Project Paper: Infrastructure Governance and Agricultural Development in Sub-Saharan Africa

by

Georg Berthold Pflomm

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Supervisor: Professor Rosemary Atieno

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Registration Number:	T51/38069/2020
College:	College of Humanities and Social Sciences
Department:	Department of Economics and Development Studies
Course Name:	Master of Development Studies
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Prof. Rosemary Atieno
Department of Economics and Development Studies
University of Nairobi

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Acronyms

Table 1: Acronyms

%	Percent
AfDB	African Development Bank
CAADP	Comprehensive Africa Agriculture Development Programme
e.g.	Example given
et al.	et alia (and others)
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross domestic product
i.e.	Id est (that is)
IDS	Institute for Development Studies
ICT	Information and Communications Technology
ILO	International Labour Organization
IMF	International Monetary Fund
IPP	Independent power provider
k	Number of independent variables
n	Number of cases
NEPAD	New Partnership for Africa's Development
ODA	Official development assistance
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary least square
p	P-value
PIMA	Public Investment Management Assessment
PPP	Public-Private Partnership
R&D	Research and development
sq.	Square
UNDP	United Nations Development Programme
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
US$	US-Dollar
VIF	Variable Inflation Factors
WDI	World Development Indicators

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Abstract

This research project examines the causal relationship between infrastructure governance and agricultural development in Sub-Saharan Africa. Researchers have recognized infrastructure as an important determinant of agricultural development. Insights on infrastructure governance have, however, not yet been incorporated into this literature, partly due to a lack of data on infrastructure governance. This research project solves both research gaps. Data on transportation, power, and water infrastructure governance is created by aggregating Afrobarometer survey data measuring individual perceptions of the government's performance regarding transportation, power, and water infrastructure. The mean of these three variables is used to measure infrastructure governance. This study computes agricultural production function with infrastructure governance as the independent variable and agricultural output as well as agricultural labor productivity as dependent variables while controlling for agricultural production factors (land, labor, capital, temperature, and rainfall).

The empirical data analysis uncovers that good infrastructure governance contributes to agricultural development in Sub-Saharan Africa by raising agricultural outputs. It does not evoke higher agricultural labor productivity, though. This implies that good infrastructure governance serves as an incentive to increase the factors of production used but not as an incentive to improve the yields per factor of production ratio. Furthermore, good transportation infrastructure governance causes agricultural output growth. However, power and water infrastructure governance do not statistically significantly contribute to agricultural development. Transportation infrastructure governance is more important for agricultural development than the two other types due to transportation infrastructure's public good nature and the importance of transportation infrastructure for agriculture. The most important recommendation to be derived from this research project is for African governments to improve their infrastructure governance by implementing accountability as well as public participation in planning, enforcing sound and clear regulatory policy frameworks, ensuring the rule of law, and preventing corruption.

1 Introduction

1.1 Background

1.1.1 Importance of Agriculture

One can hardly overestimate the importance of agriculture to Africa's economies. Agriculture is the most significant economic sector in almost all Sub-Saharan African countries. The agricultural sector, which consists of crop-yielding as well as the livestock and fishery sub-sectors, made up 18.5% of Sub-Saharan Africa's gross domestic product (GDP) directly in the year 2020 (The World Bank 2021). In some countries, such as Sierra Leone, the agricultural GDP share is as high as 60%, but in others, it is much lower (less than 2% in Seychelles). Besides the direct contribution to the GDP, agriculture contributes to the GDP indirectly, too. Hence, the actual economic contribution is even higher. The relevance of African agriculture can also be seen in the share of agricultural employment of the total employment, which amounted to 53% in Sub-Saharan Africa in 2019 (ILO 2022). In Burundi, an astonishing 86% of total employment is in the agricultural sector. Therefore, a high share of the population derives their livelihoods from agriculture in most African countries. Some countries (e.g., Mauritius with 6%) have a low percentage of agricultural employment, however. On average, 42.5% of the total land is utilized for agricultural production in Sub-Saharan Africa, according to data by the Food and Agriculture Organization of the United Nations (FAO) (2022b). There is, however, a high variability, as values range between 3% (Seychelles) and 80% (Lesotho). In summary, there are significant differences between different Sub-Saharan countries, but generally, agriculture is of enormous relevance in most African economies. This can be illustrated by the high share of agriculture in the GDP, total employment, and land utilization in most African countries. Agriculture is less crucial in other regions compared to Sub-Saharan Africa. Hence, this study covers all Sub-Saharan African countries.

Due to the crucial role of agriculture in African economies, one of the most important determinants of African countries' development is agricultural development. Agricultural development can be defined as the process of equitable growth in the agricultural production of a country (Diao et al. 2007). A country can achieve this in two ways: by achieving agricultural output growth or by achieving agricultural productivity growth. One can improve agricultural productivity by increasing the yields per factor of production ratio, e.g., by improving land or labor productivity. Agricultural output growth can be achieved by increasing the factors of production used. This is typically done by cultivating more agricultural land or by increasing the agricultural labor force's size. Importantly, agricultural productivity growth has a better developmental impact than agricultural output growth, as productivity improvements lead to decreased agricultural production costs (Diao et al. 2007). Agricultural development is vital for achieving food security, poverty reduction, and economic development. According to the 'World Food Summit' (1996), "food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (World Food Summit 1996). This definition contains four dimensions: availability, accessibility, utilization, and stability (Gross et al. 2000). Agricultural development contributes to availability and accessibility. Increased agricultural output leads to an improved food supply (assuming a constant trade balance) and hence, higher food availability. If agricultural development is achieved through improved productivity, it contributes to food accessibility indirectly. Firstly, it is an essential source of income for many farmers. A higher output results in more revenue, which improves farmers' purchasing power. Secondly, agricultural productivity improvements increase the total output and decrease food production costs (Pawlak and Kołodziejczak 2020). Depending on the price elasticity of demand and tradability, this leads to lower food prices (Diao et al. 2007). Therefore, agricultural development improves both availability of and access to food, enhancing food security. Furthermore, agriculture plays a vital role in poverty reduction. The empirical literature has shown that agricultural growth is two to three times more effective in reducing poverty than growth in other sectors (Christiaensen, Demery, and Kuhl 2011). The poverty-reducing effect of agricultural development is strongest in countries with a low GDP per capita (Ivanic and Martin 2018). The mechanism by which agriculture contributes to poverty reduction is like the one of food security. Higher rural incomes and lower prices of food benefit the poor. Additionally, agricultural development leads to the growth of rural non-farm economies, which further reduces rural poverty (Diao et al. 2007). Lastly, agricultural development assists general economic development. It contributes to capital accumulation and foreign exchange earnings and supports the development of the industrial and service sectors. It ensures the availability of raw materials for industries and provides markets for services and industrial products by raising rural incomes. Keeping the costs of food low leads to lower urban costs of living, lower urban wages, and hence, higher competitiveness of labor-intensive industries and prevention of the Ricardian trap. (Akkoyunlu 2013). Thus, agriculture plays a decisive role in Africa's development.

1.1.2 Determinants of Agricultural Development

Agriculture's contribution to Africa's development depends on the performance of the agricultural sector, though. Therefore, it is important to understand the factors determining agricultural development. The most important determinants of agricultural development are the availability and accessibility of factors of production, the macroeconomic environment, and the functioning of markets. Firstly, crucial factors of production include land, climate, labor, capital, and technology. Land describes the quality of soils, the size of farms, and institutional factors like land tenure, land tenure security, and property rights. Climate includes the temperature, the prevalence of rainfall, and climate change, leading to an increasing variability of temperature and precipitation as well as a higher prevalence of droughts and floods. Labor describes the size of and changes in the agricultural population and their human capital. This includes their health, education, knowledge of agricultural production, and their access to information on weather, markets, and other important factors. Capital contains access to finance and insurance. The last factor of production, technology, comprises the access to and availability of machinery, seeds, fertilizers, pesticides, storage equipment, the prevalence of irrigation, and research and development (R&D), which is necessary for technological advancements (Shita, Kumar, and Singh 2020; Reardon et al. 1996). Secondly, the macro-economic environment includes inflation, interest rates, exchange rates, and availability of capital, but also institutional aspects like the investment climate and economic freedoms (Kargbo 2007). Lastly, important factors for the functioning of markets are prices and demand of agricultural produce, market integration, and access to domestic and international markets (Shita, Kumar, and Singh 2020). Good availability and accessibility of factors of production, a stable macro-economic environment, and well-functioning markets contribute to agricultural development. There is vast diversity within Sub-Saharan Africa in the extent to which these determinants of agricultural development are realized.

Consequently, there is also considerable diversity in the performance of agricultural sectors. For example, there are disparities in the growth rates of the agricultural sectors. The Comprehensive Africa Agriculture Development Programme (CAADP) by the African Union states the goal that the agricultural sector should have an annual growth rate of 6% in each African country (The NEPAD Secretary 2005).

African countries in the year 2020 only had on average of 3% growth in the agricultural sector, though, according to data by the World Bank (2022b). Some countries achieved tremendous growth rates (e.g., 25,5% in Lesotho, 17,2% in Zambia, and 15,9% in Senegal), while other African countries even experienced recessions in the agricultural sector (e.g., -16,5% in Seychelles, -6% in Congo, and -5,5% in Eswatini). Another indicator of the performance of the agricultural sector is agricultural labor productivity. According to data by the World Bank (2022d) from 2019, every agricultural worker in Sub-Saharan Africa adds a value of, on average, 1500 US$. Only South Asia has similarly low labor productivity (approximately 2000 US$ value added per worker). All other regions have a value of at least 5000 US$ (East Asia and Pacific) or more. Within Sub-Saharan Africa, there is a variety between 234 US$ value added per worker in Burundi and 9900 US$ in Eswatini (The World Bank 2022d). The agricultural GDP shows a similar trend. The World Bank (2022c) data from 2019 shows that Sub-Saharan Africa has an agricultural GDP of 318 billion US$. This is less than 10% of the global agricultural output (3600 billion US$). Seychelles has the lowest agricultural output within Sub-Saharan Africa (31 million US$) and Nigeria the biggest (116 billion US$). Hence, there is a huge variance within Africa, but Africa's agriculture is generally performing rather poorly compared to other regions.

1.1.3 Importance of Infrastructure for Agricultural Development

A critical determinant of agricultural development is infrastructure, as it influences the availability and accessibility of most factors of production and the functioning of markets. Infrastructure can be defined as the "facilities, structure, equipment, or similar physical assets—and the enterprises that employ them—that are vitally important, if not essential, to people having the capabilities to thrive as individuals and participants in social, economic, political, civic or communal, household or familial, and other roles in ways critical to their own well-being and that of their society" (T. C. Miller 2021, 3). Infrastructure consists of systems and facilities. There are four kinds of infrastructure: transportation, water and sanitation, power, as well as information and communications technology (ICT) infrastructure. Transportation infrastructure includes all systems and facilities enabling the conveyance of goods and people and includes roads, railways, airports, ports, and waterways. Roads are most important for agricultural development (Juma 2015; Turley and Uzoski 2018); hence, this paper focuses on roads. Water and sanitation infrastructure provides access to clean water and enables the removal of sewage and wastewater. It consists of systems and facilities to extract water from water bodies, transport water, store water, and treat wastewater (Turley and Uzoski 2018). Water infrastructure is more important for agriculture than sanitation infrastructure, so this paper concentrates on the former. Power infrastructure comprises systems and facilities to generate, transmit, and distribute electricity. It includes both on- and off-grid solutions (African Monitor 2012). ICT infrastructure includes systems and facilities enabling the exchange of information and communication and consists of networks between landlines, mobile phones, and the internet (Juma 2015). All kinds of infrastructure contribute to agricultural development. Transportation infrastructure is necessary for market integration, which allows farmers to access markets and obtain inputs. Stable access to markets incentivizes farmers to invest in their production and grow crops with higher yields and value (Stifel and Minten 2008). It leads to lower transaction costs, which reduce the costs of inputs. Better access to and lower costs of inputs like fertilizer and pesticides improve agricultural productivity (Juma 2015). Transportation and ICT infrastructure enhance rural areas' access to finance and insurance, too (Llanto 2012). Access to water and electricity is necessary for irrigation projects. Therefore, good water and power infrastructure increases irrigation's prevalence, improving yields, reducing seasonal fluctuations in agricultural production, and decreasing vulnerability to climate shocks (Turley and Uzoski 2018). Water is an important input in livestock and fisheries (IImi 2007). Access to electricity, in combination with a good ICT infrastructure, ensures timely information on market trends and enables storage of produce to reduce post-harvest losses (Kiiza and Pederson 2012; Lee, Miguel, and Wolfram 2020). The different aspects of infrastructure are complementary and mutually reinforcing (Calderón and Servén 2004). Providing farmers with one aspect of infrastructure, but not the others, has fewer positive effects on agricultural growth than the provision of all of them. For example, farmers only invest in irrigation systems, which require good water and power infrastructure, if they are ensured access to markets, which requires good transportation infrastructure.

Despite the importance of good infrastructure for agricultural development, most African countries have relatively poor infrastructure. One can generally claim that there is a deficit in the existing infrastructure's quantity, quality, and reliability (Corrigan 2017). It is, however, mandatory to acknowledge the considerable diversity between African countries regarding this. Nevertheless, a World Bank paper by Calderon, Cantu, and Chuhan-Pole (2018) concludes that in Africa, "there is a large gap in terms of quantity, quality and access to infrastructure" (Calderón, Cantu, and Chuhan-Pole 2018, 2). Less than 50% of Africans live less than 2 kilometers away from an all-season road (AfDB 2022). Many (i.e., rural) roads are in poor condition due to insufficient maintenance (African Monitor 2012). According to Graff (2018), the allocation of transportation infrastructure does not match the needs of the populations and economies, which reduces its potential contribution. Disruptions in the transportation infrastructure (for example, traffic congestion) are relatively common (Hallegatte, Rentschler, and Rozenberg 2019). Therefore, transportation costs in Africa are higher compared to other continents and logistical bottlenecks are relatively common (Corrigan 2017). 69% of the world's 860 million people without access to electricity live in Sub-Saharan Africa and the household electrification rate in Sub-Saharan Africa is only 43% (AfDB 2022). Additionally, many African countries have relatively low reliability in their power infrastructure, which results in frequent power outages (African Monitor 2012; Hallegatte, Rentschler, and Rozenberg 2019). 68% of Africa's population has access to water and 30% to sanitation (Corrigan 2017). These numbers are significantly lower in rural areas, though. Torero and Chowdhury (2005) state that access to infrastructure (across transportation, power, water, and ICT) is unequally distributed, with lower access rates for poor and rural dwellers. The relatively low access to energy and water infrastructure (among other factors) contributes to the low prevalence of irrigation in Sub-Saharan Africa. Just 7% of Africa's cultivated land is irrigated (Shah, Namara, and Rajan 2020). ICT infrastructure is the type of infrastructure with the best progress. Due to the spread of mobiles and smartphones, more and more people in Africa have access to new communication platforms, mobile banking, and other benefits of digitalization (African Monitor 2012; Juma 2015). There are, however, huge differences between different Sub-Saharan African countries regarding the state of infrastructure. Some countries have a much better infrastructure stock, and some have a poorer one. For example, there is significant diversity in transportation infrastructure within Africa. In four countries, less than 20% of rural dwellers live less than 2 kilometers away from an all-season road (Somalia 15.2%, Gabon: 17.9%, Republic of Congo: 19.1%, and South Sudan: 19.4%). Other Sub-Saharan African countries perform much better (Mauritius: 96.9%, Seychelles: 92.5%, Cape Verde: 83,8%, and Rwanda: 80.9%) (Azavea 2022). Another example is power infrastructure: less than 15% of the population has access to electricity in four countries (South Sudan: 7.4%, Chad: 11.1%, Burundi: 11.7%, and Malawi: 14.9%) while in others the whole (Seychelles: 100%) or almost the whole population (Mauritius: 99.7%, Cabo Verde: 94.2%, Gabon: 91.6%) has (The World Bank 2022a). The same applies to other kinds of infrastructure. Hence, there is enormous diversity within Sub-Saharan Africa regarding the infrastructure stock.

1.1.4 Determinants of Infrastructural Development

Researchers have outlined two main reasons for the immense intra-African differences in the infrastructure stock and the poor state of African infrastructure: access to finance and infrastructure governance. Many countries have an infrastructure backlog caused by under-investment in new infrastructure and insufficient maintenance of existing infrastructure in the last decades (African Monitor 2012; Corrigan 2017). The World Bank estimated in 2010 that Sub-Saharan African countries would need to invest 93 billion US$ annually to ensure a reasonable quantity, quality, and reliability of infrastructure (Foster and Briceno-Garmendia 2010). The actual investments amounted to only 45 billion US$ per year in 2010 and fell short of the required investments by 48 billion US$ (Calderón, Cantu, and Chuhan-Pole 2018). In a more recent calculation in the year 2018, the African Development Bank estimated that the financing gap has become even more extensive: It calculates the investment needs to be 130-170 billion US$ per year and the financing gap to be 68-108 billion US$ (AfDB 2018). Thus, there is a huge financing gap, which has grown bigger in the last decade. It must be noted, however, that there are significant differences within Africa: some countries have no or only a tiny financing gap, and others have enormous financing gaps. Additionally, there are differences in the financing gap between different kinds of infrastructure. ICT infrastructure investments are attractive for the private sector and hence, receive sufficient funding. For transportation infrastructure, the existing investments cover the needs reasonably well. There is significant under-investment in power and water infrastructure, though (Corrigan 2017).

The issue of finance has received much attention in the last twenty years. Attention is, however, increasingly shifting to the issue of infrastructure governance. An emerging school of thought stresses the importance of good infrastructure governance and claims that poor infrastructure governance is the main reason for the financing gap and the inadequate state of infrastructure in Africa. Borrowing from the United Nations Development Programme (UNDP), governance can be defined as "the exercise of economic, political, and administrative authority to manage a country's affairs at all levels. It comprises mechanisms, processes, and institutions through which citizens and groups articulate their interests, exercise their legal rights, meet their obligations, and mediate their differences." (UNDP 1997, 2–3). The World Bank defines governance as the "manner in which power is exercised in the management of a country's economic and social resources for development" (The World Bank 1992, 1). Governance depends to a large extent on the nature and quality of institutions. Good governance consists of several aspects: transparency, accountability, the rule of law, efficiency, responsiveness, equity, consensus, and inclusion (UNESCAP 2009). Therefore, good infrastructure governance is the governance of the infrastructure stock of a country incorporating all aspects of good governance (OECD 2017a).

The emerging 'infrastructure governance' school of thought underlines the importance of governance for tapping into private sector investments. African governments do not have sufficient resources to finance overcoming the infrastructure deficit. Therefore, they are trying to tap into donor aid and, i.e., private capital (Turley and Uzoski 2018). The private sector, however, invests more in countries with better infrastructure governance. Sound sector strategies and regulatory frameworks, a proper macroeconomic environment, and the creation of incentives are crucial for incentivizing private investments (Lakmeeharan et al. 2020). Additionally, some aspects of infrastructure are unattractive to the private sector and need to be financed and provided by the government due to their public good nature (African Monitor 2012). Up to now, the public sector funds more than half of Africa's infrastructure (Foster and Briceno-Garmendia 2010). Good governance of public infrastructure ensures low costs and high quality (Corrigan 2017; Schwartz et al. 2020). Furthermore, the government needs to ensure the quality and reliability of both public and private infrastructure to prevent disruption and outages. This includes appropriately maintaining existing infrastructure (Hallegatte, Rentschler, and Rozenberg 2019). Governments must ensure that the infrastructure allocation is efficient and matches the population's and economy's needs, too (Graff 2018). A government will fulfill these roles well if there is good infrastructure governance. Hence, the quantity, quality, and reliability of infrastructure depend to a large extent on infrastructure governance. Moreover, since agricultural development depends mainly on infrastructure's quantity, quality, and reliability (Hallegatte, Rentschler, and Rozenberg 2019), infrastructure governance is likely to be a strong determinant of agricultural development.

1.2 Research Problem

Numerous studies stress the importance of infrastructure for agricultural development in Africa (Gajigo and Lukoma 2011; Juma 2015; Pinstrup-Andersen and Shimokawa 2008). Scholars agree that infrastructure's quality, quantity, and reliability significantly shape agricultural growth. During the last decades, the causal mechanisms have been analyzed in-depth. The findings of this research on infrastructure and agricultural development (Juma 2015; Pinstrup-Andersen and Shimokawa 2008) have been implemented in policies and development frameworks. For example, the CAADP has dedicated one of its four pillars to rural infrastructure (NEPAD 2009). This illustrates the importance of infrastructure for agricultural development. Contrary to the literature on the importance of infrastructure for agricultural development, the literature on infrastructure governance is still in the fledgling stage. Before the year 2015, infrastructure governance received relatively little scholarly attention. This has changed. Multilateral institutions like the World Bank (Hallegatte, Rentschler, and Rozenberg 2019), the International Monetary Fund (IMF) (Schwartz et al. 2020), and the Organisation for Economic Co-operation and Development (OECD) (2017b), think tanks like the South African Institute of International Affairs (Corrigan 2017), and the scholarly community (Akanbi 2013; Edomah, Foulds, and Jones 2016; Graff 2018; Ruiters and Matji 2015) have all stressed the importance of infrastructure governance. According to this school of thought, a government cannot deliver sufficient, reliable, and high-quality infrastructure at low costs without good infrastructure governance.

