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Natural resource revenues and public investment in resource-rich economies in sub-Saharan Africa

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Abstract: The general policy prescription for resource-rich countries is that, for sustainable consumption, a greater percentage of the windfall from resource rents should be channelled into accumulating foreign assets such as a sovereign public fund as done in Norway and other developed but resource-rich countries. This might not be a correct policy prescription for resource-rich sub-Saharan African (SSA) countries, where public capital is very low to support the needed economic growth. In such countries, rents from resources serve as opportunity to scale-up the needed public capital. Using panel data for the period 1990–2013, we find in line with the scaling-up hypothesis that resource rents significantly increase public investment in SSA and that this tends to depend on the quality of political institutions. We also find evidence of a positive effect of public investment on economic growth, which also depends on the level of resource rents. Using some of the components of public investment, such as health and education expenditure, we find a negative effect of resource rents, suggesting among other things that public spending of resource rents is directed more to other infrastructure investments.

Keywords: public investment, resource rents, growth, political institutions, sub-Saharan Africa
JEL classification: C23, E00, O10

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1 Introduction

Whether natural resource wealth is a blessing or a curse is an unsettled issue in the development economics literature that studies the effect of natural resource wealth on national economies. On the one hand is the finding that resource-rich developing countries have performed poorly in terms of economic growth and development in comparison with resource-poor developing countries (Gylfason 2000, 2001; Gylfason and Zoega 2002; Mehlum et al. 2006; Sachs and Warner 1995, 2002). This phenomenon has been baptized in the development literature as 'the curse of natural resources'. Despite the popularity of the curse of natural resources hypothesis, others have reported findings that are at variance with this view (e.g. see Brunnschweiler 2008; Brunnschweiler and Bulte 2008; Butkiewicz and Yanikkaya 2010; Ding and Field 2005).

Among other things, one important channel through which natural resource wealth may benefit or inhibit growth and development effort of a country is how revenue (rent) generated from the resource is allocated both temporally and intertemporally between public investment and public consumption expenditure. In this paper, we argue that the allocation of resource rents between public investment and consumption is conditional on the level of institutional quality. Further, the growth enhancing effect of public sector investment depends on the quantity, quality, and efficiency of public investment expenditure, which in turn depends on the presence of good institutions. Here, we focus on the 'quantity effect' of public investment on growth, conditional on the level of resource rent and institutional quality. We do not account for the growth effect of quality and efficiency of public investment growth in this paper because of lack of data on these dimensions of public investment.

Therefore, the objective of this paper is to investigate the effect of resource wealth on economic performance through public investment (and its interaction with institutions) for a sample of sub-Saharan African (SSA) countries. Our study is most similar to those of Cockx and Francken (2014) and Bhattacharyya and Collier (2013) who investigated, respectively, the relationship between resource dependence/abundance and public capital spending on health and resource rents. This paper, however, differs from these two studies by focusing solely on SSA countries owing to the peculiarities of the region in terms of management of natural resources. Bhattacharyya and Collier (2013) included only three African countries in their analysis, whereas Cockx and Francken (2014) considered a world sample without a deeper analysis of SSA. Moreover, Cockx and Francken (2014) only focused on the relationship between resource dependence/abundance and health spending, which is a narrow measure of public investment. Further, neither of the two studies analysed the interactive effect of resource rents and public investment (or its components) on growth, which this paper has considered. By analysing this interactive effect, we are able to answer the question on whether having more resource rents but not channelling a significant amount of that into public capital is one of the reasons for a resource curse beyond institutional explanation. Additionally, we also considered aggregated and disaggregated data by analysing the impact of resource rents on total public investment as well as on health and education. We extended the work of Cockx and Francken (2014) by including both aggregate public investment and education in our analysis, whereas in the case of Bhattacharyya and Collier (2013) we extended it by including both health and education and a large number of SSA countries in the analysis. However, owing to data constraints, public investment in infrastructure is omitted from the current study, although its importance is acknowledged, especially in the context of SSA where it is one of the major constraints on a firm's productivity and where the power sector is a major contributor to the region's infrastructure deficit.

This study also differs from previous studies by considering different measures of institutional quality, each capturing different aspects of institutions, with the goal of providing information on which aspects of institutions matter as a transmission channel for resource windfall on public investment

The point of convergence in the literature is that utilization of natural resource-related revenue to increase government investment may prove beneficial based on country-specific circumstances (Collier et al. 2010; Samake et al. 2013; van der Ploeg and Venables 2011). It has also been suggested that public investment policies that rely on revenue from natural resources should be carried out within the framework of fiscal sustainability that adjusts for the growth-enhancing impacts of such investment (IMF 2012; Samake et al. 2013). Also, institutional quality (i.e. governance structure) has been established to play a catalytic role in enhancing the efficiency of public investment in order to yield the desired results in growth and development (Albino-War et al. 2014). Thus, within our setup, the impact of resource windfall on public investment and hence long-term growth and development is ambiguous. In countries with weaker institutions, resource windfall will be channelled into consumption spending rather than investment. However, countries with good institutions will translate their resource windfall into productive public investment, which will translate into growth. Within SSA, Botswana and Mauritius appear to be on the path of sustained economic growth and development, which to a large extent has been credited to natural resource wealth in the presence of good institutions (e.g. see Acemoglu et al. 2003; Frankel 2016, forthcoming). In sharp contrast, the African giant Nigeria has failed to transform its oil and gas wealth into sustained economic growth and development. Sala-i-Martin and Subramanian (2013) argue that waste and poor institutional quality stemming from oil appear to have been responsible for Nigeria's long-running poor economic performance. Motivated by these polar cases of economic successes and failures of the above-mentioned SSA economies, we examined the impact of resource revenues on economic successes and failures through public investment in the presence of good institutions.

The relevance of the knowledge about whether natural resource windfalls translate into public investment and hence long-term growth cannot be over emphasized. An evaluation of the response of public investment to natural resource wealth is relevant from fiscal, growth, and natural resource sustainability perspectives. An understanding of the key drivers of public investment, and in particular of the role of natural resource revenues and institutional quality in explaining these dynamics, is relevant for public policy dialogue, design, formulation, and implementation of policies in resource-rich SSA countries. In particular, the present study provides important information relevant for the sustainable management of natural resources, particularly in SSA. The paper also provides additional information on the need to strengthen institutions in order to escape the natural resource curse syndrome. The study is relevant for countries with potential for discovering natural resources and even for those in early or advanced stages of resource exploitation.

The study revealed a number of interesting findings. First, there is robust evidence that natural resource rents exert positive impact on public investment; this effect is robust to the measure of public capital expenditure, that is, public investment rate versus public capital. Second, in addition to resource rents, we found strong evidence that differences in the level of public investment in SSA is accounted for by aid, external debt stock, openness to trade, political institutions, and the interaction effect between political institutions and resource rents. Third, consistent with models of growth, we found strong evidence of positive effect of public investment on economic growth, conditional on the level of natural resource rents. A corollary from this third finding is that the allocation of natural resource windfall income between public investment and consumption, for a given level of rents and institutional quality, is an important point of departure between successful economies and failed states, at least within SSA.

The rest of the paper is organized as follows. Section 2 reviews related literature on the role of natural resources in economic development. Section 3 presents an analysis of trends in public investment and resource rents nexus. Section 4 provides a description of our dataset and identification strategy, while Section 5 presents and discusses the empirical results. The paper concludes in Section 6.

2 Related literature

The concept of the natural resource curse remains an empirical 'conundrum' confronting researchers and development practitioners. The term coined by Auty (1994) argues that natural resource dependence (abundance) tends to mar economic growth via weakening institutions and fostering rents seeking activities (Collier 2000; Torvik 2002). This view has been largely espoused by studies such as Mehlum et al. (2006) and Sachs and Warner (1995) among others. For instance, Sachs and Warner (1995, 2001) document a negative effect of resource dependence on economic performance of resource-endowed economies. Also, Collier and Goderis (2007) assert that rents from non-agricultural resources tend to exert negative long-term impact on economic growth. Similar conclusions were also derived by Auty (2001), Neumayer (2004), and Papyrakis and Gerlagh (2004). Even at the localized level, James and Aadland affirm the presence of the resource curse hypothesis among counties in the United States: 'resource-dependent counties exhibit more anemic economic growth' relative to less-resource-intensive counties (2011: 440).

The resource curse viewpoint has also been challenged. A strand of the literature argues that the general assertion that natural resource exploitation is inimical to growth of host economies may be erroneous (e.g. see Brunnschweiler 2008; Brunnschweiler and Bulte 2008; Mehlum et al. 2006; Hodler 2006; van der Ploeg and Poelhekke 2009). They argue that the direction of impact is contingent on the quality of institutions in the economy (Mehlum et al. 2006), type of resource (i.e. point source versus non-point source; van der Ploeg and Poelhekke 2009), and the degree of ethnic fractionalization (Hodler 2006).

