectoral scope, the thesis focused on the Sub-Saharan African region. Also, in terms of the sectors covered, the thesis first carries out a multi-sectoral evaluation of PPPs before carrying out an evaluation in the four major PPP sectors (Water, ICT, Transport and Energy). As part of the diversity of approaches, the thesis exploits three evaluation methodologies to assess PPPs efficiency and performance: Stochastic Frontier Analysis, fixed effects estimations and Propensity Score Matching. Finally, most studies evaluating PPP performance are limited to defining private participation in infrastructure, which is not always considered a PPP. In our thesis, a PPP capital stock was estimated based on investments in the PPI database meeting the definition of a PPP. The remainder of this conclusion summarizes the main findings of the thesis, discusses their implications, the limitations of the results and identifies areas for future research.

Chapter 1 measures the inefficiency of infrastructure investment by economic growth and an indicator of infrastructure development in Africa which, to the best of our knowledge, has never been used as an output in a stochastic frontier approach. Furthermore, given the lack of macro studies on the contribution of PPPs as most empirical studies on PPPs consist of anecdotal evidence and case studies, our paper analyzed the relationship between PPPs and the inefficiency of public infrastructure investments. Finally, our paper sought to innovate by looking at the determinants of inefficiency as measured by the CPIA criteria and KKZ governance indicators.

The paper began by analyzing the contribution of PPPs to economic growth and infrastructure development.

Indeed, we observed that the multisectoral PPP capital stock, when used as an explanatory variable, negatively shifts the efficient production frontiers for the vast majority of SSA countries whether GDP is used as an output or AIDI. We therefore sought to understand the combined effect of PPPs and CPIA criteria (having a causal effect with PPPs and the infrastructure development index) on AIDI output. We also sought to understand the combined effect of PPPs and KKZ governance indicators on GDP output.

The results showed an improvement in the contribution of PPPs when combined with the selected CPIA criteria, compared with the situation where only PPPs are considered. We obtained also a positive and significant contribution of PPPs to GDP when combined with KKZ governance indicators. Secondly, the paper examined the role of PPPs as a determinant of inefficiency. The results showed that PPPs help to reduce inefficiency in both: economic growth measured by GDP and infrastructure development measured by AIDI.

Finally, a robustness analysis was carried out using a fixed effects estimation method as an alternative approach to analyze the effect of PPPs and CPIAs on infrastructure development instead of the SFA approach, the results obtained confirmed the robustness of our results.

Chapter 2. analyzes the efficiency of investments in two infrastructure sub-sectors: Electricity and Ports. The paper also looks at the determinants of inefficiency, i.e. the CPIA criteria. In addition to these CPIA criteria, the paper also analyzed the role of PPP sector investments on access to electricity.

For the electricity sub-sector, the tests identified two CPIA criteria: Financial Sector (c.5) and Quality of budgetary and financial management (c.13). We also analyzed the effect of exchange rate and Credit to the private sector. Regarding the shifting of the efficient frontier, the results showed a positive contribution of the inputs: public, private investments and PPPs to access to electricity. However, the contribution of PPP sector investments to shifting the efficient frontier remains negligible. The results show perfect efficiency when PPP investments in the electricity sector are considered. However, without these PPP investments, the results show an average decline in efficiency of 1% over the analysis period. More importantly, we find that when PPP capital stock is combined with an CPIA criteria or exchange rate, its contribution to the electricity rate access remains significant and positive. As for the role of PPP capital stock as a determinant of inefficiency, the results show that it contributes to improving access to electricity, as does criteria financial sector (c.5) and credit to private sector. While criteria Quality of budgetary and financial management (c.13) contributes negatively to access to electricity. Finally, the average technical efficiency without PPPs but including the determinants of inefficiency as well as credit to private sector, is 84.5% versus an increase reaching 91.3% when PPPs are considered. These efficiency scores are also widely dispersed, ranging from an average minimum over the analysis period of 58 % for Liberia to an average maximum of 99% for Mauritius and South Africa. We also analyzed the effect of instability, measured by various crises, on PPPs in the electricity sector. The results showed a non-significant effect for several reasons discussed in the document.

For the Ports sub-sector, three CPIA criteria were selected: Monetary Policy (c.1), Debt Policy (c.3) and Quality of Public Administration (c.15) alongside with trade openness and exchange rate. In terms of shifting the efficient frontier, the results showed a significant and positive contribution of PPP sector investments to container traffic. The average inefficiency without PPP sector investments is 28%, while the average inefficiency with PPP is around 25%, i.e., a 3% improvement with PPP. Used as determinants of inefficiency, the Debt Policy (c.3), Quality of Public Administration (c.15), trade openness and exchange rate contribute to improving the level of container traffic, while the Monetary Policy (c.1) criteria contributes negatively to container traffic.