Despite the increasing interest in infrastructure governance, there is a lack of data. The OECD conducted a study and generated data on the quality of infrastructure governance among its member states (OECD 2022). No African country is an OECD member; hence, there is no data on Sub-Sahara Africa. The IMF is conducting 'Public Investment Management Assessments' (PIMAs). These are in-depth qualitative analyses of the infrastructure governance of a specific country and suggestions on how to improve it (IMF 2022). PIMAs do not generate statistical data useful for cross-country analyses, however. Hence, there is no index measuring the quality of infrastructure in African countries, making it impossible to compare different countries' infrastructure quality or conduct quantitative cross-country studies with infrastructure as either a dependent or independent variable. Therefore, infrastructure governance as a concept itself has been studied in detail, but few studies have analyzed its relationship to other concepts. There is a lack of data for infrastructure governance in general and specific kinds of infrastructure governance. No index measures the quality of transportation, water, power, and ICT infrastructure governance. Different infrastructure governance types must be analyzed separately due to their distinct features. For example, transportation infrastructure is usually a public good and needs to be managed in another way than ICT infrastructure, which is a private good (Bartlett 2017). Analyzing the causes and effects of specific kinds of infrastructure governance is impossible without data measuring their quality, though.

Because of this lack of data on infrastructure governance and specific kinds of infrastructure governance, little research has been conducted on the effect of infrastructure governance on agricultural development in Sub-Saharan Africa. One recent exception is a study by Amuakwa-Mensa and Surry (2022) on the impact of power infrastructure governance on agricultural development. They claim that the effect of rural electrification on agricultural development is conditional on the quality of institutions and conclude that the governance of the power sector is an essential determinant of agricultural development (Amuakwa-Mensah and Surry 2022). In the absence of data on infrastructure governance, they operationalize power infrastructure governance with an interaction term between the quality of power infrastructure and the quality of institutions, which is an unsatisfying operationalization. Besides this study, there is a lack of research on the relationship between infrastructure governance and agricultural development. This is puzzling. Due to the high importance of agriculture in Africa's development process, agricultural development and its determinant have been studied extensively. The importance of infrastructure for agricultural development is widely recognized and supported by numerous studies. Additionally, a new school of thought stressing the importance of infrastructure governance has emerged in the last few years. Institutions like the World Bank and the IMF back up this school of thought, which underlines its relevance. Little effort has, however, been taken to synthesize these two branches of literature. Incorporating the insights on infrastructure governance in analyzing the relationship between infrastructure and agricultural development would enhance the latter's understanding. There is a lack of research on the causal relationship between infrastructure governance and agricultural development in Sub-Saharan Africa, though. This research gap is the research problem to be addressed in this thesis.

Furthermore, insufficient efforts have been undertaken to understand the effect of the quality of governance of specific aspects of infrastructure on agricultural development (except for the study on power infrastructure governance and agricultural development by Amuakwa-Mensa and Surry (2022)). The causal relationship between infrastructure governance and agricultural development depends on the type of infrastructure due to differences in how different kinds of infrastructure are provided and financed. Infrastructure with public good characteristics needs to be financed by the public sector and hence, the government is responsible for every step of the infrastructure provision. Private good infrastructure can be provided by the private sector and hence, requires different infrastructure governance. Hence, different kinds of infrastructure governance contribute to agricultural development differently and must be examined separately. The mechanism in which distinct kinds of infrastructure governance influence agricultural development has, however, not been studied sufficiently; there is a research gap. Analyzing the effect of the quality of governance of specific aspects of infrastructure (transportation, power, water, and ICT) on agricultural development contributes to understanding the factors driving agricultural development. A reason for this research gap is the lack of data on the quality of governance of specific aspects of infrastructure. In summary, the research problem to be addressed is a research gap: the relationship between infrastructure governance (and different types of infrastructure governance) and agricultural development has not been studied sufficiently due to a lack of data on the quality of infrastructure governance. This decreases the understanding of the factors driving agricultural development. Due to the importance of agriculture in the development process, the research problem is influential for development studies.

1.3 Research Questions

1.3.1 General research question

How does infrastructure governance influence agricultural development in Sub-Saharan Africa?

1.3.2 Specific research questions

1) How does transportation infrastructure governance influence agricultural development in Sub-Saharan Africa?

2) How does power infrastructure governance influence agricultural development in Sub-Saharan Africa?

3) How does water infrastructure governance influence agricultural development in Sub-Saharan Africa?

1.4 Research Objectives

1.4.1 General research objective

To examine the causal relationship between infrastructure governance and agricultural development in Sub-Saharan Africa.

1.4.2 Specific research objectives

1) To examine the causal relationship between transportation infrastructure governance and agricultural development in Sub-Saharan Africa.

2) To examine the causal relationship between power infrastructure governance and agricultural development in Sub-Saharan Africa.

3) To examine the causal relationship between water infrastructure governance and agricultural development in Sub-Saharan Africa.

1.5 Justification

This thesis's relevance for academic and development discourse originates from the mentioned research gaps: a lack of data on infrastructure governance and insufficient research on the causal relationship between infrastructure governance and agricultural development in Sub-Saharan Africa. In the last few years, academic and development stakeholders have emphasized the importance of infrastructure governance. A recent IMF publication shows that the benefits of improved infrastructure governance include higher outputs, more stable flows of investment, lower costs, and less corruption (Schwartz et al. 2020). A World Bank paper concludes that better infrastructure governance leads to a higher quality and reliability of infrastructure (Hallegatte, Rentschler, and Rozenberg 2019). Additionally, good infrastructure governance increases private sector investments (Lakmeeharan et al. 2020). Therefore, better infrastructure governance leads to higher quality, quantity, and reliability and lower infrastructure costs for both public and private infrastructure (Corrigan 2017).

These new insights on the importance of infrastructure governance have not been incorporated into the literature on the relationship between infrastructure and agricultural development. This is puzzling, considering the importance of infrastructure governance. This thesis integrates insights into infrastructure governance into the analysis of the relationship between infrastructure and agricultural development. The quality of infrastructure governance is likely to have a substantial effect on agricultural development. This hypothesis has not been tested empirically due to a lack of data on infrastructure governance, though. An index measuring the quality of infrastructure governance (including the quality of transportation, power, and water infrastructure governance) of Sub-Saharan African countries is created. Subsequently, this index is used to conduct cross-country analyses on the causal relationship between infrastructure governance (and specific aspects of infrastructure governance) and agricultural development. This contributes to a more detailed understanding of the relationship between infrastructure and agricultural development. Additionally, it leads to a better comprehension of factors driving agricultural development. Hence, this thesis contributes to the academic discourse as well as the development discourse. Agriculture plays a decisive role in Africa's development. Agricultural development contributes to food security, poverty reduction, and general economic growth. Numerous initiatives, programs, development frameworks, and policies are aimed at strengthening agricultural development. These are based on and informed by the academia's insights on the factors driving agricultural development; hence, their success depends on understanding these factors. The insights on infrastructure governance have not yet been incorporated into the analysis of the relationship between infrastructure and agricultural development. Doing this improves the understanding of the factors driving agricultural development. How important is infrastructure governance for agricultural development? Furthermore, is governance more important for specific kinds of infrastructure than for others? For example, is transportation infrastructure governance more important than water infrastructure governance for agricultural development? These questions remain unanswered. Finding answers improves the theoretical and empirical understanding of the determinants of agricultural development. This contributes to improving the efficacy of policies and development programs aimed at agricultural development, as they are built on a more solid knowledge base. Therefore, this thesis contributes to development discourse and practice by improving the understanding of the determinants of agricultural development.

2 Literature Review

2.1 Theoretical Literature Review

The theoretical literature examines the existing literature on the causal relationship between transportation, power, water, and ICT infrastructure and agricultural development. Subsequently, the literature on the state of infrastructure in Sub-Saharan Africa is outlined to establish to which extent the potential contribution of infrastructure to agricultural development is fulfilled. Furthermore, the literature review elaborates on research on two critical determinants of the state of infrastructure: finance and governance. For all of this, general trends in Sub-Saharan Africa are examined. Nevertheless, it must be kept in mind that Sub-Saharan Africa is a very diverse region. The agricultural sectors of different countries have different levels of development and face other challenges. There are huge differences regarding the quality of infrastructure governance as well as the quantity, quality, and reliability of African countries' infrastructure stock, too.

2.1.1 Infrastructure and Agricultural Development

Researchers have been trying to show that differences in the quantity, quality, and reliability of infrastructure are related to different levels of agricultural development, as the former is claimed to have an impact on the latter. According to different studies outlined below, transportation, power, water, and ICT infrastructure all aid agricultural growth. Infrastructure benefits all agricultural sub-sectors (crop-yielding, livestock, and fisheries). Transportation infrastructure is necessary for good market integration, leads to low transaction costs, and influences the incentive structure experienced by farmers (Juma 2015). Importantly, scholars claim that roads are the most important kind of transportation infrastructure for agricultural development (Gajigo and Lukoma 2011; Juma 2015; Turley and Uzoski 2018). Due to the remoteness of most farms in Sub-Saharan Africa, i.e., the construction of feeder roads, which connect remote areas to the wider transportation network, is essential. Turley and Uzoski (2018) claim that the wider transportation network consisting of highways, railways, and ports is less important for agricultural development than roads. Juma (2015) asserts that the benefit-cost ratio of feeder roads is up to four times higher compared to highways. Therefore, this paper focuses on rural roads when talking about transportation infrastructure. A good road network is of tremendous importance for agricultural growth. Berg et al. (2017) argue that improvements in the transportation infrastructure lead to lower transport costs and better market integration. These enable farmers to access markets and obtain inputs. Improved access to roads increases the input usage of farmers for several reasons. Empirical evidence shows that lower transportation and reduced transaction costs decrease the prices of inputs (Liverpool-Tasie et al. 2017; Sadoulet and De Janvry 1995), which improves the profitability and prevalence of input usage (Dorosh et al. 2012; Stifel and Minten 2015). Additionally, good transportation infrastructure prevents input supply bottlenecks. Due to the importance of timing in agricultural production, a late application of inputs caused by delivery delays negatively affects yields (Stifel and Minten 2015). Xu et al. (2009) observed in a case study of the Zambian maize sector that the timely availability of fertilizer improves yields by 11 percent. Therefore, improved transportation infrastructure improves inputs' usage and efficiency, leading to higher agricultural productivity (Gollin and Rogerson 2010). Additionally to better access to markets, lower transaction costs due to improved transportation infrastructure improve farmers' access to markets. This influences the incentive structure faced by farmers. Several studies show that farmers will only be willing to invest in productivity-improving measures if they know they can sell their surplus produce at a good and stable price (Moser, Barrett, and Minten 2009; Pinstrup-Andersen and Shimokawa 2008). Well-integrated markets are important for "dampening the effects of localized and temporary demand and supply shocks" (Moser, Barrett, and Minten 2009, 292). Equalizing surpluses and shortages in nearby regions lead to price equalization and reduced price variability (Gajigo and Lukoma 2011), improving the planning security of farmers, which positively affects their willingness to invest. Furthermore, good transportation infrastructure, in combination with power and ICT infrastructure, improves farmers' access to credit, which improves their ability to invest (Llanto 2012). Therefore, better transportation infrastructure improves the profitability of investments in productivity-improving measures and their prevalence, leading to higher yields. Similarly, transportation infrastructure, in combination with power infrastructure, influences cropping choices. Stifel and Minten (2008) and Omamo (2007) note that farmers who have either poor access to markets (due to poor transportation infrastructure) or are unable to store their produce (which depends on power infrastructure that enables cooling) come to inefficient cropping decisions. They will favor storable food crops with low yields, such as staples or pulses, over significantly more profitable but more perishable crops, such as fruits or vegetables (Omamo 2007; Stifel and Minten 2008). Different studies have demonstrated the importance of power infrastructure for post-harvest storage, as it allows using electric cooling appliances. This is specifically relevant for poultry, livestock, and fish farms, milk farms, and farms producing highly perishable crops (Iimi and Smith 2007; Lee, Miguel, and Wolfram 2020; Lighting Global 2019). Hence, power infrastructure contributes to reducing post-harvest losses. Access to electricity enables using other electric tools, which improves agricultural productivity and output, according to Khandker and Koolwal (2010). Additionally, Peters and Sievert (2016) suggest that power infrastructure enables farmers to spend more time on their farms since electrification enables doing household chores in the evening or at night. Consequently, better power infrastructure improves agricultural labor productivity and contributes to agricultural development, as shown in empirical studies by Assunção et al. (2017) and Mundlack, Larson, and Butzer (2002).

Furthermore, power infrastructure, in combination with water infrastructure, is, according to Sims et al. (2015), an enabler of irrigation. Irrigation has numerous advantages compared to rain-fed agriculture. Irrigation raises productivity substantially. Empirical evidence shows that, on average, yields are two-fold (Dillon 2011; Rosegrant, Cai, and Cline 2002). It enables farmers to grow different crops with higher values and better nutrition (Juma 2015; Turley and Uzoski 2018). Irrigation decreases the dependence on rainfall. This is especially important due to climate change and increasing variability in rainfall patterns, which negatively affect the productivity of rain-fed agriculture (Mabhaudhi et al. 2018). Gajigo and Lukoma (2011) state that another disadvantage of rain-fed agriculture is strong seasonal fluctuations in supply as planting patterns follow the rainy season. Irrigation enables lower supply fluctuations. Therefore, better power and water infrastructure improve agricultural development by allowing irrigation. According to Iimi and Smith (2007), improved water infrastructure also contributes to the development of the livestock and milk sector since water is an essential input for animal drinking purposes. According to Lankford (2005), access to water is necessary for fish production, too. Furthermore, improving access to clean water increases agricultural labor productivity. Farmers enjoy better health and have more time to attend to their farms since they spend less time fetching water (Kiendrebeogo 2012).

The last kind of infrastructure, ICT infrastructure, is vital for obtaining information on markets (Kiiza and Pederson 2012; Zanello 2012), weather, and best practices (Juma 2015). This enables farmers to make more informed and better cropping decisions. Furthermore, ICT infrastructure enables precision farming. Precision farming includes collecting information on soil quality, humidity &

temperature, the presence of parasites or fungi, the efficiency of irrigation, and the growth of plants (Mungarwal and Mehta 2019). This information is used to ensure the precise and correct application of inputs (e.g., water, seeds, fertilizer, pesticides). According to Mungarwal and Mehta (2019), this ensures higher input efficiency, high productivity, and sustainability. Additionally, it contributes to market integration by enabling e-commerce. Farmers can obtain inputs and find markets online, which improves their profit margin, as stated by Juma (2015).

Notably, the different kinds of infrastructure are complementary. For example, financial inclusion and credit access depend on transportation and ICT infrastructure (Llanto 2012). Irrigation requires a connection to both water and power infrastructure (Sims et al. 2015) and farmers will only invest in irrigation systems if they are ensured access to markets, which requires good transportation infrastructure (Blackstone 2003). Access to information and extension services depends on transportation, power, and ICT infrastructure (Kiiza and Pederson 2012). Furthermore, according to Pinstrup-Andersen and Shimokawa, "deficiencies in transportation, energy, telecommunications, and related infrastructure translate into poorly functioning domestic markets with little spatial and temporal integration, low price transmission, and weak international competitiveness" (Pinstrup-Andersen and Shimokawa 2008, 2). Hence, many factors driving agricultural development require the presence of two or more kinds of infrastructure. Additionally, different types of infrastructure have multiplier effects. For example, Amuakwa-Mensah and Surry (2022) discovered in an empirical study that improved access to electricity enhances the positive impacts of other kinds of infrastructure. ICT infrastructure "can enhance the multiplier effects of a good road network" (Gajigo and Lukoma 2011, 3). Therefore, different kinds of infrastructure are complementary and mutually reinforcing. Providing farmers with one aspect of infrastructure but not the others has fewer positive effects on agricultural development than the provision of all of them. In summary, the literature states that the quantity, quality, and reliability of infrastructure (regardless of the kind of infrastructure) are important determinants of agricultural development and that the different types of infrastructure are complementary.

2.1.2 Financing Infrastructure

As stated in the background, the state of infrastructure in Sub-Saharan Africa is, however, relatively poor and its potential contribution is only to a relatively low extent fulfilled. Two schools of thought explain the rather poor state of infrastructure governance: the finance school and the governance school. The finance school of thought emerged in the early 2000s and gives insufficient access to finance as the main reason for the relatively low quality, quantity, and reliability of most African countries' infrastructure stock (African Monitor 2012; Corrigan 2017). It claims that there is an infrastructure backlog caused by under-investment in new infrastructure and insufficient maintenance of existing infrastructure in the last decades (Corrigan 2017; Turley and Uzoski 2018). According to the AfDB (2018), Africa would need annual investments of 130-170 billion US$ per year to overcome the backlog. There is, however, an annual financing gap of approximately 68-108 billion US$. There are significant differences regarding finance within Africa and between different kinds of infrastructure, though. This school of thought has analyzed different potential sources of finance (the public sector, the private sector, development banks, bilateral investments, and official development assistance (ODA)) and how they can improve infrastructure finance. Historically, public investments have made up the bulk of infrastructure financing. Up to today, governments undertake more than half of the investments in infrastructure (Calderón, Cantu, and Chuhan-Pole 2018). A reason for this is the public good character of many kinds of infrastructure, which makes private provision difficult. Due to their non-rivalrous nature and positive externalities, public goods are undersupplied by the market and hence, need to be provided by the government. Therefore, financing public goods with private investments is difficult (Bartlett 2017). Many kinds of infrastructure are public goods. Roads (except for toll roads), water dams, and water reservoirs are typical examples of public goods. They are non-excludable and non-rivalrous. Power and water transmission and distribution systems have some characteristics of public goods and are difficult to privatize. These types of infrastructure need to be financed by the public sector (Bartlett 2017). Other kinds of infrastructure are not public goods and can be financed by the private sector. For example, power production can be privatized. Independent power providers (IPPs) can invest in power plants and sell their power directly to the public or a public power distribution company. The latter is more common as power transmission and distribution systems are difficult to privatize. ICT infrastructure is not a public good; one can easily exclude users from using it. Therefore, it is attractive to the private sector and the government does not have to provide it. Therefore, ICT is the only type of infrastructure without a financing gap (Corrigan 2017). Additionally, private investments in transportation infrastructure (i.e., in toll roads) have increased recently. Toll roads are not public goods, as they are excludable. Hence, private investments are feasible. Therefore, several types of infrastructure are not public goods and private investments are a feasible financing option (African Monitor 2012). According to a McKinsey study, private investments have risen in the last few years and have tremendous growth potential (Lakmeeharan et al. 2020). They are usually conducted in Public-Private Partnerships (PPPs). As of 2022, PPPs make up only a relatively small share of infrastructure investments in Sub-Saharan Africa, though. Additionally, they are highly concentrated. Almost half of all PPPs in Sub-Saharan Africa are in four countries (South Africa, Nigeria, Kenya, and Uganda), which are particularly attractive to the private sector and hence, have smaller financing gaps and a better infrastructure stock (Calderón, Cantu, and Chuhan-Pole 2018). Development banks usually focus on large-scale (often cross-border) projects but have a relatively small and decreasingly important role in infrastructure financing (Corrigan 2017). Contrarily, bilateral investments have gained relevance in the last years due to the increasing Chinese investments, i.e., in transportation infrastructure (African Monitor 2012). Traditionally, ODA has been used to finance the infrastructure necessary for human development (e.g., water and sanitation infrastructure) (African Monitor 2012). ODA's approach to infrastructure has changed in the last few years, though. Addison and Anand (2012) argue that ODA cannot fill the whole finance gap and should not attempt to do it, but it should increase private investments by decreasing risks (Addison and Anand 2012). Many policymakers, development institutions, and think tanks have taken up this idea of using ODA to attract other sources of finance (Turley and Uzoski 2018).