Despite the ongoing debate on whether natural resources is a curse or blessing, what remains is that the outcome of the impact depends largely on the channels via which revenues accruing from resource extraction are utilized. For instance, a popular debate in many (developing) economies that have recently discovered natural resources (such as oil) is whether to invest the rents in financial assets such as 'foreign' sovereign wealth funds or to invest in physical and human capital accumulation such as education, infrastructure, and health. Bhattacharyya and Collier (2013) argue that for resource-rich developing countries it will be more prudent to invest resource rents into public capital (i.e. education, health, and infrastructure). In other words, owing to the nature of resource rents, investing them into the development of human and physical capital is an effective way for countries to evade the curse of natural resources and turn the exploitation into a boom. To this end, recent advances in the literature on natural resources focus on the effect of resource rents on public investment or capital. Interestingly, evidence from Bhattacharyya and Collier (2013) reveals that inflow of resource rents is associated with lower public capital, with the effect more pronounced in countries with poor institutions. Gylfason (2001) also shows that public spending on health and education is lower in resource-abundant economies despite the inflow of revenues. As a result, school enrolment tends to be lower in these countries.

Findings from Cockx and Francken (2014), using a large panel dataset, suggest an empirical negative relationship between natural resource wealth and public healthcare expenditures. Juxtaposing these findings with those of Bhattacharyya and Collier (2013), therefore, raises a very important question: Why would resource-rich economies, particularly low-income countries

inundated with myriad of constraints of financing public projects, underutilize the opportunity offered by mineral revenue windfalls to spend on public capital? Put differently, what explains the diversion of resource revenues from investment into productive sectors (such as health, education, and infrastructure) to less productive uses? The literature on institutions and political economy offers some explanations. Tornell and Lane argue that in countries with low institutional quality and where power is contested between multiple groups based on say, ethnicity, the struggle for power can engender 'voracity effect' by which a shock such as resource revenue windfall generates 'a more-than-proportionate increase in fiscal redistribution' (1999: 22), thereby resulting in wastage. From a political economy perspective, Collier and Hoeffler (2009) argue that there is often low or weak demand for accountability by citizens in resource-rich economies on their governments' use of resource rents because these revenues were not generated via taxation. As a result, there is less pressure on governments to utilize revenues efficiently.

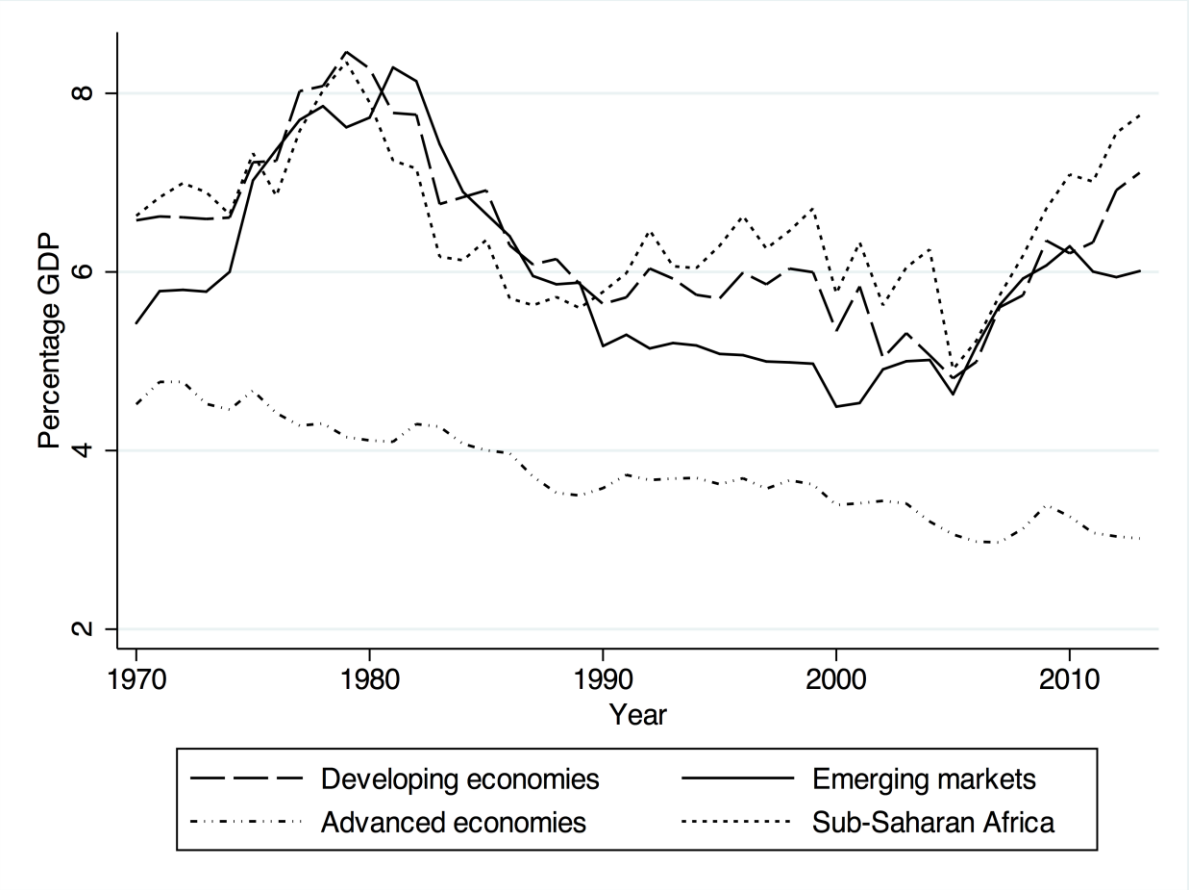
Given these propositions, it is interesting to further examine the impact of resource rents on public investments both at the aggregate public investment level and specific components such as health and education. This becomes more important for the case of SSA where, despite recent wave of spiral growth, indigenes opine that the growth impact on livelihoods and socioeconomic development is not discernible. As a result, we set out to revisit the resource curse thesis via a deeper analysis on resource rents and public investment as an important channel for the growth impact of natural resources. This helps to account for the extent to which diversion of resource revenues from investment in productive sectors mars the overall impact of natural resource abundance and dependence on socioeconomic development (Cockx and Francken 2014).

3 Trends in public investment and resource rents nexus

Given both theoretical and empirical support for the critical role of public capital, particularly high-quality public investment in infrastructure across countries in the growth process and the potential blessing or curse of resource revenues on public investment (e.g. see Arslanalp et al. 2010; Bhattacharyya and Collier 2013; Gupta et al. 2014; IMF 2014; Khan and Kumar 1997), we present in this section a brief discussion on the evolution of public investment rates across different income groups and SSA as a special case. We also illustrate by way of simple correlation analysis some preliminary stylized relationships between public investment and natural resource receipts in SSA economies.

Figure 1 shows the evolution of global public investment rates over the last four decades (i.e. 1970–2013). Evidently, public investment as a percentage share of gross domestic product (GDP) in advanced economies has witnessed a historically steady decline. Average public investment steadily declined in developed economies from about 4.4 per cent between 1970 and 1985 to a low of 3 per cent in 2013. Over the period 1970–2013, public investment as a percentage of output averaged only 3.8 per cent in developed economies. In contrast, after reaching peak public investment (per cent of GDP) rates of around 8.5 (1979), 8.3 (1981), and 8.4 (1979) per cent for developing economies, emerging markets, and SSA countries, respectively, the trend since the early 1980s has mimicked that of developed economies until around 2006–07 when it reversed towards a recovery. Declining to an average of about 4–6 per cent of GDP in the early to mid-2000s in developing and emerging markets, recovery in public investments has hovered around 5 to almost 8 per cent between 2006 and 2013.

Figure 1: Global public investment trends



Source: Authors' compilation using data from study analysis.

As shown in Figure 1 and Table 1, public investment rates have been much higher in developing countries and emerging markets than in developed economies in the past decades, ostensibly because of the declining participation of government in the provision of essential economic and social infrastructure such as roads, hospitals, schools, electricity, and public housing in developed economies as well as lower GDP growth in these economies (IMF 2014). Private sector participation (through public–private partnerships) in the provision of infrastructure is higher in developed economies than in developing countries and emerging economies where the general government is still the major provider of these public services.