To ensure the robustness of our results, our models were estimated using an alternative approach. The results from the estimation using fixed effects methods with heteroskedasticity correction or GLS confirm the robustness of our findings, except for the port sector, where the contribution of Monetary Policy and the Quality of Public Administration became non-significant in our alternative approach.

The results obtained show a positive contribution from PPP investments in the ports and electricity sub-sectors. With a view to improving the efficiency of investments in sectoral infrastructures (Ports and Electricity), governments should further strengthen the following CPIA criteria: Financial Sector (c.5); Quality of Public Administration (c.15) and Debt Policy (c.3). To promote port activities, governments should also enhance their trade openness and adopt monetary policies that support exchange rate stability. Regarding Quality of Budgetary and Financial Management (c.13) governments should ensure, its impact on low-income households in terms of access to electricity. In the future, it would be interesting to investigate the contribution of PPP investments in other sectors, such as water or roads, when data permit.

The evaluation of the effect of PPPs in Chapter 3. was carried out in three stages: the first stage involved determining the factors explaining the assignment to the model under study. The second step in our approach was to estimate propensity scores corresponding to the probability of a country benefiting from a PPP investment in a given sector (Water, ICT and Road). These propensity scores were estimated using a Logit model containing the explanatory variables for a country's probability of benefiting from a sectoral PPP. Finally, having estimated the propensity scores, we then proceeded to analyze the results (output) for each sector: the coverage rate (Water, ICT) and quality level (Roads) in the treated group versus the matched control group, to measure the effect of PPP investments in each sector. The data used in this chapter come mainly from the World Bank's database on private participation in infrastructure (PPI database).

The results obtained in the ICT sector show that the "PPP law" variable has a negative effect on the probability of implementing a PPP. As for the Country's PPP capacities, they have no significant effect on the probability of implementing a PPP. PPP investments have improved the number of telephone and Internet subscriptions. This coverage rate increases further if we consider the adoption of a PPP law in the country and improve the country's capacity to evaluate, procure and manage PPP projects.

In the water sector, the adoption of a PPP law had no significant effect on the probability of making a PPP investment in the sector. Regarding countries' PPP

capabilities, the level of preparation decreases the probability of PPP investments in the sector. As for the effect of PPPs on water access rates, the results show that countries with PPPs have a better coverage rate than countries without PPP investments. However, neither the adoption of a specific PPP law, nor the improvement of PPP player capacities had a significant effect on the coverage rate.

The adoption of a PPP law had no significant effect on the probability of making a PPP investment in the road sector. In terms of countries' PPP capabilities, the level of preparation and contract management decrease the probability of implementing PPPs in the sector. However, capabilities related to procurement increases the probability of implementing PPPs. As for the effect of PPPs on road quality, the results are not significant. However, the adoption of a PPP-specific law and improvement of PPP player capabilities indirectly improved road quality.

The various robustness tests conducted using alternative approaches such as IPW and GMM confirm the results obtained in the two sectors: Water and ICT. However, for the road sector, the GMM approach concluded that PPPs made a positive and significant contribution to quality of roads. Additionally, the placebo effect estimation confirms that the effect of PPPs was not due to mere coincidence.

In summary, both multi-sectoral and sectoral PPPs (electricity, ports, ICT, Water and roads) contribute positively to GDP and infrastructure development indicators, respectively. In addition, we noted that PPPs are efficient when they are used in the Electricity and Ports sectors. However, multi-sectoral PPPs are not efficient for most countries. In addition, we noted the positive contribution of governance indicators and CPIA when combined with PPPs. Given their relatively low score for some countries, improving them would help improve the efficiency of PPPs. Finally, given the level of efficiency of PPPs for most PPPs and the score of the determinants, it is important for the authorities to further strengthen these determinants to benefit from the efficiency gains associated with PPPs.

We cannot conclude without mentioning a few limitations of the analysis, some of which are associated with the nature of the indicators used. Indeed, the indicator on road quality is based on respondents' perception of the quality of road infrastructures, which leaves a lot of room for the subjectivity of the indicator that needs to be considered when interpreting the results. Furthermore, in Chapter 3. data measuring PPP capacity are published in 2018, whereas the analysis period ends in 2017. However, these surveys take time to finalize and publish. Another difficulty lay in the measurement of PPP investments. Indeed, some PPP investments could end up on the public investment balance sheet, given the absence of clear budgetary accounting in the countries studied. Also, the PPP investments analyzed only represent commitments at the financial closing stage and could therefore differ from investments carried out.

In the future, it would be interesting to investigate the relationship between sectoral PPP investments combined with the various CPIA criteria and sectoral AIDIs. Another area for future analysis is the impact of PPP institutional frameworks measured by the existence of a PPP unit on the number of projects renegotiating PPP contracts or the effect of PPPs resulting from spontaneous bids on the number of projects renegotiating PPP contracts. It would also be interesting to investigate the contribution of PPP investments in other sectors, such as rail or airport transport, when data allow.