2.1.3 Infrastructure Governance

The finance school of thought has, however, lost momentum. The relatively new infrastructure governance school of thought stresses that the amount of money available is less significant than how it is used and has shown that "funding is no longer the defining problem" of infrastructure and that "administration has displaced funding as the central obstacle confronting infrastructure development" (Corrigan 2017, 38). Additionally, researchers have demonstrated that good infrastructure governance improves access to finance (Akanbi 2013; Lakmeeharan et al. 2020). Consequently, attention is shifting from finance to governance. The infrastructure governance school of thought analyzes how infrastructure governance influences the infrastructure's quality, quantity, and reliability. As mentioned above, most of Africa's infrastructure is still publicly financed. An IMF publication by Schwartz et al. (2020) claims that more robust infrastructure governance improves public infrastructure delivery. It comes to several conclusions: countries with better infrastructure governance have a higher output of infrastructure, higher spending efficiency, less volatile flows of investments, and less corruption (Schwartz et al. 2020). The publication presents empirical evidence that "more than one-third of resources are lost in the process of managing public investment" (Schwartz et al. 2020, 42) for public infrastructure. Low-income countries experience losses of up to 50%. On average, a country could reduce the loss of resources by more than 50% by improving its infrastructure governance. Emerging markets and low-income developing countries have the highest potential for improvement (Schwartz et al. 2020). A study by Kenny (2007) comes to similar conclusions. He claims that corruption, a symptom of poor infrastructure governance, increases costs, reduces quality, and lessens the economic returns of infrastructure investments. Hence, good infrastructure governance improves public infrastructure delivery by raising value for money (Kenny 2007). A World Bank report by Hallegatte, Rentschler, and Rozenberg (2019) illustrates that good infrastructure governance prevents corruption, too. Additionally, it demonstrates that better infrastructure governance contributes to higher quality and reliability of infrastructure and decreases the prevalence of disruptions and outages by ensuring proper maintenance of the existing infrastructure stock (Hallegatte, Rentschler, and Rozenberg 2019). Kenny (2007) indicates that governments are incentivized to underinvest in maintenance as the construction of new infrastructure projects has more opportunities for rent-seeking and corruption. Schwartz et al. (2020) add that politicians favor investing in new infrastructure projects over maintaining existing ones as the former has higher political visibility and hence, draws more political support. Moreover, maintenance is discretionary spending and is prone to be cut in times of crisis. Furthermore, countries with poor infrastructure governance tend to lack data on infrastructure maintenance needs, which contributes to underinvestment. Hallegatte, Rentschler, and Rozenberg (2019), Kenny (2007), and Schwartz et al. (2020) agree that good infrastructure governance ensures the availability of sufficient funds for maintenance. This is important as maintenance improves the reliability of infrastructure (Hallegatte, Rentschler, and Rozenberg 2019) and is much cheaper than investing in new infrastructure (Schwartz et al. 2020). Corrigan (2017) adds that "the neglect of maintenance has been a major contributor to the dysfunctionality of much of Africa's infrastructure" (Corrigan 2017, 8). In summary, the literature states that good infrastructure governance leads to a higher quantity, quality, and reliability of public infrastructure by improving value for money, decreasing the prevalence of corruption, and ensuring proper maintenance.

Infrastructure governance is crucial not only for publicly funded infrastructure but also for infrastructure investments by the private sector and ODA. According to Collier and Dehn (2001) and Moss (2005), ODA has much higher economic returns in the context of good governance and strong institutions. Hence, good infrastructure governance improves the effectiveness of ODA investments in infrastructure. Turley and Uzoski (2018) add that an increasing number of donors invest only in countries with good governance. Hence, good infrastructure governance is likely to lead to more ODA and improve its effectiveness. This effect is even more substantial for private investments. Some scholars believe private investments to be the future of financing infrastructure, as rising debt rates constrain public infrastructure spending (Lakmeeharan et al. 2020). Private investments, however, have not risen as much as anticipated in the last few years. A McKinsey study by Lakmeeharan et al. calls this Africa's infrastructure paradox: international investors (i.e., investment companies and private-sector pension funds) are very interested in financing African infrastructure projects. In cooperation with governments, investors explore many investment opportunities. 80% of the projects are canceled at the feasibility or business plan stage, though, and only 10% of the considered projects reach financial closure (Lakmeeharan et al. 2020). In summary, Lakmeeharan et al. describe a scenario in which funding is available, spending is needed, and project ideas are plenty, but insufficient investments happen. According to them, this is caused by poor infrastructure governance. More specifically, the leading cause for failure at the feasibility or business plan stage is a lack of public long-term plans and policy frameworks regarding infrastructure but relatively short political cycles with changing agendas. This makes long-term planning difficult for investors and decreases their willingness to invest in projects with long payback periods. Additionally, the study names poor management and mitigation of political, currency, and regulatory risks as a hindrance to infrastructure development in many African countries. This is related to often unclear legal and regulatory frameworks, which reduce the extent to which revenues are guaranteed. Furthermore, Lakmeeharan et al. (2020) state that insufficient public capacity is a problem leading to delays in obtaining licenses, approvals, and permits. Similarly, Heathcote (2018) claims that the rule of law is the most important determinant of private infrastructure investments. Carrasco et al. (2021) stress the importance of good infrastructure governance for tapping into private investments, too. Therefore, countries with better infrastructure governance are more attractive to the private sector, which explains why PPPs in Africa are concentrated in very few countries. Hence, good infrastructure governance can be a solution to the financing gap. Additionally, Carrasco et al. (2021) claim that good infrastructure governance improves the investment efficiency of PPPs by improving value for money and the risk-return profile. They stress the importance of an excellent legal and regulatory framework, a high public capacity, sound risk management, and long-term infrastructure planning for the success of PPPs (Carrasco et al. 2021). Empirical evidence by Smith (2003) shows the importance of good infrastructure governance to prevent corruption and rent-seeking, even in the context of privatization. In Malaysia, IPPs, whose owners were friends of the cabinet secretary in charge and which were authorized in noncompetitive tendering, sold power up to 50% more expensive than public power plants, and due to poor contracts, the public power provider was forced to buy it at this cost (Smith 2003). Hence, he stresses that private infrastructure requires good infrastructure governance to be efficient. In summary, the literature notes the importance of good infrastructure governance for tapping into private investments and improving the quality and value for money of private investments. Therefore, the concept of infrastructure governance is likely to explain why some African countries have a considerable financing gap regarding infrastructure and others do not.

According to Corrigan (2017), good infrastructure governance is also essential to ensure that the infrastructure stock matches the needs of the population and the economy for it to contribute to development. To achieve this, he stresses the importance of accountability and participation in planning processes. After conducting an empirical analysis, Graff (2018) concludes that the distribution of Africa's transportation infrastructure is inefficient, unequally allocated, and does not match the needs, which reduces its potential welfare gains. He claims that poor infrastructure governance leading to regional favoritism is an important reason for this. Lakmeeharan et al. (2020) stress the importance of long-term sectoral planning incorporating the infrastructure needs to ensure that a country's infrastructure stock has the highest possible welfare gains. Public participation is not only important to obtain information, but public participation in the construction, management, and maintenance can also be beneficial, i.e., for rural feeder roads, an important aspect of transportation infrastructure. (Turley and Uzoski 2018). Localization decreases costs and increases the life cycle of rural roads (Corrigan 2017). In summary, the literature notes that better infrastructure governance improves public infrastructure's quantity, quality, and reliability by improving value for money, decreasing the prevalence of corruption, and ensuring proper maintenance. Additionally, it increases private investments, improves the quality and value for money of private investments, and ensures that a country's infrastructure stock matches the needs of its population and economy.

As stated in the first chapter, little effort has been undertaken to incorporate insights on infrastructure governance into the research on the relationship between infrastructure and agricultural development. One exception is a recent study by Amuakwa-Mensah & Surry (2022) on electrification, governance, and agricultural output. In an empirical study, they found out that the effect of electrification on agricultural development is conditional on the quality of governance. They state that the relationship between infrastructure, governance, and agricultural development has been under-investigated (Amuakwa-Mensah and Surry 2022).

2.2 Empirical Literature Review

The empirical literature review summarizes the research strategies and methods used in the literature on infrastructure and agricultural development. Most studies on this topic are based on positivist ontology and epistemology and utilize quantitative methods. There are two different common research approaches: case studies and cross-country analyses. Case studies analyze the effect of infrastructure on agricultural development in one country or one region of a country. They usually utilize survey data. For example, Stifel and Minten (2015) conducted a household survey in a relatively homogenous region in northwestern Ethiopia to analyze whether better road access leads to changes in agricultural production. They also conducted a study with a similar research strategy in Madagascar (Stifel and Minten 2008). Zanello (2022) conducted a comparable household survey on ICT usage and market transaction to establish the importance of ICT infrastructure for obtaining market information. To rule out reverse causality, Khandker and Koolwal (2010) conducted a panel survey studying the power infrastructure's effect on agricultural growth in Bangladesh. Dzanku and Sarpong (2010) also used data provided by a panel survey to analyze the effect of infrastructure availability on cropping decisions by farmers in Ghana. Assunção et al. (2017) used five waves of the Brazil Agricultural Census to study the same. Besides these studies based on survey or census data, a few other studies follow different research designs. For example, Moser et al. (2009) conducted a study in Madagascar on the effect of transportation and communication infrastructure on market integration. They collected data on rice prices and infrastructure availability in 1400 communes to check whether price differentials are caused by poor infrastructure or other factors. Lee, Miguel, and Wolfram (2020) conducted a field experiment to analyze the impact of electrification on agricultural production: they randomly selected rural households in Kenya, connected them to the grid, and compared these households to nearby households without access to the grid. Nevertheless, most case studies on the effect of infrastructure on agricultural development utilize survey data. Case studies are usually used for building theory on the causal relationship between infrastructure and agricultural development.

Most cross-country analyses of the impact of infrastructure on agricultural development conduct agricultural production functions to calculate the effect of different factors on agricultural development. A few papers follow different research designs, though. For example, Dorosh et al. (2012) created a data set on road connectivity using geographic information systems. They computed the effect of road connectivity on crop output and productivity utilizing spatial regression analyses. The units of analysis were ten-by-ten-kilometer big parcels of land. Iimi and Smith (2007) and Iimi (2007) conducted three-stage least squares techniques to calculate two sector-specific (coffee and livestock, respectively) supply and demand functions. They used these to estimate the importance of different kinds of infrastructure for the ability to export coffee and livestock at lower prices, which improves international competitiveness. Due to the importance of international markets for the two sectors, they decided not to conduct production functions. Supply and demand functions are relatively similar to production functions but include market characteristics, too. Another difference is that supply and demand functions are crop specific. The most common approach to computing the effect of infrastructure on agricultural development is to conduct a production function, though. Usually, five factors of production are considered: labor, land, fertilizer, irrigation, and infrastructure. Almost always, the dependent variable is either agricultural output or agricultural labor productivity. For example, Llanto (2012) conducted an agricultural production function. He computed the effect of wages (as a proxy for labor), the prevalence of irrigation, and access to shared roads and electricity (as proxies for transportation and power infrastructure) on agricultural labor productivity. Fan and Rao (2003) computed an agricultural production function to compute the impact of agricultural government expenditure on agricultural output. Besides government expenditure on agriculture, they included labor, land, fertilizer, machinery, draft animals, irrigation, road density, and literacy rate. The dependent variable was agricultural output. Iimi et al. (2015) conducted several production functions to compute the relevance of different factors of production in agricultural production. Besides road and market accessibility as two different proxies for the quality of transport infrastructure, they also included the concepts of land and labor and the prevalence of irrigation and fertilizer usage as proxies for access to technology. Their dependent variable was agricultural output. Agricultural production functions are usually used for testing theory on the causal relationship between infrastructure and agricultural development.

Different scholars have stated one common problem in agricultural production functions examining the impact of infrastructure on agricultural development: the operationalization of infrastructure (Calderón 2009; Calderón and Servén 2004; Iimi et al. 2015). The underlying problem is a "high degree of correlation among measures of infrastructure asset types (such as telecommunications, electricity-generating capacity, road and railway networks, and water and sanitation, among others)" (Calderón 2009, 2). Countries with good transportation infrastructure also tend to have good power and water infrastructure. The high degree of correlation makes including measures of different kinds of infrastructure in one agricultural production function difficult, as such functions are unlikely to obtain reliable and robust estimates (Calderón and Servén 2004). Some studies solve this problem by having a broad theoretical view of infrastructure but operationalizing it with a single kind of infrastructure (usually transportation infrastructure). According to Calderón (2015), this is a poor solution as this operationalization leads to measurement errors. Another solution could be to have a theoretical focus on one kind of infrastructure stock. For example, one could study the effect of transportation infrastructure on agricultural development and exclude power, water, and ICT infrastructure. According to Calderón and Servén (Calderón and Servén 2004), this is a better solution. Due to the complementarity and mutual reinforcement of different kinds of infrastructure stocks, it is nevertheless not perfect. Calderón (2009) and Calderón and Servén (2004) conclude that the best solution is to create an aggregate index including all kinds of infrastructure stock. Failing to do this is a shortcoming of many agricultural production functions analyzing the effect of infrastructure on agricultural development.

As stated in the first chapter, the research on the relationship between infrastructure and agricultural development has neglected infrastructure governance. One exception is a recent study by Amuakwa-Mensah & Surry (2022) on electrification, governance, and agricultural output in which they conducted agricultural production functions, too: one with agricultural output and one with agricultural labor productivity as the dependent variable. Labor, capital, land, electrification, the quality of institutions, temperature, and rainfall were included as independent variables. They included temperature and rainfall to account for climate differences, a factor neglected in most agricultural production functions. Since this production function includes electrification and governance (operationalized as the quality of institutions) but not power infrastructure governance, they computed another model with an interaction term between electrification and governance (Amuakwa-Mensah and Surry 2022). Due to the lack of data on infrastructure governance, they had to choose this indirect way of including power infrastructure governance.

2.3 Point of Departure

In summary, the theoretical literature states that the quantity, quality, and reliability of a country's infrastructure stock (regardless of the kind of infrastructure) is an important determinant of agricultural development and that different kinds of infrastructure are complementary. Additionally, an emerging school of thought is raising the importance of infrastructure governance. It demonstrates that the quality of infrastructure governance is a critical determinant of the quantity, quality, and reliability of the infrastructure stock of a given country. The two bodies of literature have not been combined yet, though. The empirical literature review indicates which methodologies are most suitable for examining the relationship between infrastructure and agricultural development: surveys for theory-building case studies conducted within a country and agricultural production functions for theory-testing cross-country comparisons. Agricultural production functions analyze the causal relationship between the variable of interest and agricultural development while controlling for agricultural production factors. Hence, the independent variable is the variable of interest (and thus, is always different), agricultural development operationalized as either agricultural output or agricultural labor productivity is always the dependent variable, and factors of agricultural production such as land, labor, capital, and sometimes access to technology, temperature, and rainfall are always included as control variables.

To summarize the literature review, there is a variety of theoretical and empirical literature on the relationship between infrastructure and agricultural development. Much theoretical literature has been written on infrastructure governance, which has emerged as a new school of thought. There is, however, a lack of data on infrastructure governance and hence, only little empirical literature. Furthermore, the insights on infrastructure governance have not yet been incorporated into the literature on the relationship between infrastructure and agricultural development. This is puzzling, as agriculture is an important component of Africa's development process, and the importance of infrastructure for agricultural development is widely recognized and supported by numerous studies. Incorporating infrastructure governance in the analysis of the relationship between infrastructure and agricultural development would further enhance the latter's understanding. In summary, there are two related research gaps: a lack of data on infrastructure governance and a lack of research on the causal relationship between infrastructure governance and agricultural development. This study solves both research gaps by creating data on infrastructure governance and incorporating the relatively new infrastructure governance school of thought's findings into the analysis of agricultural development. This improves the theoretical and empirical understanding of agricultural development's determinants, which is beneficial to the development discourse. Additionally, development practice benefits from these insights as they improve the knowledge base on which policies and development programs aimed at agricultural development are built.

2.4 Conceptual Framework

2.4.1 Infrastructure Governance

In this chapter, the two key concepts of infrastructure governance and agricultural development are briefly conceptualized and the linkages between the two are elaborated. As mentioned above, governance can be defined as the "manner in which power is exercised in the management of a country's economic and social resources for development" (UNDP 1997, 2–3). Good governance consists of several aspects: transparency, accountability, the rule of law, efficiency, responsiveness, equity, consensus, and inclusion (UNESCAP 2009). Good infrastructure governance is the governance of a country's infrastructure stock, incorporating all aspects of good governance (OECD 2017a). More specifically, the OECD defines infrastructure governance as "a range of processes, tools and norms of interaction, decision making and monitoring used by governments and their counterparts providing infrastructure services" (UNESCAP 2009). They add that it encompasses interactions within and between government institutions but also with the private sector and citizens. Buyana and Lwasa (2017) define it as "the multiple ways in which state and non-state practices articulate– or not – with formalized norms, regulations, and policy instruments for the delivery of transport, sanitation, water, recreation, and other [...] facilities" (Buyana and Lwasa 2017, 325). Hence, infrastructure governance consists of different aspects: a sector strategy, the institutional and regulatory framework, the actual practice, public capacity, and public participation. The sector strategy lays out a strategic vision for the infrastructure sector. It must be embedded in the general development plan and consider fiscal capacities. Based on this, the sector strategy elaborates on which needs regarding infrastructure the population and the economy have and which projects are prioritized. It is important for private investors as it enables long-term planning on their side (OECD 2017b). The institutional and regulatory framework consists of laws, regulations, legally binding targets, and institutional responsibilities. A proper framework guarantees returns, reduces operational risks, and ensures infrastructure investments' commercial viability. It improves the certainty regarding revenue flows such as tariffs and user charges and other sources of funding like subsidies. Additionally, it helps to avoid delays in obtaining licenses, approvals, and permits (Carrasco et al. 2021; Lakmeeharan et al. 2020). These factors are essential for increasing the willingness of the private sector to invest in, maintain and upgrade infrastructure.

A sound institutional and regulatory framework is also vital for public infrastructure projects. These are particularly vulnerable to threats to integrity, such as corruption and rent-seeking. A good framework contributes to preventing this, but practice and the implementation of the regulatory and institutional framework are just as important as the framework itself (Schwartz et al. 2020). To a large extent, this depends on public capacity: the government's skills, abilities, resources, and willingness to perform its functions. Public capacity is most important in project development, preparation, risk management, and mitigation (Lakmeeharan et al. 2020). Public capacity and, i.e., sound monitoring systems are also crucial for ensuring infrastructure maintenance (Hallegatte, Rentschler, and Rozenberg 2019). Public participation and the consideration of various interests guarantee to get good information about the needs of the economy and the population, which informs the planning and prioritization of projects. Additionally, public participation enhances the legitimacy of projects and improves accountability (Corrigan 2017). Good infrastructure governance means completing these functions by incorporating transparency, accountability, the rule of law, efficiency, responsiveness, equity, consensus, and inclusion (UNESCAP 2009).

2.4.2 Agricultural Development

Agricultural development is more straightforward to conceptualize than infrastructure governance. It describes the process of equitable growth in the agricultural production of a country (Diao et al. 2007). Agricultural production consists of crop-yielding, breeding livestock, and fisheries. A country can achieve agricultural production growth in two ways: firstly, by increasing the factors of production used (e.g., by increasing the size of the agricultural land or the agricultural labor force) or secondly, by improving the agricultural productivity (improving the yields per factor of production ratio). Agricultural productivity growth usually refers to increases in labor and land productivity. Historically, yield increases in Africa have been mainly attributed to expansions in the land under cultivation or by increasing the agricultural labor force (Rosegrant, Cai, and Cline 2002). Improving productivity has more positive consequences than increasing agricultural land or the agricultural labor force, though. Productivity growth leads to lower production costs, higher profitability, higher incomes of farmers, improved international competitiveness, and lower costs of food (depending on the price elasticity of demand and tradeability). Increasing the land under cultivation or the agricultural workforce does not lead to these positive consequences. Therefore, increasing agricultural output through productivity improvements has a better developmental impact than increasing the factors of production used (Pinstrup-Andersen and Shimokawa 2008). Importantly, agricultural growth should be equitable to qualify as agricultural development. This means that a large share of the agricultural population should benefit from it. The same applies to the livestock and fisheries sectors: output growth can be achieved with or without productivity growth.

2.4.3 Causal Relationship between Infrastructure Governance and Agricultural Development

Infrastructure governance impacts agricultural development by influencing the infrastructure stock's quantity, quality, and reliability of a country. The precise mechanism depends on the kind of infrastructure due to differences in how different kinds of infrastructure are provided and financed. Infrastructure with public good characteristics needs to be financed by the public sector and hence, the government is responsible for every step of the infrastructure provision. Private financing is feasible for other kinds of infrastructure; hence, the government only regulates and encourages private service delivery. For example, ICT infrastructure is a private good. Hence, there is a high degree of privatization (Bartlett 2017). Most African countries have no financing gap regarding ICT infrastructure as the private sector provides sufficient investments. Countries with poor ICT infrastructure governance tend to be unable to attract sufficient private investments nevertheless (African Monitor 2012). Therefore, the role of the government is to ensure sufficient quantity, good quality, high reliability, and low costs of private ICT infrastructure delivery. ICT infrastructure governance includes providing a sound regulatory and institutional framework for the ICT sector and properly implementing this framework (Carrasco et al. 2021; Lakmeeharan et al. 2020). Good ICT infrastructure governance contributes to agricultural development by improving farmers' access to information on markets, weather, and best practices, enabling precision farming, and aiding farmers' market integration and financial inclusion.

Transportation infrastructure governance is likely to be an essential determinant of agricultural development. Transportation infrastructure only contributes to agricultural development when it matches the population's and economy's needs (Graff 2018). Spatial inefficiencies decrease its potential contribution. A sound sector strategy and proper implementation, an important aspect of infrastructure governance, ensures that the transportation infrastructure stock matches the population's and economy's needs. Furthermore, roads (except for toll roads) are public goods and hence, need to be financed and provided by the government. Infrastructure governance is highly important for public infrastructure delivery (Corrigan 2017). Good infrastructure governance improves value for money, decreases the prevalence of corruption, and ensures proper maintenance, leading to a higher quantity, quality, and reliability of public infrastructure (Schwartz et al. 2020). The reliability of public-funded transportation infrastructure is of particular importance, as, i.e., rural roads tend to be in a poor state due to insufficient maintenance (Mbabazi 2019). Privately financed toll roads are getting increasingly common. Similarly to ICT infrastructure, a proper institutional and regulatory framework is crucial to tap into private investments and improve the quality and value for money of private investments in toll roads (Lakmeeharan et al. 2020). Hence, infrastructure governance is essential for transportation infrastructure provided by both the private and the public sectors. Transportation infrastructure is crucial for agricultural development as it decreases transport and transaction costs, which leads to better and more stable access to inputs, finance, and markets, better cropping choices, more investments in productivity-improving measures or high-value crops, and less price fluctuation. This depends on the transportation infrastructure governance of a country, though, which is a strong determinant of the quantity, quality, and reliability of the transportation infrastructure stock. Hence, it is hypothesized that good transportation infrastructure governance contributes to agricultural development in Sub-Saharan Africa.