Table 1: Public investment trends by income group (per cent of GDP)

	1970–80	1980–90	1990–2000	2000–10	2011	2012	2013	1970–2013
Advanced economies	4.45	3.92	3.63	3.24	3.08	3.04	3.01	3.77
Emerging markets	6.74	6.76	5.05	5.24	6.00	5.94	6.01	5.96
Developing countries	7.30	6.76	5.82	5.48	6.33	6.92	7.11	6.37
Sub-Saharan Africa	7.28	6.31	6.22	5.99	7.01	7.56	7.75	6.51

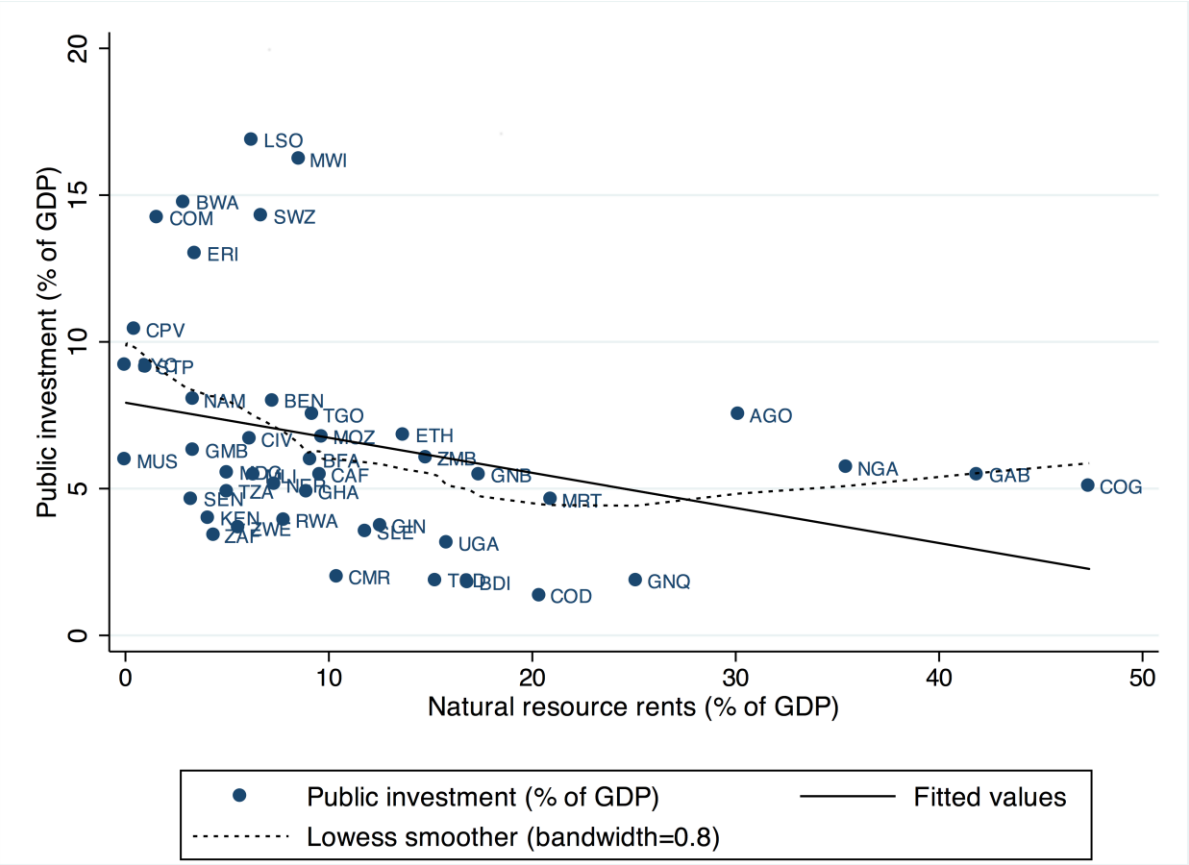
Source: Authors' compilation using data from IMF (2015).

In SSA for example, it is most governments' utmost priority to make huge political capital from provision of all forms of infrastructure in meeting the developmental needs of their respective countries while:

> . . . in many AEs [advanced economies], the private sector has largely displaced governments in providing economic infrastructures, such as communications, energy, transport, and water supply networks. The privatization of infrastructure provision is most pronounced in AEs like the United Kingdom, where private companies accounts for almost two-thirds of investment in these sectors. By contrast, in EMs [emerging markets] and LIDCs [low-income developing countries], these networks remain largely in public hands. (IMF 2015: 8)

Further, Figure 2 depicts the correlation between public investment and total natural resource rents, both a per cent of GDP, for SSA averaged over 1970–2013. The relationship for countries in SSA is illustrated using both a simple scatterplot with fitted trend and a non-parametric estimate of the same nexus using the lowess smoothing locally weighted regression. There is obviously high heterogeneity amongst SSA countries in terms of public investment rates and resource rents. Although majority of countries cluster within public investment rates <10 per cent and resource rents of at most 25 per cent of GDP (Equatorial Guinea recorded about 25.1 per cent from resource revenues), a few outlier countries are observable. Even though countries like Eritrea, Swaziland, Comoros Island, Botswana, and Malawi have a high public investment rate between 13 (Eritrea) and 17 (Lesotho) per cent, the same cannot be said of the revenues from natural resources since the corresponding receipts from these resources amounted to <10 per cent of GDP. On the other hand, four countries (Angola, Nigeria, Gabon, and Republic of Congo) recorded very high resource rents but relatively lower average public investment rate (i.e. 6.5 per cent on average).

Figure 2: Public investment versus resource rents in SSA



Source: Authors' compilation using data from study analysis.

The very high resource receipts is not surprising given huge oil deposits and commercial exploitation over the past decades (1970–2013) in Angola, Nigeria, and Gabon, with Republic of Congo having one of the richest mineral deposits (uranium, copper, gold, magnesium) in addition to petroleum and natural gas. Revenues from these resources in these countries are very substantial and contribute significantly to total domestic revenues. On the whole, the fitted regression line shows a negative relationship between public investment and natural resource rents—preliminary evidence of the natural resource curse on public capital. Interestingly, the lowess regression shows that the relationship is not completely negative for all countries. Although it is negative for many of the countries, the relationship assumes a positive trend for the lower right tail of the distribution. As the relationship here can only be described as correlational rather than causal, we leave the analysis on whether natural resource revenues cause public investment in SSA to the subsequent sections on empirical strategy and results.

4 Data and empirical strategy

4.1 Data description and sources

For this study, data on public investment and natural resource rents are taken from two main sources to empirically test the causal relationship. For all 39 sampled countries in SSA,[1] we use panel data on public investment as a share of GDP from IMF (2015) over the period 1990–2013. This is an updated comprehensive global database on disaggregated public and private investment rates as well as the stock of public capital. Public investment is measured using gross fixed capital formation of the general government (i.e. central and sub-national governments), excluding public entities such as public–private partnership, state-owned enterprises, and other parastatal organizations. Public investment series data are in constant 2005 international dollars (i.e. purchasing power parity) and normalized by each country's GDP, also measured in constant 2005 international dollars. The use of this unique database is premised on the ground that it allows for comparability across all countries sampled.

Data on natural resource revenues (total natural resource rents; per cent of GDP) are taken from the World Bank's World Development Indicators (WDI 2015). According to the World Bank, total natural resource rents consist of the sum of rents from oil, natural gas, coal, minerals, and forest resources.

Guided by the relevant empirical literature (e.g. Albino-War et al. 2014; Clements et al. 2005; Keefer and Knack 2007; Sturm 2001; Sturm and de Haan 1998; Tanzi and Davoodi 1997), we control for other potential drivers of public investment in the estimated models. Data on real per capita GDP growth, private investment as a percentage of GDP (constant 2005 international dollars), international aid (official development assistance as percentage of gross national income), external debt stock and external debt service, and trade openness (percentage of GDP) among a number of institutional variables are used in the model. (See Appendix Table A1 for detailed data definition and sources.)

[1] Angola, Benin, Botswana, Burkina Faso, Burundi, Cape Verde, Cameroon, Central African Republic, Comoros, Congo, Democratic Republic of Congo, Cote d'Ivoire, Eritrea, Ethiopia, Gabon, The Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Niger, Nigeria, Rwanda, Senegal, Seychelles, Sierra Leone, South Africa, Swaziland, Tanzania, Togo, Uganda, Zambia.

4.2 Empirical strategy

Studying the effects of natural resource rents on public investment and their consequences on growth present a number of empirical challenges. First, there is an issue of endogeneity, as there are possible feedback effects between public investment and GDP growth, institutions and natural resources rents. Second, because our model is an investment model, intuitively, a dynamic model appears appropriate and in such a case, given that our time period is only 24 years, Nickell bias is an important concern in the estimation strategy. Third, most of the variables have outliers as evident in Appendix Figure A1, which is also a concern to be considered in the estimation process.