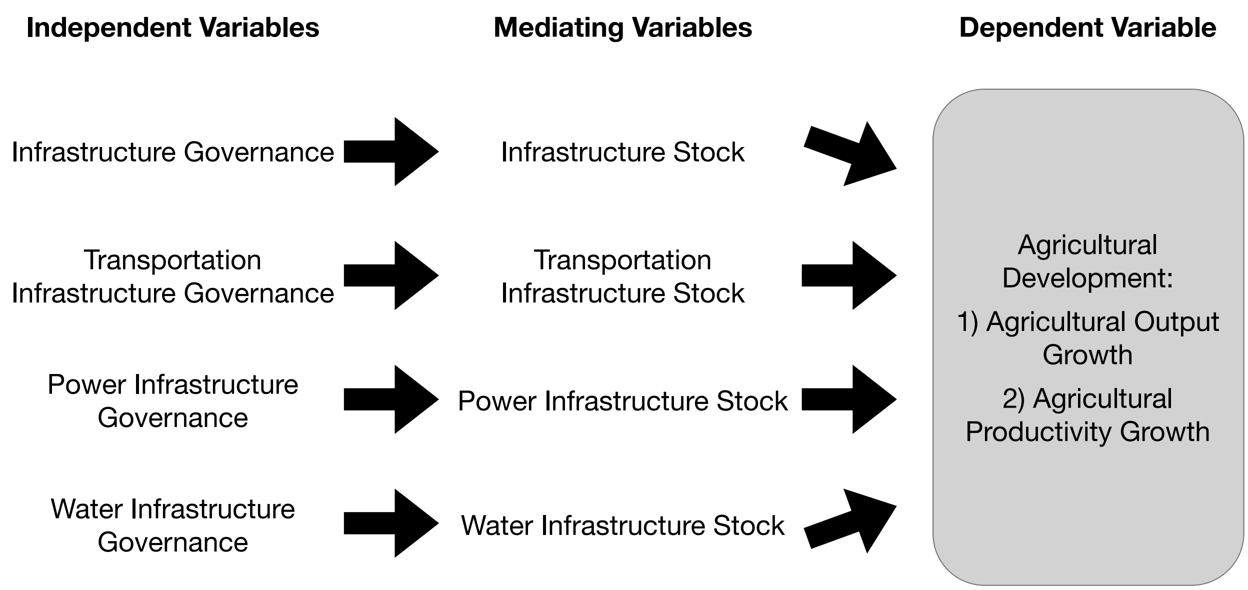
A huge financing gap characterizes the power infrastructure sectors in most African countries. Despite that, there is enormous potential for increased private sector engagement, as this sector is theoretically very interesting. Due to their public good nature, the government must provide power transmission and distribution systems and hereby ensure sufficient quantity, quality, and reliability at low costs. Other aspects are feasible for private investors, though. Power production can be privatized as the private sector can invest in IPPs. Additionally, it can provide off-grid solutions (e.g., solar home systems and microgrids). Governments should (in cooperation with development actors) nevertheless provide incentives or subsidies to make off-grid solutions commercially viable (Lighting Global 2019). Furthermore, private power provision is possible even though it comes with certain difficulties. For power provision, there are competing economic and developmental goals. Governments want to provide power access to as many people as possible and hence, want the power to be as cheap as possible. The private sector wants to make profits and, thus, wants power to be expensive as possible. If companies cannot recover their costs due to low tariffs, they will not invest. Setting power tariffs and pricing is, therefore, a politically tricky task and requires good infrastructure governance (Lakmeeharan et al. 2020). Privatizing power provision can still be beneficial in the presence of good power infrastructure governance. Generally, good infrastructure governance is needed to tap into private-sector investments. Differences in power infrastructure governance can explain different levels of private sector investments in power infrastructure among African countries (Edomah, Foulds, and Jones

2016). Additionally, it ensures better quality, reliability, and value for money of private investments. In the context of power infrastructure, reliability is of particular importance. Blackouts lead to substantial disruptions of agricultural activities dependent on power, such as cooling or irrigation (Hallegatte, Rentschler, and Rozenberg 2019). Infrastructure governance hence needs to ensure the reliability of both public and private power infrastructure. Better reliability of and higher access to power infrastructure depend on good power infrastructure governance and contribute to agricultural development by enabling irrigation and better storage of agricultural produce. This reduces post-harvest losses and serves as an incentive to invest in more perishable crops with higher values. Additionally, it improves labor productivity, as electricity enables farmers to spend more time on their farms. Therefore, it is hypothesized that good power infrastructure governance contributes to agricultural development in Sub-Saharan Africa.

Like power provision, water provision can be privatized, too. Solving the competing economic and developmental goals to ensure both affordability of power and cost-recovery of investments is a politically difficult task, which requires good governance (Ruiters and Matji 2015). Most water infrastructure needs to be provided by the government due to its public good character, though. This includes water dams, reservoirs, and transmission and distribution systems. Particularly the delivery of water dams and reservoirs requires good water infrastructure governance, as they are very vulnerable to corruption (Kenny 2007). Due to the critical role of the public sector in providing water infrastructure, good water infrastructure is needed to ensure a reasonable quantity, quality, and reliability of public water infrastructure at low costs. This is important for agricultural development, as water infrastructure enables irrigation, provides water, an essential input for fish production and the livestock sector, and improves labor productivity by improving the health and increasing the available time of farmers. Thus, it is hypothesized that good water infrastructure governance contributes to agricultural development in Sub-Saharan Africa.

As different kinds of infrastructure are complementary and mutually reinforcing (Gajigo and Lukoma 2011; Pinstrup-Andersen and Shimokawa 2008), different kinds of infrastructure governance are complementary and mutually reinforcing, too. Every single aspect of infrastructure governance is likely to have a positive effect on agricultural development. Aggregated, better infrastructure governance improves a country's infrastructure stock's quantity, quality, and reliability and enhances agricultural development. The precise mechanism depends on the kind of infrastructure. Therefore, it is hypothesized that good infrastructure governance contributes to agricultural development in Sub-Saharan Africa. *Figure 1* summarizes the conceptual framework and the theorized causal relationship in a schematic presentation. Furthermore, the hypotheses derived from the conceptual framework can be found below.

Figure 1: Schematic Presentation of the Conceptual Framework



Source: Illustration by author

2.5 Hypotheses

2.5.1 General hypothesis

Good infrastructure governance contributes to agricultural development in Sub-Saharan Africa.

2.5.2 Specific hypotheses

1) Good transportation infrastructure governance contributes to agricultural development in Sub-Saharan Africa.

2) Good power infrastructure governance contributes to agricultural development in Sub-Saharan Africa.

3) Good water infrastructure governance contributes to agricultural development in Sub-Saharan Africa.

3 Methodology

3.1 Research Design

This research project incorporates the theory on infrastructure governance into the analysis of agricultural development and tests whether three is a causal relationship between the two concepts in Sub-Saharan Africa. Hence, this research paper is theory-testing, confirmative, and deductive. For this purpose, a quantitative macro study is the most applicable research design, as such studies have a high external validity and generalizability. The most common theory-testing research design for analyzing the determinants of agricultural development are agricultural production functions. This research project follows suit and conducts agricultural production functions based on the Cobb-Douglas production function, the most used model of agricultural production functions, in which agricultural output is assumed to be the function of the factors of production (Iimi et al. 2015). The three most important factors of production, which are part of almost every agricultural production function, are land, labor, and capital. Many agricultural production functions include access to technology, too. This is usually operationalized as the prevalence of tractors or irrigation (Llanto 2012). Additionally, researchers are increasingly acknowledging the importance of temperature, rainfall, and other climate-related factors for agricultural production. Climate-related variables have, i.e., in the context of rain-fed agriculture, a substantial effect on agricultural output and productivity. Therefore, the climate is also included in many recent agricultural production functions (Amuakwa-Mensah and Surry 2022). Additionally, scholars usually include the variable of interest. Hence, agricultural production functions following the Cobb-Douglas model include land, labor, capital, access to technology, climate, and the variable of interest as independent variables. There are two options for the dependent variable: agricultural output and agricultural productivity. Using agricultural output as the dependent variable helps to understand which factors contribute to increasing agricultural output (regardless of whether it is caused by increased input usage or improved productivity). Using agricultural productivity as the dependent variable helps to understand which factors contribute to improving agricultural productivity (Amuakwa-Mensah and Surry 2022). Therefore, they are often computed complementarily, as both shed light on a different aspect of agricultural development. There are two important kinds of agricultural productivity: land and labor productivity. Usually, research focuses on agricultural labor productivity.

The most significant advantage of agricultural production functions is the ability to compute the effect of the variable of interest on agricultural output and labor productivity growth. By including land, labor, capital, access to technology, and climate in the function, all important agricultural factors of production are acknowledged, and no important variables are omitted. If changes in the variable of interest are associated with changes in agricultural output or labor productivity (while controlling for all other factors of production), these changes can be attributed to the variable of interest. Hence, agricultural production functions enable researchers to understand the strength and direction of the relationship between the variable of interest and agricultural development. Agricultural production functions following the Cobb-Douglas model nevertheless have significant weakness, too: They assume that agricultural output is a function of all factors of production and ignore other issues like the macroeconomic environment and the functioning of markets. Generally, it is difficult to account for the macroeconomic environment when estimating the importance of the variable of interest for agricultural development. It is, however, possible to consider the functioning of markets by computing supply and demand functions. These can only be computed for one specific crop and not the whole agricultural sector of a country, though, as different kinds of crops have different markets. Supply and demand functions are most common for cash crops, as international market forces heavily influence their production. Crop-specific data is more complex to collect than data on the whole agricultural sector. Additionally, as different countries grow different kinds of crops, supply and demand functions have only minimal potential for cross-country comparisons. Usually, they are used to compare different locations within a country or region. Therefore, supply and demand functions are not viable in this study, which focuses on cross-country comparison.

Despite its shortcomings, conducting agricultural production functions based on the Cobb-Douglas model is the most viable option for this study. The variable of interest in this study is infrastructure governance. Computing agricultural production functions allows researchers to establish whether changes in the quality of infrastructure governance are associated with changes in agricultural output and labor productivity. Therefore, agricultural production functions are the best method for answering this study’s research questions and achieving the research objectives. Eight agricultural production functions are computed - two for each research objective. The main research objective is to examine the causal relationship between infrastructure governance and agricultural development in

Sub-Saharan Africa. Two agricultural production functions are computed to achieve this: one on the effect of infrastructure governance on agricultural output and one on the effect of infrastructure governance on agricultural labor productivity. The more specific research objectives are to understand the importance of transportation, power, and water infrastructure governance for agricultural development in Sub-Saharan Africa. Two agricultural production functions are computed for each kind of infrastructure governance to estimate their causal relationship with agricultural production and labor productivity.

The research question indicates that the population comprises all Sub-Saharan African countries. The units of analysis are countries. The World Bank considers all African countries except Algeria, Djibouti, Egypt, Libya, Morocco, Tunisia, and Western Sahara as Sub-Saharan Africa (The World Bank 2022f). This study follows the World Bank's definition of Sub-Saharan Africa. Therefore, 48 countries are included in this study. The population is Sub-Saharan African countries for theoretical and empirical reasons. Despite significant differences between various African countries, there is some level of homogeneity. In Sub-Saharan African countries, the agricultural sector tends to be very important economically. Almost all Sub-Saharan African countries are yet to undergo the structural transformation (Barrett et al. 2017). Therefore, agricultural development plays a fundamental role in Sub-Saharan Africa's development. North African countries have already undergone a structural transformation; hence, agriculture plays a less critical role in their development. Additionally, the agricultural sectors of Sub-Saharan African countries are somehow similar despite differences between different countries and sub-regions. Sub-Saharan Africa's agriculture tends to be characterized by smallholder farms, low levels of mechanization, and low productivity (Collier and Dercon 2014). This differs in other regions, such as North Africa, where the agricultural sectors have different characteristics. Thus, the agricultural sector in Sub-Saharan Africa is more important and has different features compared to North Africa. Therefore, it makes theoretical sense to focus on Sub-Saharan Africa. Furthermore, most cross-country studies on the relationship between infrastructure and agricultural development focus on one region. Many focus on Sub-Saharan Africa, and only very few include North Africa. This paper focuses on Sub-Saharan African countries as the population to make this study more comparable to similar studies.

3.2 Operationalization and Data Sources

3.2.1 Dependent variables

This study relies on secondary data. The World Bank, the International Labour Organization (ILO), and the FAO provide data for most concepts. The agricultural production functions' two dependent variables are agricultural output and labor productivity. As mentioned above, agricultural development is either growth in agricultural output or productivity. Hence, both concepts are included. This study follows the World Bank's operationalization of agricultural output, predominantly used in development research and practice. The World Bank operationalizes agricultural output as the absolute GDP of the agricultural sector, which is measured as "Agriculture, forestry, and fishing, value added (constant 2015 US$)" (World Bank 2022c). This variable's data source is the World Development Indicators (WDI) by the World Bank (2022c). The WDI can be accessed on DataBank, the World Bank's statistical database. This variable is measured in constant 2015 US$ to enable comparisons of countries with different currencies and prevent distortions by inflation or fluctuating currency exchange rates. The same applies to all other monetary variables. The other monetary variables' unit is 'in Millions, constant 2015 US$. To ensure better comparability with the other variables, this variable is divided by 1,000,000 and becomes "Agriculture, forestry, and fishing, value added (in Millions, constant 2015 US$)". An alternative to using the absolute agricultural GDP would have been to standardize the GDP of the agricultural sector by the total GDP to account for different sizes of economies. Agricultural development, however, leads to a higher absolute GDP of the agricultural sector but a lower relative share of the total GDP. Hence, the agricultural sector's relative share of the GDP is a rather unclear operationalization of agricultural development. Therefore, the absolute GDP of the agricultural sector is the better measure of the agricultural output. Additionally, the control variable agricultural land controls for countries' different sizes.

The second dependent variable, agricultural labor productivity, is operationalized as the agricultural output per worker measured as "Agriculture, forestry, and fishing, value added per worker (constant 2015 US$)" by the World Bank (2022d). This operationalization follows the World Bank's definition of labor productivity, which is conventionally used. This variable's data source is the WDI accessed on DataBank. It is a perfect measure of labor productivity. An alternative to using labor productivity would have been to use land productivity. However, almost all empirical literature uses labor productivity and to ensure good comparability, this study follows suit.

3.2.2 Control variables

Agricultural production functions include factors of agricultural production as control variables. The three traditional factors of production are land, labor, and capital. Sometimes, researchers include access to technology, rainfall, and temperature, too. Borrowing from the World Bank (2022g), land is operationalized as the agricultural land's total size measured as "Total agricultural land in square kilometers" (The World Bank 2022g). This operationalization is commonly used. Its data source is the WDI by the World Bank accessed on DataBank (2022g). The conventionally used operationalization of labor is the ILO's definition, which operationalizes it as the share of the agricultural sector in total employment or the "Percentage of employment in agriculture of total employment" (ILO 2022). This variable's data source is ILOSTAT, the statistical database of the ILO (ILO 2022). Regarding capital, this study follows the FAO's operationalization: Capital is operationalized as the total value of investments in the agricultural sector, which is measured as the "Net capital stock in agriculture, forestry, and fishery (in Million, constant 2015 US$)" (FAO 2022c). The FAO's operationalization of capital is commonly used. This variable's data source is FAOSTAT, the statistical database of the FAO (FAO 2022c). Compared to the other factors of production, access to technology is more difficult to operationalize. Traditionally, it has often been operationalized and measured as the prevalence of tractors ("Agricultural machinery, tractors per 100 sq. km of arable land" by the FAO (2009)). This dataset is no longer up to date, though. For many countries, the most recent data is from the 1970s or 1980s and the FAO stopped updating it in 2009. Another operationalization of access to technology is the prevalence of irrigation ("Agricultural irrigated land as percentage of total agricultural land" by the FAO (2022a)). This dataset, however, has either missing or only old data for many countries. Therefore, the two datasets measuring access to technology are not viable options and most recent agricultural production functions do not include access to technology as a factor of production. This study follows suit and does not include access to technology in the agricultural production functions. This is unfortunate but unavoidable due to the lack of viable data. In addition to the traditional factors of production, scholars have recently started including climate-related variables in agricultural production functions, too (Amuakwa-Mensah and Surry 2022). Climate-related factors significantly impact agricultural production, i.e., in Sub-Saharan

Africa, where rain-fed agriculture is the norm. Therefore, adding climate-related variables improves the explanatory power of agricultural production functions. Climate is operationalized with two variables: temperature ("Mean annual temperature in degrees Celsius") and rainfall ("Total annual rainfall in millimeters"). Each operationalization follows the World Bank's definition, which are conventionally used (The World Bank 2022e). Yearly fluctuations caused by weather phenomena characterize these variables, possibly leading to distortions. Thus, their five-year smooths, the mean of five years, are used. These two variables' data source is the Climate Change Knowledge Portal of the World Bank (2022e).

3.2.3 Independent variables

Contrary to the dependent and control variables, no data on the independent variable infrastructure governance is available. As outlined in the introduction, this lack of data is a research problem. Hence, this study cannot borrow from an operationalization established in development theory and practice. A new operationalization must be created. This study operationalizes infrastructure governance as popular perception of the government's performance regarding infrastructure. As elaborated in the conceptual framework, infrastructure governance essentially describes how well a government performs its functions and tasks. Good infrastructure governance is a necessary and sufficient condition for the government's good performance regarding infrastructure provision. Therefore, the government's performance regarding infrastructure provision is a good proxy for infrastructure governance. The government's performance regarding infrastructure provision can be measured by looking at the popular perception of the government's performance.

Performance perception is not a perfect measure of performance since it is subjective, though. For example, perception bias caused by partisanship or political ideology, among other factors, influences how an individual perceives the government's performance (Tilley and Hobolt 2011). Additionally, demographic characteristics such as age, health status, education, and gender influence citizens' evaluation of the government's performance (Yang 2010). Some people perceive the government to perform better than it does, and others perceive it to perform worse. While the individual perception of the government is biased, aggregating people's perception of the government's performance gives a reasonably accurate picture of the actual performance due to the law of large numbers (Kaufmann, Kraay, and Mastruzzi 2005). If the government performs well, a high percentage of the population will be satisfied with the way the government is handling a particular matter. Hence, it is claimed that aggregating the population's perception of the government's performance regarding infrastructure is a good operationalization of a country's quality of infrastructure governance. World Bank research supports this claim: 'soft' perceptive data on governance tends to be more reliable than 'hard' objective data. This is because 'hard' data often fails to reflect corruption, a symptom of poor governance, adequately. Since corruption is illegal, it leaves no paper trail, making it difficult to measure it directly. Therefore, the World Bank recommends including perceptions in measures of governance (The World Bank 2007). Additionally, Kaufmann, Kraay & Mastruzzi (2005) claim that 'hard' data tends to overestimate rules and formal institutions (de jure regulations) but neglects the implementation of these (de facto regulations). They add that "concerns about the importance of ideological biases in subjective governance assessments are relatively unimportant" (Kaufmann, Kraay, and Mastruzzi 2005, 3–4). Hence, the literature supports the claim that the popular perception of the government's performance regarding infrastructure provision is a good proxy for infrastructure governance. Therefore, infrastructure governance is operationalized as the population's perception of the government's performance regarding infrastructure. Transportation infrastructure governance is operationalized as the population's perception of the government's performance regarding transportation infrastructure. The same applies to power and water infrastructure governance.

The Afrobarometer provides data on popular perception of the government's performance regarding infrastructure. The Afrobarometer survey is conducted in 34 African countries and covers African citizens' political, economic, and social opinions and attitudes. To ensure comparability with the other variables, whose point of observation is 2018, this study uses round seven from 2019, measured in 2017 and 2018 (Afrobarometer 2019). The Afrobarometer provides individual-level data, which can be aggregated to provide information on the opinions of a country's population. It includes the question "How well or badly would you say the current government is handling the following matters, or haven't you heard enough to say?" (Question 50). There are five possible answers: "very badly", "fairly badly", "fairly well", "very well", and "don't know". This question measures the population's perception of the government's performance regarding crucial issues. Fifteen matters are included, three of which are related to infrastructure: "Maintaining roads and bridges", "Providing a reliable source of electricity", and "Providing water and sanitation services" (Afrobarometer 2019). Providing the population with access to electricity is the government's most important goal regarding power infrastructure. Therefore, "Providing a reliable source of electricity" is an excellent measure of the population's perception of the government's performance regarding power infrastructure. The same applies to "Providing water and sanitation services" and water infrastructure. "Maintaining roads and bridges" is not a very good measure of the population's perception of the government's performance regarding transportation infrastructure. Transportation infrastructure consists of roads, bridges, ports, airports, and railways, among others. However, only roads and bridges are considered in the Afrobarometer. This is an unfortunate shortcoming, but as roads are the most important aspect of transportation infrastructure for agriculture (Juma 2015) and this paper has a theoretical focus on roads, it is acceptable. Another shortcoming is the lack of data on the government's performance regarding ICT infrastructure.

For each of the three mentioned issues, an indicator measuring the respective kind of infrastructure governance's quality is created. As mentioned above, infrastructure governance is operationalized as the population's perception of the government's performance regarding infrastructure. The same applies to specific kinds of infrastructure governance. Hence, the transportation infrastructure governance indicator is created by calculating the percentage of a country's population which has a positive perception of the government's performance regarding transportation infrastructure and answers either "fairly well" or "very well" (as opposed to those perceiving it negatively and answering either "very poor" or "fairly poor"). The same is done for power and water infrastructure governance. The three resulting indicators measure the quality of transportation, power, and water infrastructure governance, respectively, on a scale between 0 and 100. Combining the answers "fairly well" and "very well" leads to a certain loss of information. There is, however, no better way of creating one ratio variable with the four possible answers. Valuing "very well" answers stronger than "fairly well" answers would mean that the variable becomes ordinal, negatively affecting the data analysis. Hence, this is the best possible solution. Subsequently, an index measuring the overall quality of infrastructure governance is created by computing the average of the transportation, power, and water infrastructure governance indicators. In summary, three indicators measuring the quality of transportation infrastructure governance, power infrastructure governance, and water infrastructure governance, as well as an index measuring the overall quality of infrastructure governance, are created for each Sub-Saharan African country. *Table 2* provides an overview of all variables, their operationalizations, and data sources.

3.2.4 Data needs table

Table 2: Data Needs Table

Variable	Operationalization	Data Source
Dependent variables		
Agricultural output	Agriculture, forestry, and fishing, value added (in Millions, constant 2015 US$)	World Development Indicators, accessed on the World Bank's statistical database DataBank
Agricultural labor productivity	Agriculture, forestry, and fishing, value added per worker (constant 2015 US$)	World Development Indicators, accessed on the World Bank's statistical database DataBank
Variables of interest		
Transportation Infrastructure Governance	Percentage of the population which perceives the government's performance regarding 'maintaining roads and bridges' as fairly well or well	Afrobarometer
Power Infrastructure Governance	Percentage of the population which perceives the government's performance regarding 'providing a reliable source of electricity' as fairly well or well	Afrobarometer
Water Infrastructure Governance	Percentage of the population which perceives the government's performance regarding 'providing water and sanitation services' as fairly well or well	Afrobarometer
Infrastructure Governance	Average of transportation, power, and water infrastructure governance	Afrobarometer
Factors of agricultural production		

Land	Total agricultural land (sq. kilometer)	World Development Indicators, accessed on the World Bank's statistical database DataBank
Labor	Employment in agriculture (% of total employment)	The ILO's statistical database ILOSTAT
Capital	Net capital stock in agriculture, forestry, and fishery (in Millions, constant 2015 US$)	The FAO's statistical database FAOSTAT
Temperature	Mean annual temperature (°C), five-year smooth	The World Bank's Climate Change Knowledge Portal
Rainfall	Total annual rainfall (mm), five-year smooth	The World Bank's Climate Change Knowledge Portal

3.3 Data Analysis

In total, eight agricultural production functions are conducted – two for each research objective. Each function has one infrastructure governance variable as the independent variable, one measure of agricultural development as the dependent variable, and the factors of agricultural production (land, labor, capital, temperature, and rainfall) as control variables. Since a high degree of covariation between the different infrastructure governance variables (the variables of interest) is likely, they cannot be included in one function. Furthermore, there are two different measures of agricultural development and hence, two agricultural production functions are computed for each variable of interest: one with agricultural output as the dependent variable and one with agricultural labor productivity as the dependent variable. Hence, there are two agricultural production functions for each research objective. The data analysis starts with the general research objective and examines the causal relationship between infrastructure governance and agricultural development. The results of the two agricultural production functions show whether good infrastructure governance positively affects agricultural output and labor productivity. If infrastructure governance has a positive and statistically significant coefficient in the first agricultural production function, it will be concluded that better infrastructure governance leads to higher agricultural output. If infrastructure governance has a positive and statistically significant coefficient in the second agricultural production function, it will be concluded that better infrastructure governance leads to higher agricultural labor productivity. Thus, the two agricultural production functions with infrastructure governance as the variable of interest enable answering the first research question. The same approach is taken for the three specific research questions: two agricultural production functions are computed for transportation, power, and water infrastructure governance respectively. Their results contribute to understanding whether there is indeed a causal relationship between transportation, power, and water infrastructure governance and agricultural output and labor productivity. The agricultural production functions are based on the functional relationship

$$Y = X * N * L * C * T * R,$$

whereas (Y) is either agricultural output or agricultural labor productivity, (X) describes infrastructure governance, (N) measures land, (L) is labor, (C) capital, (T) temperature, and (R) rainfall. *Table 3* below summarizes the eight agricultural production functions.

Table 3: Agricultural Production Functions

	Independent Variable	Control Variables	Dependent Variable
1)	Infrastructure Governance	Land, Labor, Capital, Temperature, Rainfall	Agricultural Output
2)	Infrastructure Governance	Land, Labor, Capital, Temperature, Rainfall	Agricultural Labor Productivity
3)	Transportation Infrastructure Governance	Land, Labor, Capital, Temperature, Rainfall	Agricultural Output
4)	Transportation Infrastructure Governance	Land, Labor, Capital, Temperature, Rainfall	Agricultural Labor Productivity
5)	Power Infrastructure Governance	Land, Labor, Capital, Temperature, Rainfall	Agricultural Output
6)	Power Infrastructure Governance	Land, Labor, Capital, Temperature, Rainfall	Agricultural Labor Productivity
7)	Water Infrastructure Governance	Land, Labor, Capital, Temperature, Rainfall	Agricultural Output
8)	Water Infrastructure Governance	Land, Labor, Capital, Temperature, Rainfall	Agricultural Labor Productivity

All variables to be included in the agricultural production functions are ratio variables. The only exception is temperature, which is an interval variable. Therefore, all agricultural production functions are computed as ordinary least square (OLS) regressions (the most common method of computing linear regressions). The different scales of the variables do not influence the data analysis but need to be considered when interpreting the results. This study is cross-sectional. 2018 is the latest year in which all variables have observations. To ensure that all data is measured at the same time, data from 2018 is used for all variables. The only two exceptions are the two climate variables (temperature and rainfall). A five-year smooth is used to avoid distortions caused by weather-induced yearly fluctuations. Hence, the mean of the yearly observations from 2016 to 2020 is used. Another exception is the infrastructure governance variables. They are based on data provided by round seven of the Afrobarometer, conducted in 2017 and 2018.

Additionally, several diagnostics to test whether all OLS regression assumptions are fulfilled must be run and if not, corrective measures must be implemented. If all assumptions are fulfilled, the OLS regression will compute coefficient estimates close to the actual values of the population. If some assumptions are not fulfilled, corrective measures will be needed to get correct and precise results. The assumptions to be tested are the absence of multicollinearity, outliers, and leverage points, a linear relationship between independent and dependent variables, and heteroskedasticity (Bollen and Jackman 1985). Since the agricultural production functions have several independent variables, one must confirm that there is no multicollinearity between them, as this would make it difficult to distinguish the effect of different independent variables. The most common method of detecting multicollinearity is Variable Inflation Factors (VIF) and hence, this study uses this method. Secondly, the absence of outliers must be confirmed since regression results tend to be very sensitive to outliers. Cook's distance is computed to test this and, following Bollen and Jackman (1985), all cases having a Cook's distance value higher than $\frac{4}{n}$ [n: number of cases] are excluded from the regression. Furthermore, leverage points are excluded, too, as they similarly distort regression results. Following Bollen and Jackman (1985), leverage points are defined as observations with leverage higher than $3 * \frac{\mathrm{k+1}}{\mathrm{n}}$ [k: number of independent variables], which in the case of this study's data analysis is 0.66 ($3 * \frac{6+1}{32}$). Additionally, it is checked whether the relationships between the independent and dependent variables are linear. Lastly, it is confirmed whether the assumption of homoskedasticity is fulfilled and whether the error term has a constant variance by computing the Breusch-Pagan test. If a regression model is characterized by heteroskedasticity, this model will be run with robust standard errors (Bollen and Jackman 1985).

To summarize the results of the diagnostic tests, no function is characterized by multicollinearity. A function will be characterized by multicollinearity if one of its variables has a VIF-value higher than 5. However, no function has a variable with a VIF-value higher than 2. Hence, the assumption 'no multicollinearity' is fulfilled for all agricultural production functions. Contrarily, the assumption that 'no outliers' is fulfilled for none of the functions. All functions have at least three countries with Cook's distance value higher than $\frac{4}{n}$. Each function with agricultural output as the dependent variable has four outliers: Lesotho, Nigeria, South Africa, and Sudan. Most functions with agricultural labor productivity as the dependent variable have four outliers: Lesotho, Nigeria, South Africa, and Sudan. However, in the function with transportation infrastructure governance as the independent variable, Nigeria is not an outlier and in the function with water infrastructure governance as the independent variable, Gabon is a further outlier. The regressions are run without the observations detected as outliers. All eight functions have one leverage point with leverage higher than $3 * \frac{\mathrm{k}+1}{\mathrm{n}}$: Nigeria. Hence, Nigeria is excluded from the eight regressions. The assumption 'linear relationship' is fulfilled for the eight agricultural production functions. For each of them, a scatterplot with a fitted line indicates that the relationship between the dependent and independent variable is linear and adding the squared independent variable does not improve the explanatory power of any function. Lastly, the assumption 'homoskedasticity' is fulfilled for half of the agricultural production functions. The Breuscher-Pagan Test shows that all functions with agricultural output as dependent variables are characterized by heteroskedasticity and hence, these regressions are run with robust standard errors. Contrarily, the assumption 'homoskedasticity' is fulfilled for the four functions with agricultural labor productivity as the dependent variable and hence, no corrective measure is needed.

3.4 Limitations

This research project has two potential limitations: Firstly, limitations caused by gaps in the data provided by the Afrobarometer, and secondly, limitations inherent to agricultural production functions.

The Afrobarometer lacks data in two ways: Firstly, there is a lack of data on ICT infrastructure governance. The Afrobarometer includes questions regarding transportation, power, and water infrastructure governance. There is no question regarding ICT infrastructure governance, though. Hence, ICT is missing from the composite infrastructure governance index and the relationship between ICT infrastructure governance and agricultural development cannot be analyzed. This is a shortcoming. Secondly, the Afrobarometer does not cover all Sub-Saharan African countries. In round seven, 34 countries (32 from Sub-Saharan Africa) were included. 16 Sub-Saharan African countries were not included. Therefore, the quality of infrastructure governance of these countries cannot be measured and they are excluded from the data analysis. This reduces the number of cases from 48 to 32. A sample size of 32 (which is further reduced by outliers and leverage points) is very small and having such few cases reduces the probability of getting statistically significant and robust results in the data analysis. The low sample size increases the probability of having false negative errors. Additionally, there might be a sampling bias. The 16 Sub-Saharan African countries not included in the Afrobarometer (Angola, Burundi, Central African Republic, Chad, Comoros, DR Congo, Congo, Equatorial Guinea, Eritrea, Guinea-Bissau, Mauritania, Rwanda, Seychelles, Somalia, and South Sudan) tend to be characterized by lower levels of agricultural development (World Bank 2022c, World Bank 2022d) and relatively poor governance (Mo Ibrahim Foundation 2022). Therefore, the countries included in the Afrobarometer might not be representative of Sub-Saharan Africa. Thus, the relatively high number of countries excluded from the Afrobarometer and the data analysis is a significant limitation.

Another potential limitation is derived from a general weakness of agricultural production functions: they do not consider the macroeconomic environment and the functioning of markets. Only factors of production are included. Supply and demand functions consider the functioning of markets but are not feasible for cross-country analyses. Therefore, agricultural production functions are, despite this weakness, the most suitable approach. A more specific weakness of the agricultural production functions to be computed in this research is the lack of recent data on the prevalence of tractors or irrigation, the two most common operationalizations of access to technology. Hence, access to technology as a factor of production cannot be included. This is unfortunate as it reduces the explanatory power of the agricultural production functions, but unavoidable.

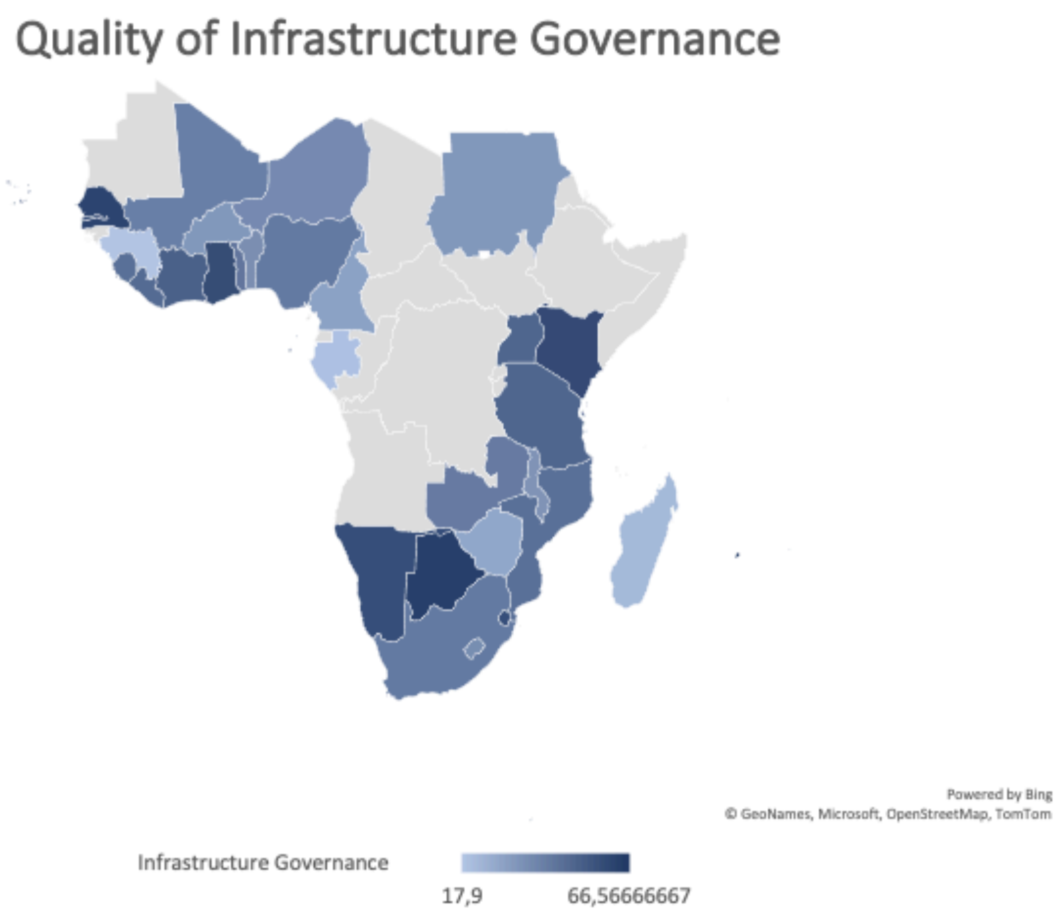
4 Results and Discussions

4.1 Description of the Results

4.1.1 Infrastructure Governance

The chapter on the results starts with descriptive statistics of the variables measuring infrastructure governance: the indicators measuring transportation, power, and water infrastructure governance and the index measuring the overall quality of infrastructure governance. In theory, values could range between 0 and 100 for these variables. The values for infrastructure governance range between 66.57 and 17.9. The countries with the best infrastructure governance are Mauritius (66.57), Botswana (63.17), and Senegal (61.8). Guinea (17.9), Gabon (19.27), and Madagascar (22.33) are characterized by the worst infrastructure governance. The mean of this variable is 44.85, the median is 44.88, and the standard deviation is 13.06. Its values are summarized in *Figure 2*.

Figure 2: Quality of Infrastructure Governance in Sub-Saharan Africa



Source: Illustration by author based on data by the Afrobarometer

The countries with the best transportation infrastructure governance are Cote d'Ivoire (68.3), Namibia (67.2), and Senegal (66.8); Zimbabwe (12.7), Gabon (17.4), and Guinea (18.3) have the worst transportation infrastructure governance. The mean of this variable amounts to 46.78, the median is 51.2, and the standard deviation is 15.12. Mauritius (81), Botswana (71.2), and Ghana (70.8) are characterized by excellent power infrastructure governance; Malawi (13.3), Madagascar (13.7), and Guinea (17.9) by relatively poor ones. Power infrastructure governance has a mean of 43.87, a median of 43.25, and a standard deviation of 16.73. The countries with the best water infrastructure governance are Eswatini (64.9), Botswana (62.5), and Mauritius (61.9); the countries with the worst infrastructure governance are Gabon (15.6), Guinea (17.5), and Sudan (27.4). The mean of this variable is 43.9, its median is 43.85, and its standard deviation is 12.14. Each Sub-Saharan country's value for these variables (and any other variable), as well as the mean, median, and standard deviation of each variable, is provided in the appendix.

On average, Sub-Saharan African countries have better governance of their transportation infrastructure compared to their power and water infrastructure. Power infrastructure governance has the highest variance; some Sub-Saharan African countries perform very well, but others quite poorly. The water sector has the lowest heterogeneity among the three sectors; few countries perform extraordinarily well or poorly. The precise value of each country for these variables (and the dependent and control variables) are outlined in the appendix.

4.1.2 Causal Relationship between Infrastructure Governance and Agricultural Development

The next sub-chapters summarize the results of the eight agricultural production functions. In the beginning, the results of the first two functions measuring the causal relationship between infrastructure governance and agricultural development are elaborated. It was hypothesized that infrastructure governance contributes to agricultural development in Sub-Saharan Africa and expected that countries with better infrastructure governance have higher agricultural output and agricultural labor productivity. Infrastructure governance, however, only positively affects agricultural output but does not induce higher agricultural labor productivity. Keeping all other variables constant, a one-unit increase in the quality of infrastructure governance causes a 50.15 million US$ higher agricultural output. This effect is statistically significant at the 90% confidence interval. Hence, better infrastructure governance does indeed have a positive effect on agricultural output. Countries with better infrastructure governance have a higher agricultural output. Additionally, a higher share of agricultural employment as a percentage of total employment and a higher net capital stock in agriculture, forestry, and fishery have a statistically significant and positive effect on agricultural output. The other independent variables (agricultural land, mean temperature, and mean rainfall) do not influence agricultural output in a statistically significant way.

Better infrastructure governance does, however, not induce higher agricultural labor productivity. Holding all other variables constant, a one-unit increase in the quality of infrastructure governance results in a 14.99 US$ lower value added per worker within the agricultural sector. This effect is not statistically significant, though. There is no statistically significant relationship between the quality of infrastructure governance and agricultural labor productivity and countries with better infrastructure governance do not have significantly higher agricultural labor productivity. More agricultural land does contribute to higher agricultural labor productivity, though. Interestingly, a higher share of employment in agriculture as a percentage of total employment is associated with significantly lower agricultural labor productivity. The other control variables do not have a statistically significant effect. *Table 4* shows the precise results of both agricultural production functions.