We apply the following strategies to handle these challenges. First, to control for the effect of endogeneity and Nickell bias, we use a two-step system generalized method of moment (GMM) estimator, which is designed to correct for both. The two-step system GMM estimator was introduced by Blundell and Bond (1998) as an alternative to the Arellano and Bond (1991) difference GMM estimator for cases where the data are highly persistent. In such cases, the lagged levels of endogenous regressors are likely to be correlated with their first difference, thereby rendering them weak instruments in the difference GMM. The system GMM adds a level equation to the difference equation to correct for the potential bias due to weak internal instruments resulting from the high persistency of the data (Roodman 2009). The two-step approach system GMM is more efficient than the one-step approach. However, in the two-step approach the standard errors are generally biased downwards, as proved by Windmeijer (2005). Therefore, in our empirical application we apply the so-called Windmeijer correction to obtain robust standard errors for coefficient estimates.

In addressing the last concern, we log-transformed all the variables, except the political institutional index, to reduce the effects of potential outliers, which also has the added advantage of making the variables approximate a normal distribution. Our baseline model for estimating the effect of natural resource rents on public investment takes the following form:

$$\begin{aligned}\ln GI_{it} &= \alpha_1 \ln GI_{it-1} + \alpha_2 GGDP_{it-1} + \alpha_3 \ln RR_{it-1} + \alpha_4 Pol_{it-1} + \alpha_5 \ln RR_{it-1} \times Pol_{it-1} \\ &\quad + \alpha' \mathbf{X}_{it-1} + v_i + u_t + \varepsilon_{it}\end{aligned}, \qquad (1)$$

where $\ln GI_{it}$ and $GGDP_{it-1}$ are the log public investment and the GDP growth rate, respectively, and $\ln RR_{it-1}$, Pol_{it-1}, $\ln RR_{it-1} \times Pol_{it-1}$, and $\mathbf{X}_{it-1}$ represent log natural resource rents, institutions, interaction term between natural resource rents and institutions, and a vector of controls, respectively. The random error term is denoted by ε_{it}; v_i is the country fixed effects and u_t is the time fixed effects. Subscript i is the country dimension and t denotes time. We lagged each of the right-hand side variables, except the fixed effect terms by one year to address the concern that the impact of the variables on investment is not immediate, and also to reduce the feedback effect. The choice of variables in the above model is influenced by standard hypotheses in the literature and previous empirical research on public investment in particular, especially that of Sturm (2001) and Bhattacharyya and Collier (2013). The set of controls in the vector X_{it} includes aid, private investment, trade, debt service, and external debt stock. The total effect of rents on public investment is given by $\partial \ln GI_{it} / \partial \ln RR_{it-1} = \alpha_3 + \alpha_5 \times \mathrm{Pol}_{it-1}$. Whether the effect is positive, negative, or zero depends on the signs and relative magnitudes of each of these coefficients (α_3 and α_5) as well as the level of political institutions.

The inclusion of real GDP growth rate is to control for cyclical factors. We hypothesized a negative effect of real GDP growth on public investment. The reason is that policy makers are

likely to increase public spending during recession in order to create jobs and move the economy out of recession and the reverse is expected during economic boom periods.

High level of government debt is generally hypothesized to lead to less government spending on public capital. For instance, Roubini and Sachs (1989) argue that in periods of restrictive fiscal policies and fiscal consolidation, public capital spending is the first to be reduced because it is an easy target relative to, for example, recurrent expenditure. De Haan et al. (1996) and Sturm (2001) provided evidence in support of this hypothesis for Organization for Economic Co-operation and Development (OECD) and developing countries, respectively. We tested this hypothesis by considering both the stock of external debt and its servicing. The stock captures the level effect of the size of the debt on public capital spending, whereas debt servicing reflects the link between public investment/capital and interest rate associated with the funds used in the investment.

Another commonly presented hypothesis in the literature on public capital spending, especially for developing countries is that foreign aid helps create an enabling environment for sustainable growth because the use of aid funds are generally specified, mostly targeting areas such as infrastructure improvement, health care, and education. The general expectation, therefore, is that foreign aid is positively related to public capital spending.

The openness hypothesis, according to which countries more open to trade are likely to spend more on public capital to scale-up the necessary infrastructure requirement and be competitive in attracting business interest, is considered in our model by including trade as one of the covariates. Trade is expected to be positively related to public capital spending.

Additionally, it is possible that the level of public investment is influenced by private investment, either as substitute or complement, and therefore moves in tandem. We examine this by including private investment as one of the covariates. However, the direction of the effect is ambiguous; it could go in either direction depending on whether they are substitutes or complements.

We also consider the hypothesis that resource rents in a developing country could be a channel for scaling up public capital spending (which is often in short-supply) or for accumulating foreign assets by, for instance, putting windfalls from natural resources into sovereign wealth funds. However, the levels of rents that are either put into accumulating foreign financial assets for the country or channelled into improving public capital depend greatly on political institutions and how strong they are in providing checks on government to prevent appropriation of most of the windfall from resource rents for personal gains. The direction of the effect of resource rents and the interaction between resource rents and political institutions with regard to public capital spending are also ambiguous. Resource-rich countries might actually spend less on public capital if the political institutions that provide checks on the political class are weak, thereby making it attractive for the politician to misappropriate the windfall from natural resource rents rather than investing in public capital. Another view is that because resource rents are government revenues that are not sourced from taxing the citizenry, less scrutiny is provided by the public on the use of such funds (Besley 2006; Collier and Hoeffler 2009). It could also be positive if other sources of government revenues are very low to support public capital spending. For example, channelling some of the resource rents into public capital spending is one of the major options for governments to scale-up public capital at least in the provision of basic infrastructure requirements for its citizens. The direction of the effect, therefore, will depend on the magnitude of these effects and the strength of these opposing forces.

To address our second question, we estimate a growth model with the assumption that the channel of transmission of the effect of resource windfall on growth is via public investment. This growth model is expressed as:

$$\begin{aligned} GGDP_{it} &= \beta_1 \ln GDP_{it-1} + \beta_2 \ln GI_{it-1} + \beta_3 \ln PI_{it-1} + \beta_4 \ln RR_{it-1} + \beta_5 Pol_{it-1} \\ &+ \beta_6 \ln GI_{it-1} \times \ln RR_{it-1} + \beta_7 \ln PI_{it-1} \times \ln RR_{it-1} + B'\mathbf{S}_{it-1} + v_i + u_t + \upsilon_{it} \end{aligned}, \quad (2)$$

where $\ln GDP_{it-1}$, $\ln PI_{it-1}$, $\ln GI_{it-1} \times \ln RR_{it-1}$, $\ln PI_{it-1} \times \ln RR_{it-1}$, and $\mathbf{S}_{it-1}$ are GDP per capita, log private investment, interaction term between public investment and resource rents, interaction term between private investment and resource rents, and a vector of controls, respectively. The random error term is denoted by υ_{it}, whereas the other variables are the same as in equation (1). The choice of variables is motivated by the literature on growth empirics (e.g. Barro 1997; Bassanini and Scarpetta 2001; Islam 2005) and also by Arslanalp et al. (2010). The other controls denoted in the model by $\mathbf{S}_{it-1}$ include trade and aid. Notice that as the channel of transmission of resource rents on growth is through public investment, the effect of rents on growth from equation (2) is regarded as a partial effect, whereas the total effect of rents on growth is the direct partial effect of rents from the growth model and the indirect partial effect from the investment model. Total growth effect of rents can be obtained by

$$\left(\partial GGDP_{it} / \partial \ln RR_{it-1}\right) + \left(\partial GGDP_{it} / \partial GI_{it}\right) \times \left(\partial GI_{it} / \partial \ln RR_{it-1}\right).$$

This is because rents affect growth directly in equation (2) and indirectly in equation (1) as the transmission channel.

5 Results

First, we present the results based on the public investment model, using political institutional index to proxy for the quality of institutions. Next, we assess how sensitive the results are to different institutional proxy indices (World Bank's Worldwide Governance Indicators; see WGI 2015) and also the measure of public spending (public capital stock instead of public investment as a share of output). As a final step in our analysis, we present and discuss the results based on the economic growth model in which we control for public investment and resource rents. The variable of interest in the growth model is resource rent and its interaction with public investment.