Table 4: Causal Relationship between Infrastructure Governance and Agricultural Output and Labor Productivity

Agricultural Production Functions: Infrastructure Governance

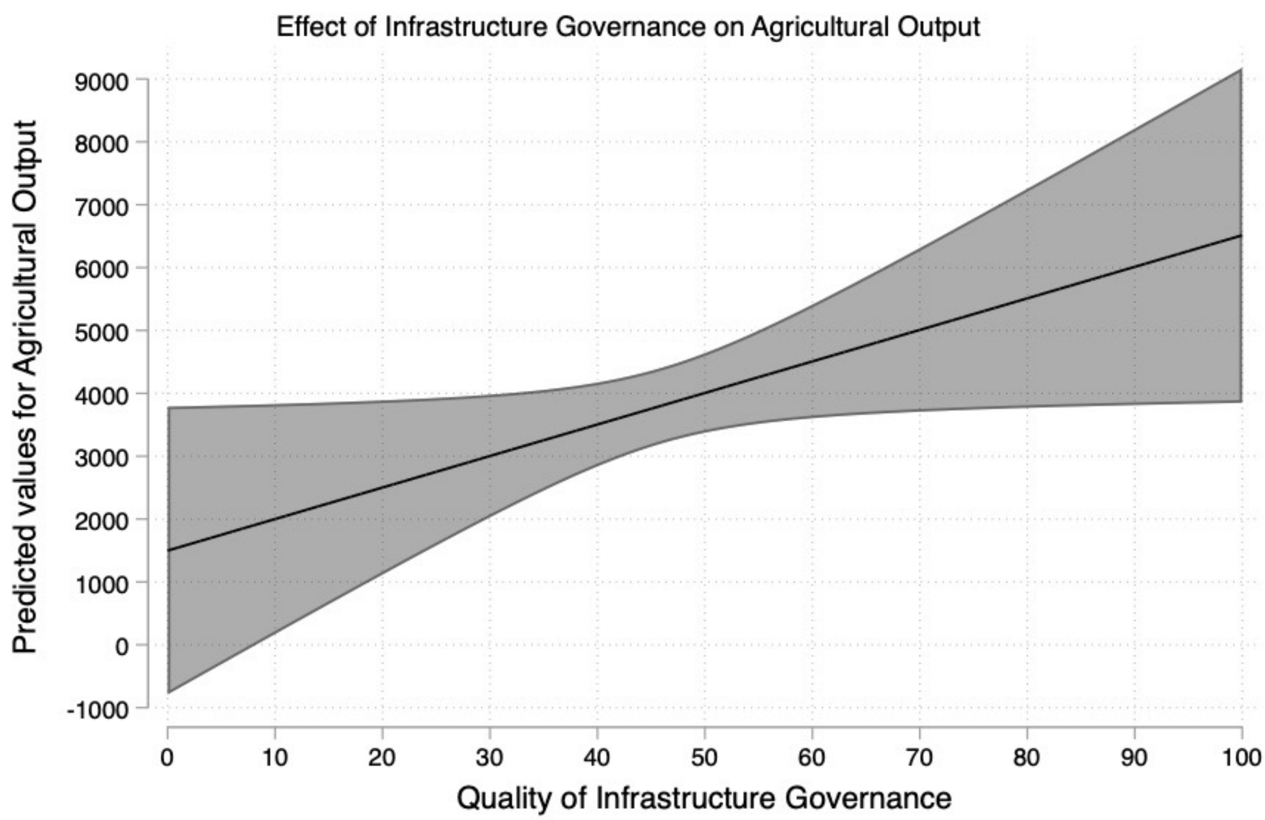
	(1)	(2)
VARIABLES	Agricultural Output	Agricultural Labor Productivity
Infrastructure Governance	50.15*	-14.99
	(27.92)	(16.64)
Land	0.00450	0.00278**
	(0.00333)	(0.00124)
Labor	52.15**	-69.74***
	(20.59)	(10.06)
Capital	0.751***	0.0506
	(0.139)	(0.0443)
Temperature	180.4	-23.61
	(134.4)	(72.58)

Rainfall	0.500	0.220
	(0.642)	(0.402)
Constant	-8,955**	5,385**
	(3,861)	(2,304)
Observations	28	28
R-squared	0.846	0.767

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

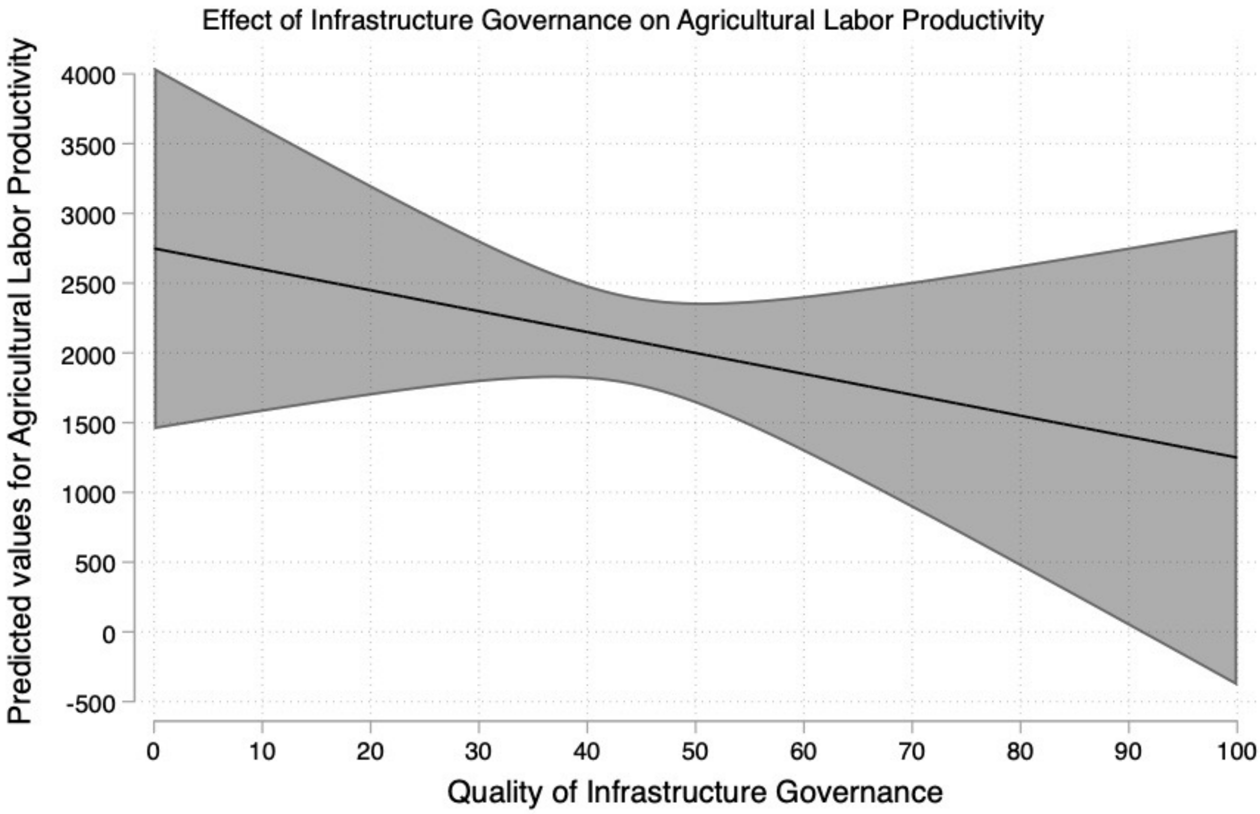
To visualize these results, the values of agricultural output and labor productivity are predicted for different levels of the quality of infrastructure governance in two separate graphs (*Figure 3* and *Figure 4)*. The equations include the control variables kept constant at their means. Additionally, the confidence intervals (set at 90%) are included in the graphs. The values for infrastructure governance range between 17.9 and 66.57, so the graphs are most meaningful in this interval.

Figure 3: Effect of Infrastructure Governance on Agricultural Output



Source: Illustration by author based on data by the Afrobarometer, DataBank, ILOSTAT, and FAOSTAT

Figure 4: Effect of Infrastructure Governance on Agricultural Labor Productivity



Source: Illustration by author based on data by the Afrobarometer, DataBank, ILOSTAT, and FAOSTAT

These graphs show that infrastructure governance has a positive effect on agricultural output, but it does not positively impact agricultural labor productivity. In conclusion, the empirical evidence suggests that the hypothesis "Good infrastructure governance contributes to agricultural development in Sub-Saharan Africa." is partly right and partly wrong. Improving infrastructure governance does evoke higher agricultural output but does not cause higher agricultural labor productivity.

4.1.3 Causal Relationship between Transportation Infrastructure Governance and Agricultural Development

It was hypothesized that good transportation infrastructure governance contributes to accelerated agricultural development in Sub-Saharan Africa. Transportation infrastructure governance will positively impact agricultural output and labor productivity if this is the case. Accordingly, the quality of transportation infrastructure governance does result in a higher agricultural output according to the empirical data, but it does not have any effect on agricultural labor productivity. A one-unit increase in the quality of transportation infrastructure governance causes a 46.76 million US$ higher agricultural output holding all other variables constant. This effect is statistically significant at the 95% confidence interval. Hence, countries with better infrastructure governance have significantly higher agricultural output. Like in the first function, the share of employment in agriculture as a percentage of total employment and agricultural capital stock have a statistically significant and positive effect on agricultural output, but agricultural land, mean temperature, and mean rainfall do not.

There is no statistically significant relationship between transportation infrastructure governance and agricultural labor productivity, though. Keeping all other variables constant, a one-unit increase in the quality of infrastructure governance results in an 0.03 US$ increase in the value added per worker within the agricultural sector. This effect is not statistically significant, though. Better transportation infrastructure governance does not increase agricultural labor productivity and countries with better infrastructure governance do not have significantly higher agricultural labor productivity. Just as in the first agricultural production function, more agricultural land is associated with higher and more agricultural employment is associated with lower agricultural labor productivity. The other variables (capital, temperature, and rainfall) do not influence agricultural labor productivity statistically significant. *Table 5* elaborates the results of the two agricultural production functions.

Table 5: Causal Relationship between Transportation Infrastructure Governance and Agricultural Output and Labor Productivity

Agricultural Production Functions: Transportation Infrastructure Governance

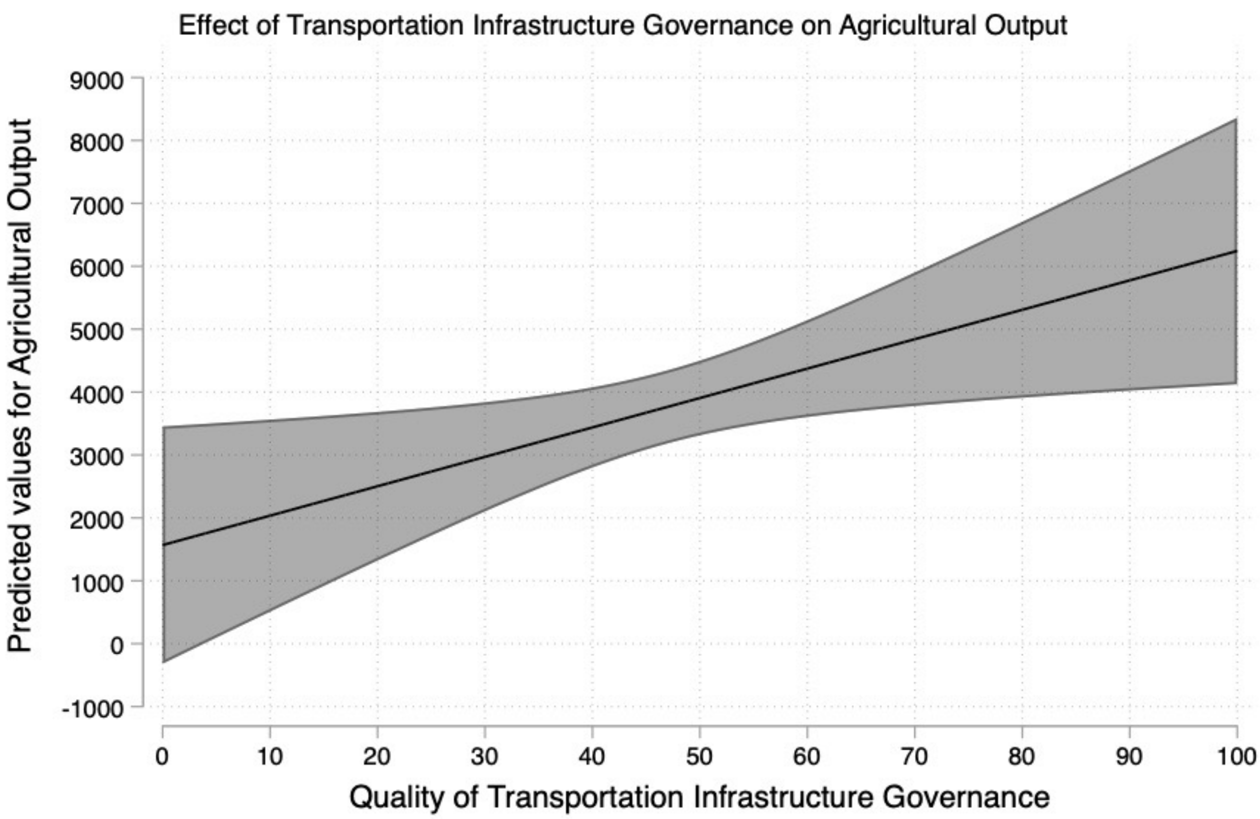
	(1)	(2)
VARIABLES	Agricultural Output	Agricultural Labor Productivity
Transportation Infrastructure	46.76**	0.0273
Governance	(22.28)	(12.67)
Land	0.00459	0.00310**
	(0.00308)	(0.00123)
Labor	44.23**	-67.11***
	(17.37)	(9.889)
Capital	0.772***	0.0398
	(0.127)	(0.0439)
Temperature	166.7	-20.85
	(128.2)	(73.92)
Rainfall	0.537	0.322
	(0.569)	(0.402)

Constant	-8,317**	4,398*
	(3,165)	(2,218)
Observations	28	28
R-squared	0.857	0.758

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

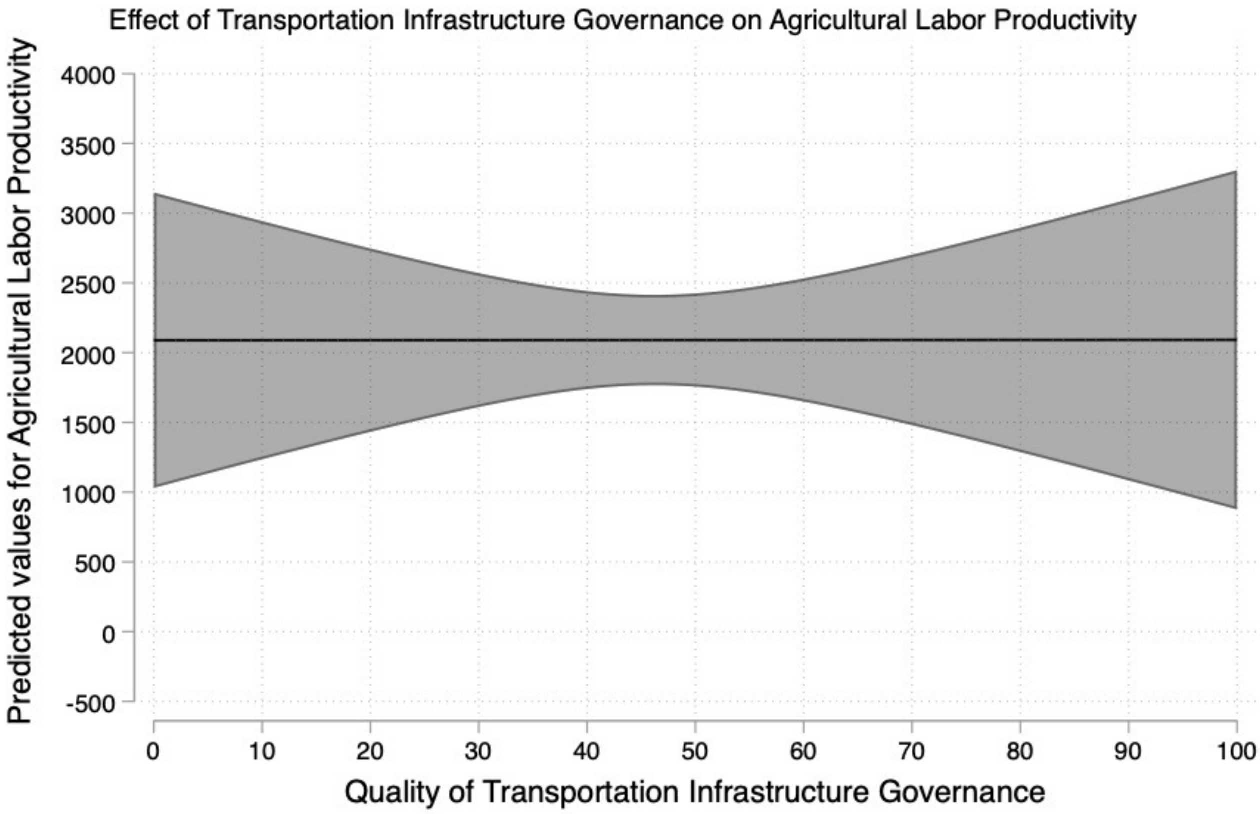
For a better overview of the results, they are visualized with the predicted values of agricultural output and labor productivity for different levels of the quality of transportation infrastructure governance in two separate graphs (*Figure 5* and *Figure 6)*. 90% confidence intervals are included in the graphs and the control variables (kept constant at their mean) are inserted in the equations. The graphs are most meaningful in the range between 12.7 and 68.3 on the x-axis.

Figure 5: Effect of Transportation Infrastructure Governance on Agricultural Output



Source: Illustration by author based on data by the Afrobarometer, DataBank, ILOSTAT, and FAOSTAT

Figure 6: Effect of Transportation Infrastructure Governance on Agricultural Labor Productivity



Source: Illustration by author based on data by the Afrobarometer, DataBank, ILOSTAT, and FAOSTAT

The empirical analysis underlines that good transportation infrastructure governance does indeed lead to higher agricultural output but does not cause higher agricultural labor productivity. The hypothesis "Good transportation infrastructure governance contributes to agricultural development in Sub-Saharan Africa." is therefore partly true and partly incorrect. Better transportation infrastructure governance does result in higher agricultural output, but it does not cause higher agricultural labor productivity.

4.1.4 Causal Relationship between Power Infrastructure Governance and Agricultural Development

It was hypothesized that good power infrastructure governance contributes to agricultural development in Sub-Saharan Africa and hence, expected that the quality of power infrastructure governance positively affects agricultural output and agricultural labor productivity. The empirical findings on this are not in line with this expectation, though. The quality of power infrastructure governance does not have a statistically significant and positive effect on agricultural output or agricultural labor productivity. Countries with better power infrastructure governance are characterized by neither significantly higher agricultural output nor significantly higher agricultural labor productivity. Keeping all other variables constant, a one-unit increase in the quality of power infrastructure governance is associated with a 22.88 million US$ higher agricultural output. This effect, however, is not statistically significant. Among the control variables, only agricultural capital stock has a statistically significant and positive effect on agricultural output; all other variables are not statistically significant.

Additionally, better power infrastructure governance does not cause improved agricultural labor productivity. Contrarily, a one-unit increase in power infrastructure governance results in a 17.63 US$ decrease in the value added per worker within the agricultural sector, holding all other variables constant. This negative effect is not statistically significant, though. Like in the previous two agricultural output functions with agricultural labor productivity as the dependent variable, more agricultural land is associated with higher and a higher share of employment in agriculture as a percentage of total employment results in lower agricultural labor productivity; the other control variables do not have a statistically significant effect. *Table 6* displays the complete results of both agricultural production functions.

Table 6: Causal Relationship between Power Infrastructure Governance and Agricultural Output and Labor Productivity

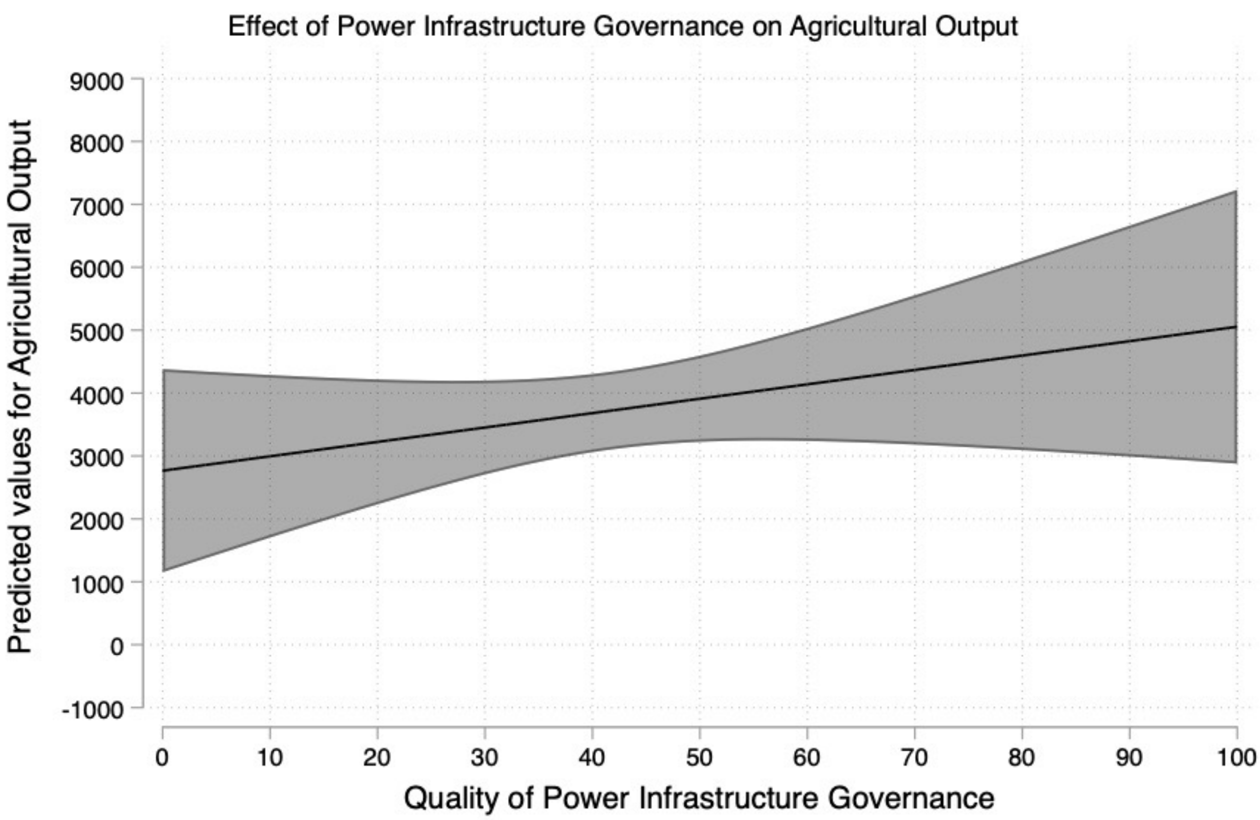
Agricultural Production Functions: Power Infrastructure Governance		
	(1)	(2)
VARIABLES	Agricultural Output	Agricultural Labor Productivity
Power Infrastructure Governance	22.88	-17.63
	(20.81)	(14.74)
Land	0.00482	0.00256*
	(0.00382)	(0.00126)
Labor	45.67	-72.29***
	(27.73)	(10.43)
Capital	0.756***	0.0628
	(0.142)	(0.0463)
Temperature	170.3	-21.15
	(141.5)	(71.51)
Rainfall	0.415	0.168
	(0.668)	(0.402)

Constant	-7,122*	5,588**
	(3,481)	(2,233)
Observations	28	28
R-squared	0.834	0.773

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

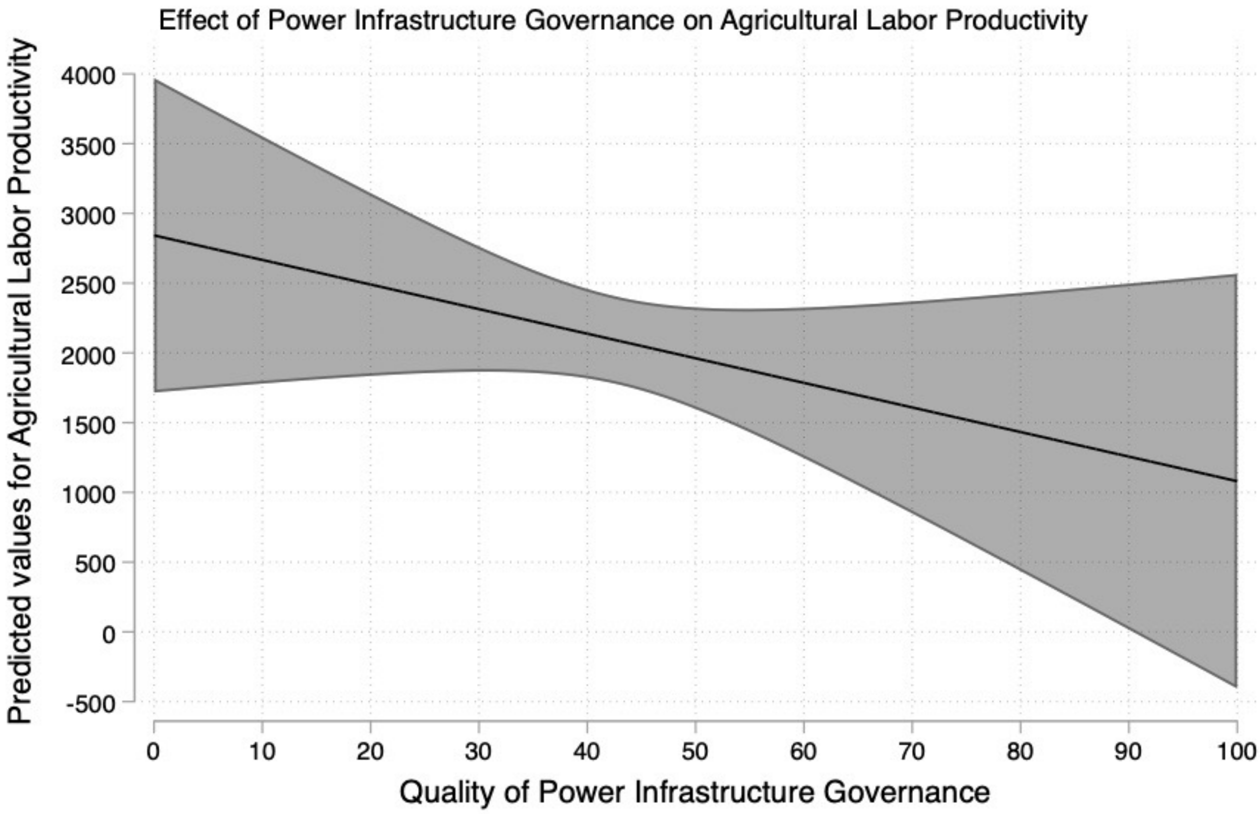
Again, these results are visualized in two separate graphs with the predicted values of agricultural output and labor productivity for different levels of the quality of transportation infrastructure governance and all control variables are kept constant at their mean (*Figure 7* and *Figure 8*). Additionally, 90% confidence intervals are included. As the values for power infrastructure governance are in the range of 13.3 to 81, the graphs are most meaningful in this range.

Figure 7: Effect of Power Infrastructure Governance on Agricultural Output



Source: Illustration by author based on data by the Afrobarometer, DataBank, ILOSTAT, and FAOSTAT

Figure 8: Effect of Power Infrastructure Governance on Agricultural Labor Productivity



Source: Illustration by author based on data by the Afrobarometer, DataBank, ILOSTAT, and FAOSTAT

In summary, there is no relationship between the quality of power infrastructure governance and agricultural development. Better power infrastructure governance does not result in higher agricultural output or labor productivity. The hypothesis "Good power infrastructure governance contributes to agricultural development in Sub-Saharan Africa." cannot be supported with empirical data and hence, is wrong.

4.1.5 Causal Relationship between Water Infrastructure Governance and Agricultural Development

The last causal relationship to be analyzed empirically is the relationship between water infrastructure governance and agricultural development. It was hypothesized that good water infrastructure governance contributes to agricultural development in Sub-Saharan Africa and expected that better water infrastructure governance would cause an increase in both agricultural output and agricultural labor productivity. The empirical findings show that water infrastructure governance is associated with neither in a statistically significant way, though. Holding all other variables constant, a one-unit increase in the quality of water infrastructure governance brings about a 38.3 million US$ higher agricultural output. Even though this effect is not statistically significant, the rather low p-value indicates that there might be a positive effect, nevertheless. The data, however, does not conclusively show that better water infrastructure governance causes increased agricultural output. As in most other production functions with agricultural output as the dependent variable, agricultural employment and agricultural capital stock have a statistically significant and positive effect on agricultural output, but agricultural land, mean temperature, and mean rainfall do not.

There is no statistically significant relationship between the quality of water infrastructure governance and agricultural labor productivity. A one-unit increase in the quality of water infrastructure governance is associated with a decrease in the value added per worker within the agricultural sector of 1.9 US$, keeping all other variables constant. This effect is not statistically significant, though. Hence, better water infrastructure governance does not result in higher agricultural labor productivity. As in all other agricultural production functions with labor productivity as the dependent variable, more agricultural land contributes to higher labor productivity and a higher share of employment in agriculture evokes lower agricultural labor productivity. The other variables do not influence agricultural labor productivity. *Table 7* displays the results of these agricultural production functions.

Table 7: Causal Relationship between Infrastructure Governance and Agricultural Output and Labor Productivity

Agricultural Production Functions: Water Infrastructure Governance

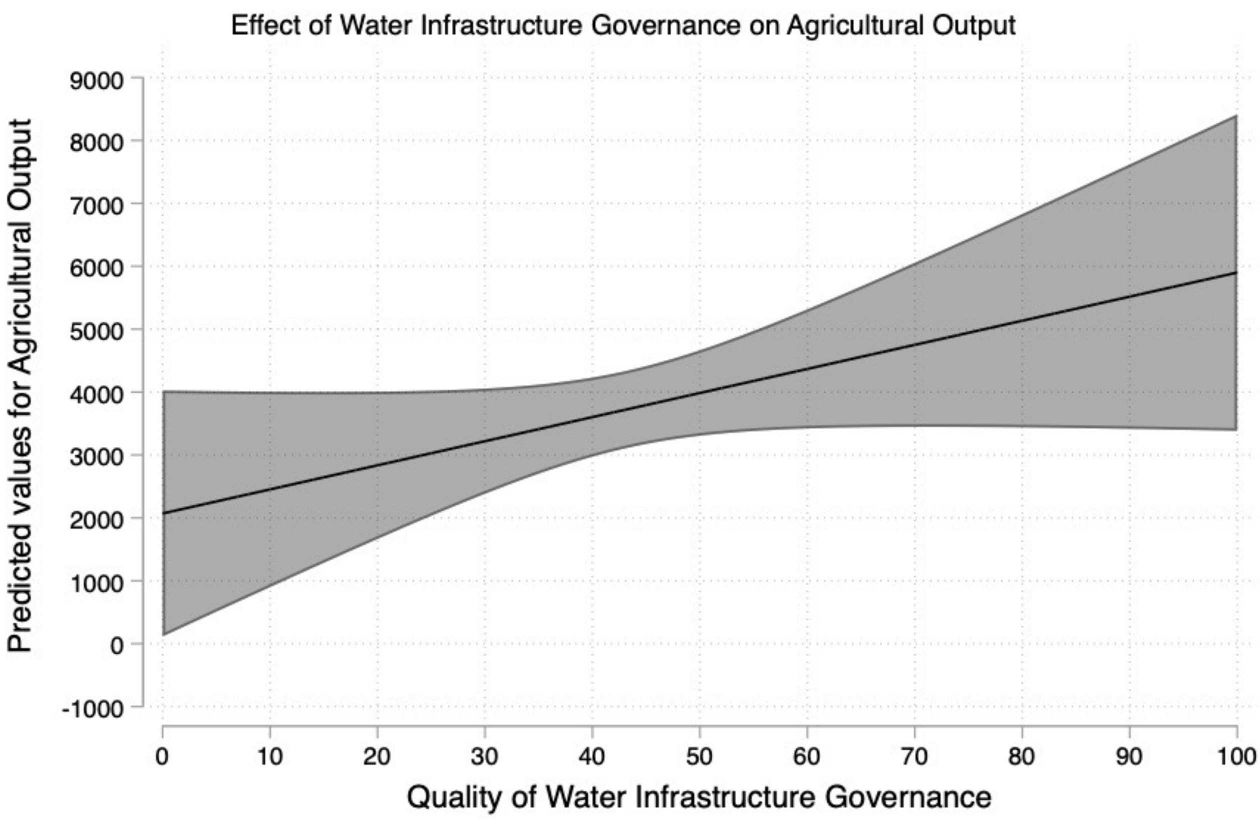
VARIABLES	(1) Agricultural Output	(2) Agricultural Labor Productivity
Water Infrastructure Governance	38.30	-1.902
	(24.97)	(17.54)
Land	0.00447	0.00303***
	(0.00363)	(0.00105)
Labor	45.31**	-62.77***
	(20.03)	(9.019)
Capital	0.783***	0.0519
	(0.150)	(0.0372)
Temperature	178.0	-20.07
	(138.7)	(62.63)
Rainfall	0.450	0.0988
	(0.680)	(0.341)

Constant	-8,061*	4,382*
	(4,132)	(2,108)
Observations	28	27
R-squared	0.838	0.819

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

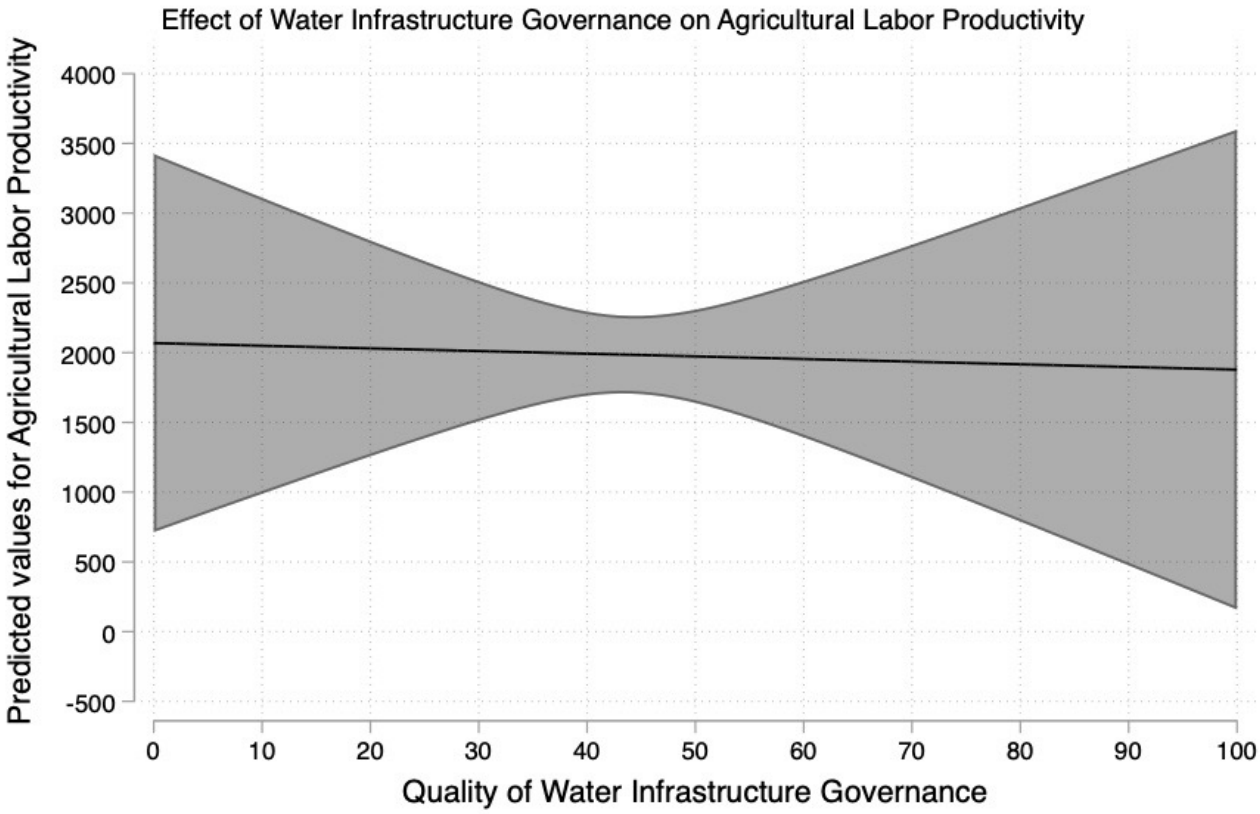
The results are once again visualized with the predicted values of agricultural output and labor productivity for different levels of the quality of infrastructure governance in two separate graphs (*Figure 9* and *Figure 10*). The control variables kept constant at their means and 90% confidence intervals are included in the graphs, too. The graphs are most meaningful for values between 15.6 and 64.9 of the water infrastructure governance variable.

Figure 9: Effect of Water Infrastructure Governance on Agricultural Output



Source: Illustration by author based on data by the Afrobarometer, DataBank, ILOSTAT, and FAOSTAT

Figure 10: Effect of Water Infrastructure Governance on Agricultural Labor Productivity



Source: Illustration by author based on data by the Afrobarometer, DataBank, ILOSTAT, and FAOSTAT

The empirical results underline that the quality of water infrastructure governance contributes to neither agricultural output nor agricultural labor productivity in a statistically significant way. There is a positive but not statistically significant effect of the quality of water infrastructure governance on agricultural output, though. Nevertheless, the hypothesis "Good water infrastructure governance contributes to agricultural development in Sub-Saharan Africa." cannot be supported and must be rejected. Better water infrastructure governance does not lead to accelerated agricultural development in Sub-Saharan Africa and countries with better water infrastructure governance are not characterized by statistically significant higher agricultural output or labor productivity.

4.1.6 Summary of the Results

Infrastructure governance (including every specific aspect of infrastructure governance) was expected to have a positive and statistically significant effect on both agricultural output and agricultural labor productivity. The results, however, show that the empirical data supports this empirical expectation only to some extent. Better infrastructure governance does indeed result in increased agricultural output, but it does not cause agricultural labor productivity growth. Good transportation infrastructure governance leads to an increased agricultural output but does not evoke agricultural labor productivity growth. Water infrastructure governance has a positive, but not statistically significant effect on agricultural output and does not affect agricultural labor productivity. There is no causal relationship between power infrastructure governance and agricultural output or labor productivity. Hence, infrastructure governance in general and transportation infrastructure governance have an effect on agricultural development, but water and power infrastructure governance do not. The empirical data suggests that among the three specific kinds of infrastructure governance, transportation infrastructure governance is the most important determinant of agricultural development, followed by water infrastructure governance. Power infrastructure governance is the least important for agricultural development. Among the three agricultural production functions with a specific kind of infrastructure as the independent variable and agricultural output as the dependent variable, transportation infrastructure governance has the highest coefficient, followed by power and water infrastructure governance. The same applies to the production functions with agricultural labor productivity as the dependent variable. Lastly, there are some interesting findings on the control variables. The agricultural land's size has no effect on agricultural output, but a positive effect on labor productivity. Agricultural employment as a percentage of total employment influences agricultural output positively and agricultural labor productivity negatively. The net capital stock in agriculture, forestry, and fishery affects agricultural output positively, but has no effect on agricultural labor productivity. Temperature and rainfall do not influence agricultural output or labor productivity.

4.2 Interpretation of the Results

The interpretation of the empirical results is separated into two parts: Firstly, it is examined why good infrastructure governance could impact agricultural output positively but not agricultural labor productivity. And secondly, it is investigated why transportation infrastructure governance seems more important for agricultural development than water infrastructure governance and why power infrastructure governance seems to be the least influential.

4.2.1 Differences between Agricultural Output and Agricultural Labor Productivity

Good infrastructure governance was hypothesized to contribute to growth in agricultural output and agricultural labor productivity. Empirical data, however, demonstrates that good infrastructure governance results in only higher agricultural output but not higher agricultural labor productivity. To understand this, one must go back to the concept of agricultural development, which can be defined as the process of equitable growth in the agricultural production of a country (Diao et al. 2007). There are two pathways for achieving agricultural production growth: increasing the agricultural output by using more factors of production and improving the agricultural productivity by increasing the yields per factor of production ratio. The former usually refers to expanding the size of agricultural land under cultivation or increasing the size of the agricultural labor force. The latter usually refers to rising labor or land productivity.

Since good infrastructure governance induces higher agricultural output without enhancing agricultural productivity, it increases the agricultural production factors used without raising the yields per factor of production ratio. There are two possible explanations for this: good infrastructure governance could lead to an increase in the agricultural workforce or an expansion in the agricultural land being cultivated. Importantly, productivity is improved in neither possible explanation. Each could illustrate why there is an increased output but no change in labor productivity. Only one of them is consistent with the empirical data, though. The empirical data shows that an increase in the agricultural land cultivated causes increased labor productivity but does not increase agricultural output. Better infrastructure governance hence cannot expand the land under cultivation without improving labor productivity since increasing the land under cultivation ignites higher labor productivity. Therefore, the first possible explanation must be crossed out.

On the other hand, the second explanation is in line with the empirical results. These illustrate that increasing the agricultural labor force's size positively affects agricultural output and negatively affects agricultural labor productivity. Thus, better infrastructure governance could lead to a bigger agricultural labor force without improving labor productivity. Better infrastructure governance, in combination with a bigger agricultural labor force, could create a greater agricultural output without increasing labor productivity. The explanation that better infrastructure governance in combination with a more extensive agricultural workforce induces higher agricultural output without evoking higher labor productivity can be tested rather quickly with two additional agricultural production functions: each with an interaction term between the quality of infrastructure governance and the share of agricultural employment as the independent variable; land, capital, temperature and rainfall as control variables; and as the dependent variable agricultural output in the first function and agricultural labor productivity in the second function. If this explanation is true, the interaction term will have a positive and statistically significant effect on agricultural output, but it will not have such an effect on agricultural labor productivity.

And indeed, this is the case. The interaction term between infrastructure governance and the share of agricultural employment as a percentage of total employment positively and statistically significantly influences agricultural output. Keeping all other variables constant, a one-unit increase in the interaction term causes a 3.3 million US$ higher agricultural output. This effect is statistically significant at the 95% confidence interval. The interaction term does not evoke higher agricultural productivity, though. A one-unit increase in the interaction term results in a decrease in the value added per worker within the agricultural sector of 0.45 US$, holding all other variables constant. This, however, is not statistically significant. In summary, the empirical data suggests that better infrastructure governance in combination with a bigger agricultural labor force results in higher agricultural output, but it does not cause higher labor productivity. The results of these agricultural production functions are elaborated in *Table 8*.

Table 8: Causal Relationship between the Interaction Term between Infrastructure Governance and Labor and Agricultural Output and Labor Productivity

Agricultural Production Functions: Interaction Term between Infrastructure Governance and Labor

	(1)	(2)
VARIABLES	Agricultural Output	Agricultural Labor Productivity
Infrastructure Governance	-90.06	29.03
	(59.22)	(43.82)
Labor	-105.0	-40.49
	(65.19)	(41.32)
Interaction term between	3.339**	-0.452
Infrastructure Governance and Labor	(1.478)	(0.878)
Land	0.00445	0.00357***
	(0.00288)	(0.00101)
Capital	0.710***	0.0516

	(0.114)	(0.0389)
Temperature	80.82	18.05
	(139.1)	(46.58)
Rainfall	0.356	0.230
	(0.575)	(0.340)
Constant	931.8	1,623
	(5,737)	(2,680)
Observations	28	28
R-squared	0.878	0.823

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Hence, good infrastructure governance causes higher agricultural output by increasing the agricultural labor force. It incentivizes people to engage in agricultural activities and become farmers, pastoralists, or fishermen /-women. It does not provide an incentive to invest in productivity-improving measures, though, and hence, does not contribute to improved agricultural productivity. Many positive developmental impacts of agricultural development depend on improved productivity, however. Positive effects of agricultural productivity growth include higher profitability, higher incomes of farmers, improved international competitiveness, and lower costs of food (depending on the price elasticity of demand and tradeability). Increasing agricultural output without improving productivity does not bring about these positive consequences (Pinstrup-Andersen and Shimokawa 2008), so improving agricultural productivity has a more positive developmental impact than solely expanding the output. Additionally, increasing the agricultural labor force without improving agricultural labor productivity comes with a risk: disguised unemployment. This refers to a situation when somebody works redundantly without improving the economic output. Hence, their labor productivity is zero (Investopedia 2022).