5.1 Determinants of public investment and the interaction effect of rents and political institutions

The public (government) investment model as presented in equation (1) was estimated using the approach outlined in the empirical section and the results are presented in Table 2. The results are interpreted as elasticities, as all the variables are in natural logarithm, except the institutional variable, which is not in logarithm owing to negative values. Seven different models were estimated, adding one variable at a time. The explanatory variables were added sequentially to assess the impact of the inclusion and exclusion of the relevant determinants of public investment on the estimate for our variable of interest in terms of direction and level of statistical significance.

Table 2: System GMM estimates for public investment for sub-Saharan countries

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Government investment ($\ln GI_{t-1}$)	0.880***	0.876***	0.865***	0.865***	0.840***	0.836***	0.835***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Real GDP growth ($GGDP_{t-1}$)	–0.002	–0.002	–0.002	–0.002	–0.001	–0.0004	–0.0003
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Rents ($\ln RR_{t-1}$)	–0.002	0.003	0.003	0.002	0.005	0.008	0.059**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)
Private investment ($\ln PI_{t-1}$)		0.040**	0.041**	0.041**	0.025	0.022	0.019
		(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Aid ($\ln Aid_{t-1}$)			0.019	0.020	0.032**	0.034**	0.044***
			(0.02)	(0.02)	(0.01)	(0.01)	(0.02)
External debt ($\ln ED_{t-1}$)			–0.032*	–0.033	–0.050*	–0.048*	–0.058**
			(0.02)	(0.02)	* (0.02)	(0.03)	(0.03)
Debt service ($\ln DS_{t-1}$)				0.007	–0.004	–0.004	–0.008
				(0.02)	(0.02)	(0.02)	(0.02)
Trade ($\ln TD_{t-1}$)					0.083***	0.095***	0.093***
					(0.03)	(0.03)	(0.03)
Institution ($\ln Pol_{t-1}$)						0.026	0.150**
						(0.04)	(0.06)
$\ln Pol_{t-1} \times \ln RR_{t-1}$							–0.065**
							(0.03)
Constant	0.250***	0.148**	0.244**	0.254**	0.025	–0.0429	–0.113
	(0.06)	(0.07)	(0.09)	(0.10)	(0.13)	(0.12)	(0.12)
Effect of rents							0.022**
							(0.009)
Test (*p* value)							
AR2	0.586	0.630	0.574	0.567	0.711	0.583	0.586
Hansen (diff.)	0.385	0.638	0.618	0.533	0.302	0.346	0.361
Instruments count	34	27	29	30	31	32	33
Groups	38	39	39	39	39	38	38
Integration	I(0)	I(0)	I(0)	I(0)	I(0)	I(0)	I(0)
N	890	890	882	880	864	841	841

Note: GMM, generalized method of moment (based on Blundell and Bond 1998); GDP, gross domestic product. The dependent variable is Government investment ($\ln GI_{t-1}$). Standard errors are in parentheses; *, **, and *** denote significance at 10, 5, and 1 per cent, respectively. Robust standard error, based on Windmeijer's (2005) finite-sample correction, is used to calculate the standard errors. We consider per capita real GDP growth as endogenous and use only the second lag as instrument. We also use the first lag of all other independent variables as their respective instruments. *AR2* denotes second-order autocorrelation. Hansen (diff.) represents the Hansen test for exogeneity of instruments.

Source: Authors' compilation using data from study analysis.

The results based on equation (1) indicate that the total effect of resource rents on public investment depends on the level of resource rents and the interaction between rents and level of institutional quality. Both estimates for resource rents and its interaction with political institutional quality variable are significant at the 5 per cent level in the case of column (7). However, in all other specifications that do not account for the interaction between institutional quality and resource rents, the estimate for rents is insignificant even at the 10 per cent level. The results also reveal that previous level of public investment, aid, trade, and external debt are significant covariates in the public investment model. The results in Table 2 should be treated as short-run estimates as it is a dynamic model. (The corresponding long-run estimates are presented in Appendix Table B1.) Consistent with the Samuelson–Le Chatelier principle, based on both theory and intuition, the significant long-run estimates are all larger in magnitude relative to their corresponding short-run estimates. We find a positive sign on the resource rents coefficient for all the specifications except for column (1), where it is negative. However, they are all insignificant except for the specification in column (7), which is statistically significant.

In our preferred specification (column (7)), the effect of resource rent on public investment depends on the signs of the estimates on resource rents and the interaction between rents and

institutions. In other words, the effect of resource rents on public investment is conditional on the level of institutions as the effect is given by $\partial \ln GI_{it} / \partial \ln RR_{it-1} = \alpha_3 + \alpha_5 \times Pol_{it-1}$.

The effect of resource rents based on the model in column (7) evaluated at the mean of institutional quality is 0.02, which is significant at the 5 per cent level. This result indicates that natural resource rents on average tend to induce public investment. However, as can be seen from Table 2, the interactive effect between rents and institutions on public investment is negative. The implication of this together with the positive coefficient on rent is that the overall effect of resource rent varies across countries in our sample. In particular, and surprisingly, our results suggest that the aggregate effect of resource rent on public investment is larger for countries with relatively poor political institutions than countries with stronger political institutions. This finding is contrary to the positive interaction effect found by Bhattacharyya and Collier (2013).[2] A possible explanation for the negative interaction effect is that natural resource-rich countries tend to invest more in national security, especially the military, to protect either their interests or the ethnic minority located in the resource-concentrated geographical region, or both. As argued by Ross, 'resource-rich, ethnically fractured states' (2001: 336), such as Angola, the Democratic Republic of Congo, Nigeria, Papua New Guinea, Sierra Leone, and South Africa, among others, may invest more in the military to reduce ethnic tension as regional and local actors compete for resource rights. This type of investment may reduce ethnic tension but may also lead to less development in political institutions such as democracy. This is line with the political economy argument of the so-called repression effect, where resource-rich countries would rather invest more in national security to create anti-democratic pressures to promote their interests.

The above explanation gains some support from the data when we focus attention on specific components of public investment—public investment in education and health, which are mostly donor-supported investments and are often linked to countries promoting good political institutions. Estimates presented in Appendix Table B4 show positive and significant interactive effects between rent and institutions when expenditures on education and health are used as dependent variables. We also obtain a negative aggregate effect of resource rent on education and health investments, which is consistent with Bhattacharyya and Collier (2013). This suggests that the aggregate positive effect of resource rent in the aggregate public investment model is driven by other types of investment rather than by investment in health and education. Another possible reason for this finding is that there is large investment deficit in countries with weaker institutions to begin with (e.g. countries that have experienced civil war); hence, the higher elasticity of rents on investment. The conclusion from our preferred specification is as follows:

- Public investment increases when a country is more open in terms of trade.
- Previously accumulated debt stock reduces current public spending.
- Good institutions promote public spending, but its impact in terms of magnitude depends on the level of natural resource rents.
- Foreign aid impacts positively on public investment.

[2] Bhattacharyya and Collier (2013) consider a sample of 45 resource-rich countries (with only three SSA countries in the sample) for the period 1970–2005, using public capital per capita and without controlling for other factors such as aid, external debt, debt service, or private investment in their model.

- The total effect of resource rents on public investment is positive; however, the size of the effect depends on the quality of institutions. GDP growth is insignificant, contrary to the significant positive effect found by Sturm (2001).[3]

5.2 Effect of different aspects of institutions on the link between public investment and resource rents

A valid concern is the possibility that the type of institutional index used, as reported in Table 1, influences our preferred results. To address this concern we use the World Bank's WGIs[4] (Kaufman et al. 2009; WGI 2015) as an alternative to the *polity2* institutional index. The following five dimensions are considered: (i) government effectiveness (e.g. the quality and competence of public service provision, independence from political pressures); (ii) regulatory quality (e.g. lack of excessive and arbitrary regulations); (iii) rule of law (e.g. fair and predictable rules, effectiveness of the judiciary); (iv) control of corruption (e.g. lack of exercise of public power for private gains); and (v) political stability (for detailed description of each of the indicators, see Appendix Table A1 and Appendix Figure A1).

Table 3 presents the results for each of the five dimensions of institutional quality based on our preferred specification. Each of the columns in the table represents each of the institutional quality indicators. For easy comparison, we also include the results based on the *polity2* index (last column of Table 3). The results from each of the five dimensions of institutional quality are not qualitatively different from our baseline model based on the *polity2* institutional quality index. There are, however, minor noticeable differences such as a significant economic growth effect in each of the new institutional results, whereas it is insignificant in our baseline *polity2* results. Also, we find differences in the sign of the debt service estimate for our baseline results relative to each of the results from the five institutional variables, although they are generally insignificant at the 5 per cent level. The implication from this exercise is that the general conclusion from our preferred public investment model is qualitatively robust to the choice of institutional index; however, the magnitude of the effects based on our variable of interest (the total effect of natural resource rents) varies with the institutional index used. The total effects range from 0.02 to 0.05 for *polity2* and control of corruption index, respectively. Each of the five indices from WGI (2015) produced slightly higher total effects of natural resource rents relative to our baseline institutional index.