Nevertheless, improving the agricultural output has several positive consequences, too. It contributes to achieving food security, decreasing poverty, and fueling economic development (Diao et al. 2007). Additionally, the concept of disguised unemployment is not applicable in this case. As shown in the agricultural production functions, a higher share of agricultural employment as a percentage of total employment positively impacts agricultural output. Therefore, improving infrastructure governance has a positive developmental impact by raising the agricultural output. Its developmental impact would, however, be more positive if it improved labor productivity, too.

4.2.2 Relative Importance of Different Kinds of Infrastructure Governance

It was hypothesized that all kinds of infrastructure governance contribute to agricultural development in Sub-Saharan Africa. Transportation, power, and water infrastructure governance were expected to result in higher agricultural output and agricultural labor productivity equally. The causal mechanism of this expected relationship is separated into two: Firstly, infrastructure governance (the independent variable) was expected to positively impact a country's infrastructure stock (the mediating variable). Secondly, the mediating variable was expected to positively affect agricultural development (the dependent variable). The causal mechanism was expected to equally apply to transportation, water, and power infrastructure governance. The data analysis, however, shows that the three kinds of infrastructure governance are of different relative importance for agricultural development. Transportation infrastructure governance seems to be a more critical determinant than water infrastructure governance and power infrastructure governance appears to be the least important of the three. This contradicts the theoretical expectation of them being equally important. There are two possible explanations for this: Firstly, there could be differences in how infrastructure governance affects a country's infrastructure stock. This could be caused by specific features of transportation infrastructure (e.g., its public good nature), which water and power infrastructure do not share, and which make governance more important. Or secondly, there could be differences in how a country's infrastructure stock affects agricultural development. This would imply that transportation infrastructure is more important for agricultural development than water and power infrastructure.

The first possible explanation could be the first part of the causal mechanism: the relationship between infrastructure governance and a country's infrastructure stock. There could be differences between transportation, water, and power infrastructure regarding this. The three kinds of infrastructure have different properties, i.e., regarding their excludability and rivalry in consumption. Except for toll roads, transportation infrastructure is of public good nature. Transportation infrastructure is, in almost all cases, non-excludable and non-rivalrous. Therefore, the government must provide it. Similarly, most water infrastructure needs to be provided by the government due to its public good character. This includes water dams, reservoirs, and transmission and distribution systems. Water provision can be privatized, however. Hence, the government must provide most water infrastructure, but the private sector can play a role in providing certain water infrastructure, too. Among the three kinds of infrastructure, power infrastructure has the most potential for private sector involvement. The government needs to provide power transmission and distribution systems, which are public goods. Other aspects are feasible for private investors, though. Power production can be privatized as the private sector can invest in IPPs. Additionally, it can provide off-grid solutions (e.g., solar home systems and microgrids). Furthermore, private power provision is possible. In summary, the government must supply transport infrastructure almost entirely. The government is the most important provider of water infrastructure, but the private sector can contribute in some aspects, too. Lastly, the government needs to provide some aspects of power infrastructure, but the private sector can also administer most. The governance of public infrastructure differs from the governance of private infrastructure. The kinds of infrastructure governance with a higher share of public infrastructure are more important for agricultural development than those with a higher percentage of private infrastructure. An explanation could be that infrastructure governance is more important for public infrastructure than private infrastructure. Hence, infrastructure governance plays a more important role for the types of infrastructure with a higher share of public infrastructure. This could explain why the governance of transportation infrastructure (which in almost all cases needs to be provided by the government) is more important for agricultural development than the governance of water infrastructure (which in most cases needs to be provided by the government but can sometimes be provided by the private sector). Additionally, it could explain why the governance of power infrastructure (which can often be provided by the private sector) is least important for agricultural development.

Another approach for explaining the different relative importance of the three kinds of infrastructure governance for agricultural development is looking at the second part of the causal mechanism: How a country's infrastructure stock affects agricultural development. Transportation infrastructure stock could be more important for agricultural development than water and power infrastructure. It was hypothesized that they are equally important. In the conceptual framework, it was theorized that good transportation infrastructure reduces transport and transaction costs and hence, contributes to agricultural development by providing better and more stable access to inputs, finance, and markets, ensuring better cropping choices, instituting more investments in productivity-improving measures or high-value crops, and leading to less price fluctuation. It was also claimed that good water infrastructure aids agricultural development by enabling irrigation, providing water as an input for fish production and the livestock sector, and improving labor productivity, as a safe and stable water supply improves farmers' health and increases farmers' available time. Lastly, it was claimed that good power infrastructure enables irrigation, allows better storage of agricultural produce, which reduces post-harvest losses and serves as an incentive to invest in more perishable crops with higher values, and improves labor productivity, as electricity enables farmers to spend more time on their farms. It could, however, be that the causal relationship between transportation infrastructure and agricultural development is stronger than the one between water infrastructure and agricultural development and that the causal relationship between power infrastructure and agricultural development is weakest. This would explain why transportation infrastructure governance is a more important determinant of agricultural development than water infrastructure governance and why power infrastructure governance is the least important.

Importantly, both explanations for the different relative importance of the three kinds of infrastructure governance are consistent with the empirical findings. Both explanations may be accurate. It is also possible that only one or even none is true, though. More research is needed to analyze this.

5 Summary, Conclusions, and Recommendations

5.1 Summary of the Study

Researchers have demonstrated that agricultural development is a crucial determinant of African countries' overall development and that the agricultural sector can be promoted by improving the quantity, quality, and reliability of infrastructure, which are important determinants of agricultural development. Furthermore, an emerging school of thought stresses the importance of infrastructure governance for the quantity, quality, and reliability of a country's infrastructure stock. Despite the relevance of infrastructure governance for a country's infrastructure stock and the importance of infrastructure for agricultural development, these two bodies of research have not yet been combined. The insights on infrastructure governance have not yet been incorporated into the literature on the relationship between infrastructure and agricultural development. This is a research gap. A related research gap is a lack of data on infrastructure governance. Due to this lack of data, conducting quantitative large-n analyses on the impact of infrastructure had been difficult. This study solves both research gaps by creating data on infrastructure governance and incorporating the findings of the relatively new infrastructure governance school of thought into the analysis of factors driving agricultural development. It examines the causal relationship between infrastructure governance and agricultural development in Sub-Saharan Africa. This enhances the understanding of the determinants of agricultural development and, given the high importance of agriculture for African states' development, is beneficial to the development discourse. Additionally, development practice benefits from these insights as they improve the knowledge base on which policies and development programs aimed at agricultural development are built.

This study's units of analysis are countries and the population consists of all Sub-Saharan African countries. Its methodology follows the Cobb-Douglas model of agricultural production functions, in which agricultural production is seen as a function of the factors of production (Iimi et al. 2015). This is the most common methodology for cross-country comparisons examining the causal relationship between infrastructure and agricultural development. The factors of production included in this study's agricultural production functions are land, labor, capital, temperature, and rainfall. Eight agricultural production functions are computed, two for each of the four hypotheses and the respective variables of interest: one with agricultural output and one with agricultural labor productivity as the dependent variable, respectively. The variables of interest are infrastructure governance, transportation infrastructure governance, power infrastructure governance, and water infrastructure governance. This study follows the operationalizations of agricultural output, agricultural labor productivity, land, labor, capital, and climate conventionally used in the empirical literature. There is, however, a lack of data on infrastructure governance and specific kinds of infrastructure governance in the literature. The variables measuring the three specific types of infrastructure governance are created by aggregating individual perceptions of the government's performance regarding transportation, power, and water infrastructure. For this, the percentage of a country's population which has a positive perception of the government's performance in the respective sector is measured. Infrastructure governance is calculated as the mean of transportation, power, and water infrastructure governance. The agricultural production functions are computed as ordinary least square (OLS) regressions. This study is cross-sectional and all variables were measured in 2018. To ensure that all OLS assumptions (absence of multicollinearity, outliers, and leverage points, a linear relationship between independent and dependent variables, and homoskedasticity) are fulfilled, several diagnostic tests are run and if necessary, corrective measures are implemented.

In summary, the empirical results illustrate that better infrastructure governance does indeed result in an increased agricultural output but does not evoke agricultural labor productivity growth. Good infrastructure governance in general and good transportation infrastructure governance contribute to higher agricultural output in a statistically significant way. Good water infrastructure governance has a quite strong and positive, but not statistically significant, effect on agricultural output. The quality of power infrastructure does not seem to influence agricultural output, though. Nevertheless, the empirical data shows that infrastructure governance is an essential determinant of agricultural output in Sub-Saharan Africa. On the other side, neither the quality of infrastructure governance in general nor the quality of transportation, power, or water infrastructure governance has a statistically significant effect on agricultural labor productivity. Hence, the empirical evidence illustrates that infrastructure governance is not a determinant of agricultural labor productivity. Therefore, my general hypothesis (Good infrastructure governance contributes to agricultural development in Sub-Saharan Africa.) is partly supported and partly rejected by the empirical analysis. In Sub-Saharan Africa, better infrastructure governance does indeed lead to increased agricultural output but not to accelerated agricultural growth. The first specific hypothesis can be partly accepted and partly rejected, too. Better transportation infrastructure governance does cause higher agricultural output in Sub-Saharan Africa but does not result in higher agricultural labor productivity. However, the second and third specific hypotheses must be rejected. Neither good power infrastructure governance nor good water infrastructure governance contributes to agricultural development in Sub-Saharan Africa (even though empirical evidence suggests that better water infrastructure governance might cause higher agricultural output).

Additionally, there are interesting divergences between different types of infrastructure governance. African countries perform best in transportation infrastructure governance and worst in power infrastructure governance. Furthermore, transportation infrastructure governance has the highest coefficient among the agricultural production functions with agricultural output as the dependent variable. Water infrastructure governance has the second highest coefficient and power infrastructure governance has the lowest coefficient. A similar pattern can be seen in the agricultural production functions with agricultural labor productivity as the dependent variable: transportation infrastructure governance has a slightly positive coefficient, water infrastructure governance a somewhat negative one, and power infrastructure governance a very negative one. This indicates that among the three specific kinds of infrastructure governance, good transportation governance is most important for agricultural development, followed by good water infrastructure governance, and good power infrastructure governance is least important for agricultural development.

Lastly, there are some interesting findings on the control variables. A higher share of agricultural employment as a percentage of total employment and a higher net capital stock in agriculture, forestry, and fishery have a statistically significant and positive effect on agricultural output. Additionally, more agricultural land results in higher agricultural labor productivity and a higher share of employment in agriculture as a percentage of total employment evokes lower agricultural labor productivity. The other control variables do not have any statistically significant effect.

5.2 Conclusions

The empirical results enable answering the research questions. Good infrastructure governance influences agricultural development in Sub-Saharan Africa by increasing a country's agricultural output. However, it does not evoke agricultural labor productivity growth. The same applies to transportation infrastructure governance: good transportation infrastructure governance contributes to agricultural output growth but does not lead to higher agricultural labor productivity. Contrarily, power and water infrastructure governance do not influence agricultural development in Sub-Saharan Africa in a statistically significant way. Nevertheless, water infrastructure governance seems to be a somehow more important determinant of agricultural development than power infrastructure governance. Infrastructure governance increasing agricultural output, but not agricultural labor productivity, implies that good infrastructure governance serves as an incentive to use more factors of production without improving the yields per factor of production ratio. This could have two explanations: An increased agricultural workforce or an expansion in the cultivated land. Empirical data indicates that the first explanation might be true. More research is, however, needed to answer this conclusively. There are two explanations for transportation infrastructure governance being more important for agricultural development than water infrastructure governance and power infrastructure governance being the least important of the three: Firstly, there could be differences in how infrastructure governance affects a country's infrastructure stock. Governance could be more important for infrastructure delivered by the government compared to the one provided by the private sector. Transportation infrastructure’s public good nature could make governance more important and the private good nature of some aspects of power infrastructure could decrease governance’s relevance. Secondly, there could be differences in how a country's infrastructure stock affects agricultural development. Transportation infrastructure could be more important for agricultural development than water and power infrastructure. More research is, however, needed to determine which of the explanations is true.

5.3 Suggested Further Research

While conducting this study, several research gaps have emerged, which should be solved by further research. Firstly, ICT infrastructure governance has not been included in this analysis due to the Afrobarometer's lack of data on ICT infrastructure governance. Research utilizing other data sources could, however, analyze the effect of ICT infrastructure governance on agricultural development.

Secondly, this study has not conclusively answered why good infrastructure governance contributes to agricultural production but does not lead to higher labor productivity. Although this study has come up with an explanation, a qualitative case study could shed more light on this. The same applies to the third area of suggested further research: This study has not conclusively answered why transportation infrastructure governance is more important than the other kinds of infrastructure governance. Again, there are two possible explanations, but further research is needed to examine whether one of them is true. A qualitative case study seems the most promising approach for this, too.

5.4 Recommendations

This study demonstrates the importance of infrastructure governance for agricultural output growth. This study has shown that infrastructure governance positively impacts agricultural output in Sub-Saharan Africa. Empirical evidence has revealed that improving infrastructure governance can be a pathway to achieving agricultural development. Due to the high developmental impact of agricultural growth, African countries should work on this: improve their infrastructure governance to ensure a higher quantity, better quality, and improved reliability of infrastructure, higher spending efficiency, more value-for-money, and more stable flows of investments. It is recommended that governments should do this by implementing long-term plans, ensuring accountability as well as public participation in planning, implementing sound and clear regulatory policy frameworks, enforcing the rule of law, managing and mitigating political, currency, and regulatory risks, improving public capacity, and preventing corruption. If a country manages its infrastructure incorporating these issues, its infrastructure stock will likely be of good quantity, quality, and reliability, contributing to agricultural output growth. Notably, the governance of public infrastructure seems slightly more important than the governance of privately provided infrastructure. Furthermore, transportation infrastructure governance appears to be a more important determinant of agricultural output growth than power and water infrastructure governance. Therefore, it is recommended that governments should start by improving the delivery of public transportation infrastructure governance, as this is likely to have the highest developmental impact. Infrastructure governance, however, does only increase agricultural production but does not affect agricultural labor productivity. Improving agriculture's productivity has more positive developmental impacts than improving the output. Hence, improving infrastructure governance must be supplemented by other measures enhancing agricultural productivity.

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Appendix

Data sets used

Table 9: Data sets: Infrastructure Governance, Transportation Infrastructure Governance, Power Infrastructure Governance, Water Infrastructure Governance, Agricultural Output, and Agricultural Labor Productivity

Country	Infrastructure Governance	Transportation Infrastructure Governance	Power Infrastructure Governance	Water Infrastructure Governance	Agricultural Output	Agricultural Labor Productivity
Angola					10225,66	1699,91
Benin	36,40	37,20	34,90	37,10	3780,98	2117,94
Botswana	63,17	55,80	71,20	62,50	306,15	1890,01
Burkina Faso	33,53	28,90	30,30	41,40	3023,79	1680,13
Burundi					962,32	234,78
Cabo Verde	54,37	60,70	57,30	45,10	95,34	3926,75
Cameroon	29,93	29,80	27,50	32,50	6050,64	1106,10
Central African Republic					599,42	474,29
Chad					5562,56	1299,14
Comoros					329,90	4349,09
Congo, DR					7423,57	414,63
Congo, Rep					759,23	1173,30
Cote d'Ivoire	51,93	68,30	50,40	37,10	8775,00	2826,38
Equatorial Guinea					249,04	1359,85
Eritrea					0,00	
Eswatini	58,30	56,20	53,80	64,90	352,75	9896,42
Ethiopia					26795,28	791,13
Gabon	19,27	17,40	24,80	15,60	850,47	4931,83
The Gambia	57,93	55,90	63,00	54,90	302,77	1594,37
Ghana	58,73	45,90	70,80	59,50	11298,06	3010,32
Guinea	17,90	18,30	17,90	17,50	2132,32	845,81
Guinea-Bissau					553,88	1198,20
Kenya	59,33	62,00	68,20	47,80	14445,51	1760,78

Country	Infrastructure Governance	Transportation Infrastructure Governance	Power Infrastructure Governance	Water Infrastructure Governance	Agricultural Output	Agricultural Labor Productivity
Lesotho	37,30	36,80	37,30	37,80	94,53	287,55
Liberia	48,00	51,60	40,50	51,90	1206,75	924,63
Madagascar	22,33	18,70	13,70	34,60	3002,94	363,82
Malawi	34,73	50,80	13,30	40,10	1804,91	319,39
Mali	41,80	47,80	28,20	49,40	5918,83	1458,43
Mauritania					1540,69	3920,35
Mauritius	66,57	56,80	81,00	61,90	376,47	10711,35
Mozambique	47,23	50,10	48,20	43,40	4095,27	469,47
Namibia	58,33	67,20	51,20	56,60	823,97	4994,51
Niger	37,77	46,30	28,10	38,90	4186,15	711,28
Nigeria	43,20	52,70	36,60	40,30	110459,67	5611,32
Rwanda					2365,46	610,49
Sao Tome and Principe	55,00	52,70	53,30	59,00	37,73	3143,71
Senegal	61,80	66,80	60,80	57,80	3224,47	2714,32
Seychelles					33,54	
Sierra Leone	47,37	53,80	43,60	44,70	2802,14	2025,20
Somalia						
South Africa	43,40	42,60	43,30	44,30	8783,31	7947,22
South Sudan					842,45	
Sudan	33,80	36,10	37,90	27,40	16634,75	4040,24
Tanzania	50,57	56,00	48,10	47,60	14543,24	859,06
Togo	44,53	53,90	43,20	36,50	1171,88	1346,78
Uganda	49,73	59,50	43,80	45,90	8407,04	741,10
Zambia	42,60	47,70	42,40	37,70	950,06	302,05
Zimbabwe	28,37	12,70	39,30	33,10	2068,53	477,79
Mean	44,85	46,78	43,87	43,90	6527,16	2330,94
Median	45,88	51,20	43,25	43,85	2100,42	1409,14
Standard Deviation	13,06	15,12	16,73	12,14	16589,74	2452,09

Table 10: Data sets: Land, Labor, Capital, Temperature, and Rainfall

Country	Land	Labor	Capital	Temperature	Rainfall
Angola	569525	50,91	10384,32	21,85	1000,66
Benin	39500	39,08	1634,46	28,25	1063,26
Botswana	258616	20,37	277,12	22,55	383,31
Burkina Faso	121000	27,08	1528,96	28,96	878,64
Burundi	20330	86,25	399,11	20,73	1278,40
Cabo Verde	790	11,84	180,29	23,34	378,46
Cameroon	97500	44,17	4866,89	25,07	1585,58
Central African Republic	50800	70,30	624,85	25,42	1262,58
Chad	502380	75,39	1769,81	27,36	364,72
Comoros	1310	34,99	247,23	24,80	1799,15
Congo, DR	315000	64,81	7595,42	24,41	1548,73
Congo, Rep	106280	33,74	1132,06	25,19	1677,06
Cote d'Ivoire	212000	41,01	9921,11	27,02	1349,30
Equatorial Guinea	2840	39,15	296,12	24,80	2106,95
Eritrea	75920	63,76	230,52	27,12	314,60
Eswatini	12220	12,50	679,89	21,33	768,22
Ethiopia	379030	67,29	12742,07	23,19	915,20
Gabon	22126	30,59	973,09	25,61	1785,53
The Gambia	6050	27,71	199,34	28,19	946,03
Ghana	147827	31,05	16496,86	28,01	1204,44
Guinea	145000	61,32	2084,35	26,41	1680,36
Guinea-Bissau	8151	61,06	202,36	27,67	1530,81
Kenya	276300	55,08	12657,26	25,34	866,18
Lesotho	24333	44,91	95,68	13,23	657,71
Liberia	19540	42,78	630,56	25,91	2249,11
Madagascar	408950	64,68	1955,50	22,98	1399,26
Malawi	56500	76,64	873,78	22,62	1099,46
Mali	412010	63,00	2135,68	28,94	336,54
Mauritania	396610	31,52	1290,26	28,44	99,40
Mauritius	860	6,20	923,15	24,22	1774,43

Country	Land	Labor	Capital	Temperature	Rainfall
Mozambique	414138	70,59	2074,36	24,55	995,82
Namibia	388100	22,59	1122,93	20,70	267,86
Niger	466000	72,86	1286,81	27,82	203,04
Nigeria	691235	35,53	181511,74	27,38	1190,63
Rwanda	18117	63,35	1115,90	19,40	1232,43
Sao Tome and Principe	440	19,61	39,42	23,42	2081,95
Senegal	88780	30,83	2361,80	28,89	712,29
Seychelles	16		31,95	27,88	2102,70
Sierra Leone	39490	55,36	1144,92	26,80	2435,04
Somalia	441250	80,49	678,96	27,26	307,20
South Africa	963410	5,16	20316,02	18,85	407,70
South Sudan	285332	60,84		27,52	990,84
Sudan	681862	38,95	595,38	27,80	280,43
Tanzania	396500	65,67	8032,21	23,07	1133,60
Togo	38200	33,10	708,70	27,74	1186,76
Uganda	144150	72,45	5023,76	23,33	1392,78
Zambia	238360	50,11	2174,69	22,23	996,00
Zimbabwe	162000	66,02	5142,34	22,00	636,42
Mean	211389	47,29	6987,02	24,91	1101,2
Median	132575	44,91	1144,92	25,27	1081,36
Standard Deviation	226412	21,19	26421,72	3,20	602,53