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[3] Sturm (2001) considers 123 non-OECD countries for the period 1970–1998 based on a fixed effect model. This approach, however, does not control for possible endogeneity between GDP growth, private investment and public investment.

[4] The term 'governance' is used by Kaufmann et al. (2009) as a generic description of a large set of variables measuring institutional quality, whereas we focus on five of the indicators more relevant to investment decisions in a country.

Table 3: System GMM estimates for public investment using five different institutional quality indicators

Variables	(RL)	(CC)	(GE)	(RQ)	(PS)	(Pt2)
Government investment (lnGI_{t-1})	0.816***	0.805***	0.818***	0.824***	0.796***	0.835***
	(0.032)	(0.031)	(0.033)	(0.032)	(0.036)	(0.02)
Real GDP growth ($GGDP_{t-1}$)	–0.011**	–0.011*	–0.011**	–0.011**	–0.011**	–0.0003
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.00)
Rents (lnRR_{t-1})	0.073***	0.094***	0.055*	0.057**	0.093**	0.0263**
	(0.023)	(0.029)	(0.028)	(0.023)	(0.038)	(0.01)
Private invest. (lnPI_{t-1})	0.0341	0.025	0.027	0.038	0.026	0.019
	(0.042)	(0.041)	(0.039)	(0.042)	(0.040)	(0.02)
Aid (lnAid_{t-1})	0.073***	0.076***	0.073***	0.072***	0.073***	0.044***
	(0.015)	(0.015)	(0.016)	(0.015)	(0.016)	(0.02)
External debt (lnED_{t-1})	–0.079***	–0.076***	–0.074***	–0.077***	–0.086***	–0.058**
	(0.022)	(0.022)	(0.023)	(0.024)	(0.023)	(0.03)
Debt service (lnDS_{t-1})	0.038	0.044*	0.038	0.039	0.043*	–0.008
	(0.023)	(0.024)	(0.024)	(0.024)	(0.024)	(0.02)
Trade (lnTD_{t-1})	0.065**	0.058*	0.073**	0.074**	0.052	0.093***
	(0.031)	(0.030)	(0.032)	(0.031)	(0.031)	(0.03)
Institution (lnPol_{t-1})	0.270*	0.497***	0.240*	0.185	0.447**	0.007**
	(0.134)	(0.115)	(0.130)	(0.125)	(0.171)	(0.00)
lnPol_{t-1}×lnRR_{t-1}	–0.070***	–0.102**	–0.047	–0.057**	–0.082*	–0.003**
	(0.025)	(0.042)	(0.031)	(0.027)	(0.044)	(0.00)
Constant	0.011	–0.058	0.006	0.008	–0.001	–0.038
	(0.177)	(0.190)	(0.204)	(0.192)	(0.178)	(0.12)
Effect of rents	0.039**	0.047***	0.034**	0.026**	0.044**	0.020**
	(0.013)	(0.012)	(0.014)	(0.009)	(0.015)	(0.009)
Test (*p* value)						
AR2	0.193	0.202	0.191	0.184	0.203	0.586
Hansen (diff.)	0.587	0.610	0.662	0.672	0.615	0.361
Instruments count	24	24	24	24	24	33
Groups	39	39	39	39	39	38
N	491	490	490	491	491	841

Note: RL, rule of law; CC, control of corruption; GE, government effectiveness; RQ, regulatory quality; PS, political stability; Pt2, represents *polity2*. The dependent variable is Government investment (lnGI_{t-1}). Standard errors are in parentheses; *, **, and *** denote significance at 10, 5, and 1 per cent, respectively. Standard errors are based on Windmeijer's (2005) finite-sample correction. We consider per capita real GDP growth as endogenous and use only the second lag as instrument. We also use the first lag of all other independent variables as their respective instruments. *AR2* denotes second-order autocorrelation. Hansen (diff.) represents the Hansen test for exogeneity of instruments.

Source: Authors' compilation using data from study analysis.

5.3 Results from using public capital stock rather than investment as a share of GDP

Another valid concern raised by Bhattacharyya and Collier (2013) is the potential influence that business cycles could have on public investment, which could generate endogeneity problems. This is because in periods of recession public spending is likely to be cut relative to periods of increasing growth. However, using the public capital measure effectively addresses this issue. We follow Bhattacharyya and Collier (2013) and apply their public capital measure to assess the robustness of our positive finding on the impact of resource rents on public investment. We consider both the aggregate stock of public capital and a per capita measure.

The results from this exercise, based on our preferred specification, are presented in Table 4. These results are once again not qualitatively different from our baseline, and this is true whether we use the public capital per capita or aggregate capital stock measure. We still find a positive effect of rents irrespective of the measure of public spending. This implies that the concern of the influence of business cycles on government spending and the possible endogeneity it introduces when measured as public investment does not appear to be serious in our model, possibly owing to the design of the econometric model that controls for endogeneity issues, and

also the use of GDP growth that reduces the effect of business cycles. Hence, our baseline model is generally robust to the measure for public spending.

Table 4: System GMM estimates for public capital measure

	Log public capital per capita	Log public capital, aggregate
(Log public capital per capita)$_{t-1}$	0.985*** (0.00)	
Real GDP growth ($GGDP_{t-1}$)	0.0001 (0.00)	0.0001 (0.00)
Rents (lnRR_{t-1})	0.017** (0.01)	0.021*** (0.01)
(Log private capital per capita)$_{t-1}$	0.007* (0.00)	
Aid (lnAid_{t-1})	0.012*** (0.00)	0.015*** (0.00)
External debt (lnED_{t-1})	–0.025*** (0.01)	–0.026*** (0.01)
Debt service (lnDS_{t-1})	0.004 (0.00)	0.004 (0.00)
Trade (lnTD_{t-1})	0.023*** (0.01)	0.011* (0.01)
Institution (lnPol_{t-1})	0.041** (0.02)	0.045*** (0.02)
lnPol_{t-1}×lnRR_{t-1}	–0.023*** (0.01)	–0.023*** (0.01)
(Log public capital)$_{t-1}$		0.987*** (0.00)
(Log private capital)$_{t-1}$		0.011** (0.00)
Constant	–0.011 (0.03)	0.034 (0.04)
Effect of rents	0.004* (0.003)	0.01** (0.003)
Test (*p* value)		
Hansen (diff.)	0.431	0.560
Instruments count	34	34
Groups	38	38
N	845	845

Note: The dependent variables are the column headings. Standard errors are in parentheses; *, **, and *** denote significance at 10, 5, and 1 per cent, respectively. Standard errors are based on Windmeijer's (2005) finite-sample correction. We consider per capita real GDP growth as endogenous and use only the second lag as instruments. We also use the first lag of all other independent variables as their respective instruments. Hansen (diff.) represents the Hansen test for exogeneity of instruments.

Source: Authors' compilation using data from study analysis.

5.4 Role of public investment and its interaction effect on economic growth

A key hypothesis to test in our study is whether the effect of public capital spending on growth is conditional on the level of resource rents. We test this hypothesis by estimating a growth model as specified in equation (2). We then follow the same procedure of sequential addition of covariates as in the public investment estimation. The results are reported in Table 5. Each column in the table adds one more covariate to the model in the previous column until column (5), the preferred specification to test for the interactive effect of public investment and resource rents on economic growth. Column (6) adds the interaction between rents and institutions to our preferred model. The initial level of real GDP is significant (negative) only for the specification presented in column (2), in all other specifications it is insignificant at all of the conventional significance level.

Table 5: System GMM estimates for the growth model

	(1)	(2)	(3)	(4)	(5)	(6)
Real GDP per capita ($\ln GDP_{t-1}$)	–0.001	–0.007*	–0.004	–0.005	–0.0002	0.0001
	(0.004)	(0.004)	(0.004)	(0.006)	(0.007)	(0.007)
Government investment ($\ln GI_{t-1}$)	–0.014	–0.015	–0.015	–0.023	–0.089	–0.088*
	(0.013)	(0.014)	(0.015)	(0.014)	(0.053)	(0.052)
Private investment ($\ln PI_{t-1}$)	0.010*	0.007	0.006	0.005	0.054***	0.055***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.020)	(0.020)
Rents ($\ln RR_{t-1}$)	–0.004*	–0.005**	–0.004*	–0.003	–0.010	–0.010
	(0.002)	(0.002)	(0.002)	(0.002)	(0.023)	(0.023)
$(\text{Population Growth})_{t-1}$	0.010***	0.012***	0.011***	0.013***	0.011***	0.011***
	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Trade ($\ln TD_{t-1}$)		0.028**	0.027*	0.032**	0.022**	0.022**
		(0.013)	(0.014)	(0.014)	(0.010)	(0.010)
Aid ($\ln Aid_{t-1}$)			0.003	0.004	0.007	0.007
			(0.004)	(0.005)	(0.007)	(0.007)
Institution ($\ln Pol_{t-1}$)				0.033***	0.022**	0.016
				(0.009)	(0.010)	(0.014)
$\ln GI_{t-1} \times \ln RR_{t-1}$					0.035*	0.034*
					(0.017)	(0.017)
$\ln PI_{t-1} \times \ln RR_{t-1}$					–0.021***	–0.021***
					(0.007)	(0.007)
$\ln Pol_{t-1} \times \ln RR_{t-1}$						0.004
						(0.008)
Constant	0.0278	–0.044	–0.061	–0.095*	–0.080	–0.081
	(0.028)	(0.033)	(0.049)	(0.054)	(0.060)	(0.058)
Effect of government investment					0.066*	–0.023
					(0.033)	(0.019)
Effect of private investment					0.014*	0.014*
					(0.007)	(0.007)
Test (*p* value)						
AR2	0.434	0.466	0.472	0.545	0.416	0.421
Hansen (diff.)	0.452	0.429	0.385	0.411	0.493	0.504
Instrument count	8	9	10	11	13	14
Groups	39	39	39	38	38	38
N	891	875	869	846	846	846

Note: The dependent variable is log real GDP per capita. Standard errors are in parentheses; *, **, and *** denote significance at 10, 5, and 1 per cent, respectively. Standard errors are based on Windmeijer's (2005) finite-sample correction. We consider public investment as endogenous. We also use the first lag of all other independent variables as their respective instruments. *AR2* denotes second-order autocorrelation. Hansen (diff.) represents the Hansen test for exogeneity of instruments.

Source: Authors' compilation using data from study analysis.

Our variables of interest are public investment and the interaction between public investment and natural resource rents. The direct partial effect of public investment on growth is conditional on the level of resource rents. This is due to the significant positive interaction term between rents and public investment. The implication is that the effect of partial direct rents on growth depends on the level of natural resource rents; that is, a country with high rents from natural resources is likely to impact more on growth, as more rents are channelled into government capital spending. The total public investment effect on growth evaluated at the mean of resource rents is positive (0.07) and significant. For completeness, we also interacted private investment with resource rents and the result reveals a significant negative effect at the 10 per cent level, implying that high resource rents have a damping effect on the impact of private investment on economic growth. The total private investment effect on growth is positive (0.01) and statistically significant when evaluated at the mean of resource rents.

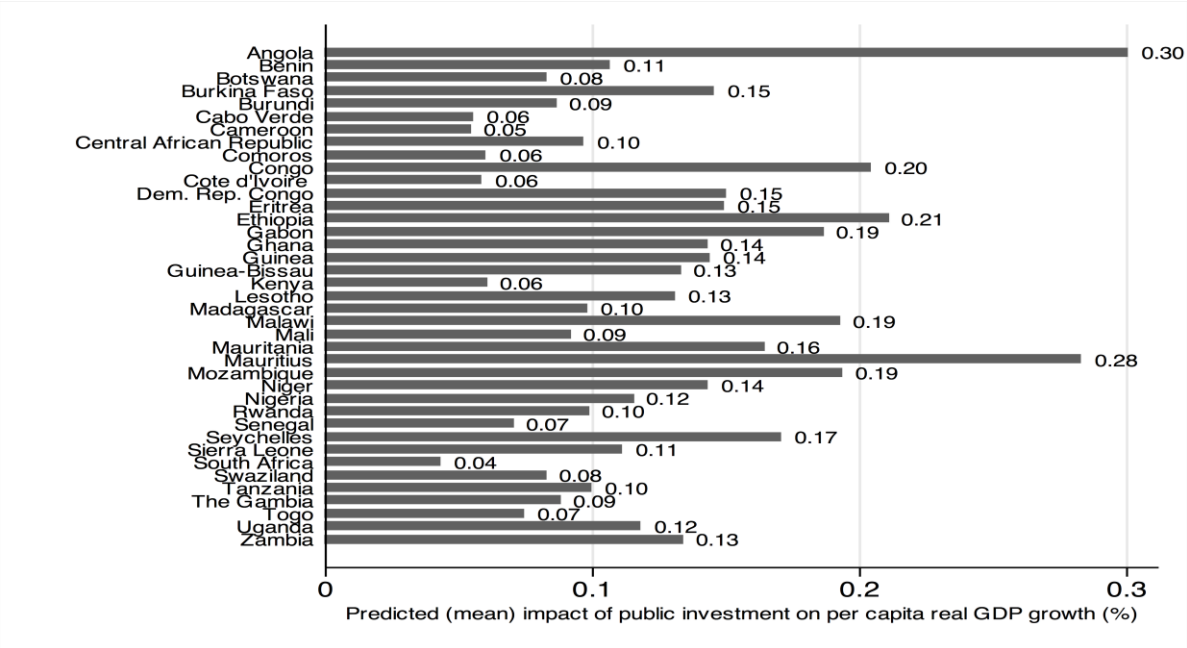
Thus, both private and government investment are growth enhancing, but the impact of public investment on growth, on average, is larger than that of private investment for the sampled countries in our dataset. Notice that the impact of resource rents on growth from our preferred

specification is evident only through the interaction of rents with public and private investments. This is because the coefficient estimate for rents is insignificant, whereas it is significant for interactions with both public and private investments. The total growth effect of rents at the mean of public investment, private investment, rents, and quality of institutions is 0.011.[5]

5.5 Predicted impact of public investment on growth

Using the estimated growth model (Table 5, column 5), we can calculate the predicted impact of public investment on growth by taking the partial derivative of the growth equation with respect to public investment. Using only the significant coefficients from the estimates, the predicted impact is calculated as $\beta_6 \times (\ln GI_{t-1} \times \ln RR_{t-1})$. The results from the prediction are reported in Figure 3 and reveal differences across the sampled countries on the mean impact of public investment on economic growth. The predicted impact ranges from 0.04 to 0.30, with South Africa as the country with the least predicted impact, whereas Angola has the highest impact value. The interpretation of these numbers is as follows. For instance, the value of the predicted impact of public investment on growth for South Africa is 0.04, implying public investment due to an increase in resource rents resulted in a 0.04 per cent increase in per capita GDP growth in South Africa.

Figure 3: Predicted impact of public investment on economic growth



Source: Authors' compilation using data from study analysis.

The implication is that a percentage change in per capita GDP growth due to a percentage change in public investment is small in South Africa relative to other countries. This further

[5] This is calculated by

$$\left(\partial GGDP_{it}/\partial \ln RR_{it-1}\right)+\left(\partial GGDP_{it}/\partial GI_{it}\right)\times\left(\partial \ln GI_{it}/\partial \ln RR_{it-1}\right)=\beta_4+\beta_6\times \ln GI_{it-1}+\beta_7\times \ln PI_{it-1}$$
$$+\left(\beta_2+\beta_6\times \ln RR_{it-1}\right)\times\left(\alpha_3+\alpha_5\times Pol_{it-1}\right),$$

but we only used the significant coefficients, implying β_2 and β_4 are excluded from the calculation. The total effect evaluated at the median of public investment, private investment, rents, and quality of institutions is 0.015, which is about the same value evaluated at the mean of the stated variables. This means that the calculated total growth effect of rents as reported in the text is not driven by outliers.

implies that, among other things, the South African economy is less sensitive to government spending of resource rents on public capital, possibly because of the relatively good level of public capital in terms of basic infrastructure (i.e. good roads, rail network, telecommunication, health facilities, educational infrastructure) relative to most of the other SSA countries. This means that there will be less pressure to scale-up public spending on such infrastructure. However, in aggregate terms, this does not mean that government spending on public capital from resource rents in South Africa is smaller compared to the other countries, but rather the sensitivity of per capita growth is less. Other countries with relatively higher predicted impact are Mauritius, Ethiopia, Congo-Brazzaville, Mozambique, Malawi, and Seychelles. The remaining predicted values for the other countries in the dataset could also be interpreted in the same manner. These values are predictions from our estimated model as presented in Table 5 and should be interpreted as such. They are in line with the general conclusion from the total elasticity estimate for public investment, which is positive, when evaluated at the mean of resource rents for the sampled countries in our study. It is also important to emphasize that the predictions presented in Figure 3 are for the short term.

5.6 Sensitivity analysis

As a check on how sensitive our main results are to business cycle effects and to the imposition of a dynamic structure on the public investment model, and how some specific government spending is related to resource rents, we considered the following. First, we apply both least squares with country fixed effects (fixed effect model) and a pooled ordinary least square (OLS) model by relaxing the dynamic structure on the public investment model. The results are reported in Appendix Table B2 and show that, qualitatively, the results from the fixed effect model are not significantly different from our main results (long-term estimates) (reported in Appendix Table B1, column 7), especially for our variables of interest (rents and the interaction between rents and the political institution index). The only major difference is the change of sign in the estimates for GDP growth and debt service, but both are insignificant in our main results. The estimate for GDP growth, however, is positive and significant in the fixed effect model, whereas it is negative but insignificant in our main results. The results based on the pooled OLS are significantly different from our main results, at least for our variables of interest in the public investment model. The estimates for resource rents are negative but insignificant in the preferred specification. The adjusted R^2 from this model is rather low, suggesting a poor fit using the pooled model and that the results from this model are not credible by not accounting for country-specific differences in the estimation.

As a further check on the effects of business cycles, we apply five-year averages to control for this effect and assess whether our main results are affected by business cycles that the inclusion of the GDP growth is unable to fully control for. The results for this exercise are reported in Appendix Table B3 and clearly indicate that, generally, our main results are robust (qualitatively) to business cycles and to data frequency, especially for our variables of interest.

Finally, we also consider two different public/government spending: health and education expenditures. The results from using these two expenditures are reported in Appendix Table B4 and provide similar conclusion to resource rent impacts, in line with Bhattacharyya and Collier (2013), but completely contrary to our main results. These results may indicate that the positive effect of resource rents in our main results is likely driven by investments in road and railways and other public infrastructure projects that are less likely to be financed by foreign aid. To confirm this, disaggregated data on public investment are needed, which we currently do not have on a consistent basis for the countries in our sample. Additionally, the differences in the results from both education and health expenditures relative to the aggregate public investment

also highlight the potential problems of aggregation when estimating investment models, which practitioners have to be aware of when interpreting such results.

6 Conclusion

This paper explores four key policy-relevant aspects of the link between public investment and resource rents for SSA countries. More specifically, the study attempts to answer the following key policy-relevant questions:

- What are the key drivers of public investment in resource-rich SSA countries?
- Do revenues from natural resources play any significant role in scaling up public investment?
- Does the interaction between resource rents and institutional quality explain public investment levels in SSA given country differences?
- What are the implications of the impact of resource rents via public investment on economic growth and management of natural resource windfalls in avoiding the resource curse in SSA economies?

Addressing the above questions, we use data on public investment, resource rents, political institutional index, real GDP growth, aid, and other macroeconomic and institutional variables for a sample of SSA countries for the period 1990–2013. The empirical analysis provides evidence of a positive effect of resource rents on public investment. The positive effect holds irrespective of the measure used for public capital spending (public investment rate or public capital stock). The positive effect is also robust to different econometric estimators such as a fixed effect model that controls for country fixed effects, but not in the case of a pooled OLS estimator. Results based on pooled OLS indicate a rather negative effect of resource rents, although insignificant at any of the conventional levels of significance. Importantly, the pooled model indicates a poor model fit based on the adjusted R^2 relative to the fixed effect model, therefore suggesting that the pooled OLS is a poor model to estimate the public investment model. The implication is that the pooled OLS results are not credible. Furthermore, the results are also robust to different time frequencies such as five-year averages.

Evidence indicates that resource rents, aid, external debt stock, trade, political institutions, and the interaction between political institutions and resource rents are key drivers of public investment, obviously with different effects in terms of sign and size. Moreover, we also find that public investment has a positive effect on economic growth and the impact tends to depend on the level of resource rents.

The findings have important policy implications on the management of resource rents and the links between resource rents, public investment and economic growth. Most policy prescriptions for resource-rich countries by the international community tend to advocate the accumulation of foreign financial assets such as through sovereign wealth funds (Bhattacharyya and Collier 2013). However, in most of these countries, there is a fundamental shortage of domestic capital, implying that most of the long-term capital accumulation will have to come from public investment. Consequently, this implies that resource rents should be channelled into the provision of public capital rather than be invested in foreign assets, as previously shown by van der Ploeg and Venables (2011), or a significant share should be invested in scaling-up pubic capital and accumulation of foreign assets for sustainable reasons, as shown by Berg et al. (2012). This will enhance the level and quality of public capital, which will ultimately impact positively on economic growth.

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Appendix A:Study data and variables

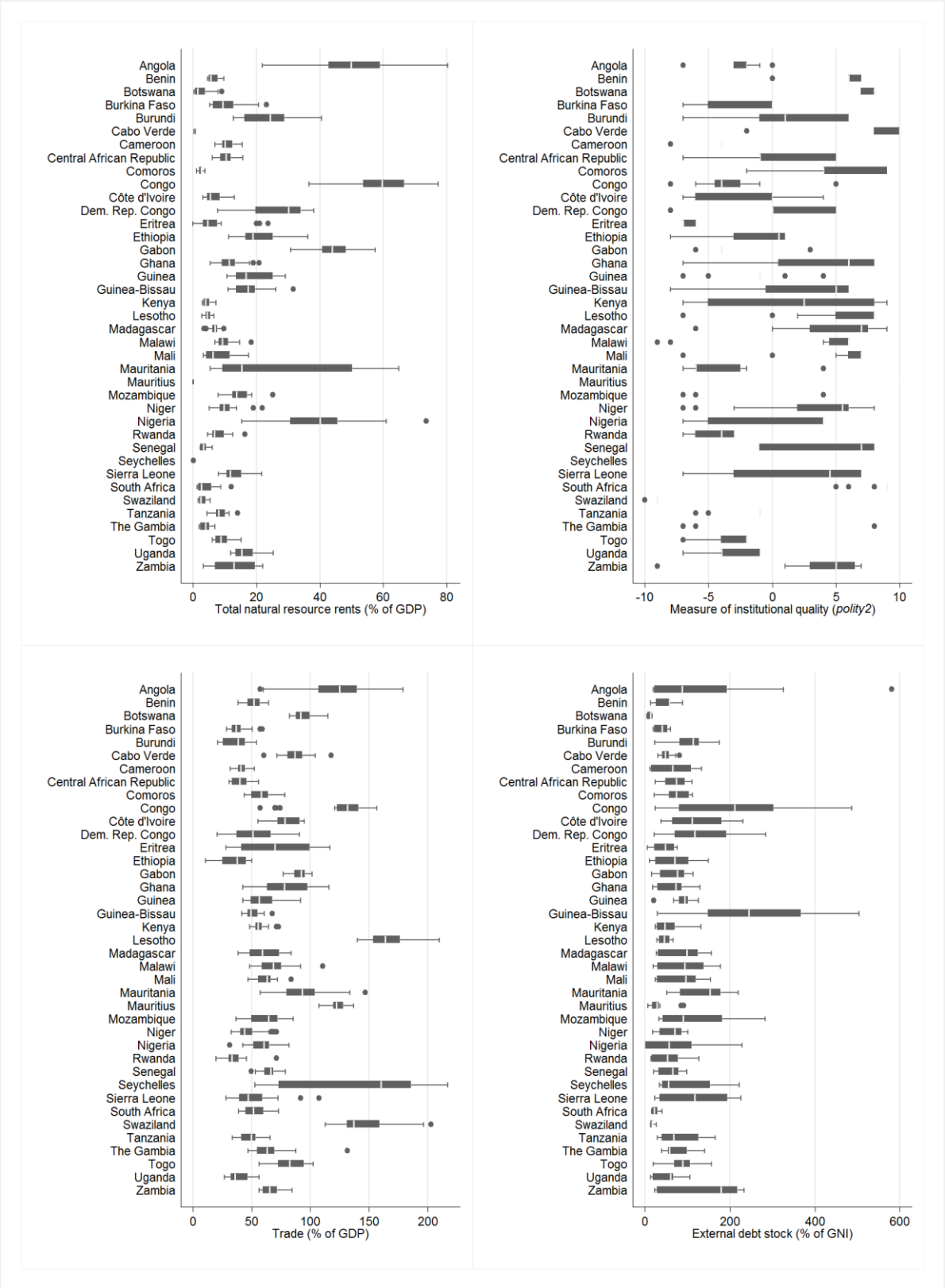
Table A1: Data description and sources

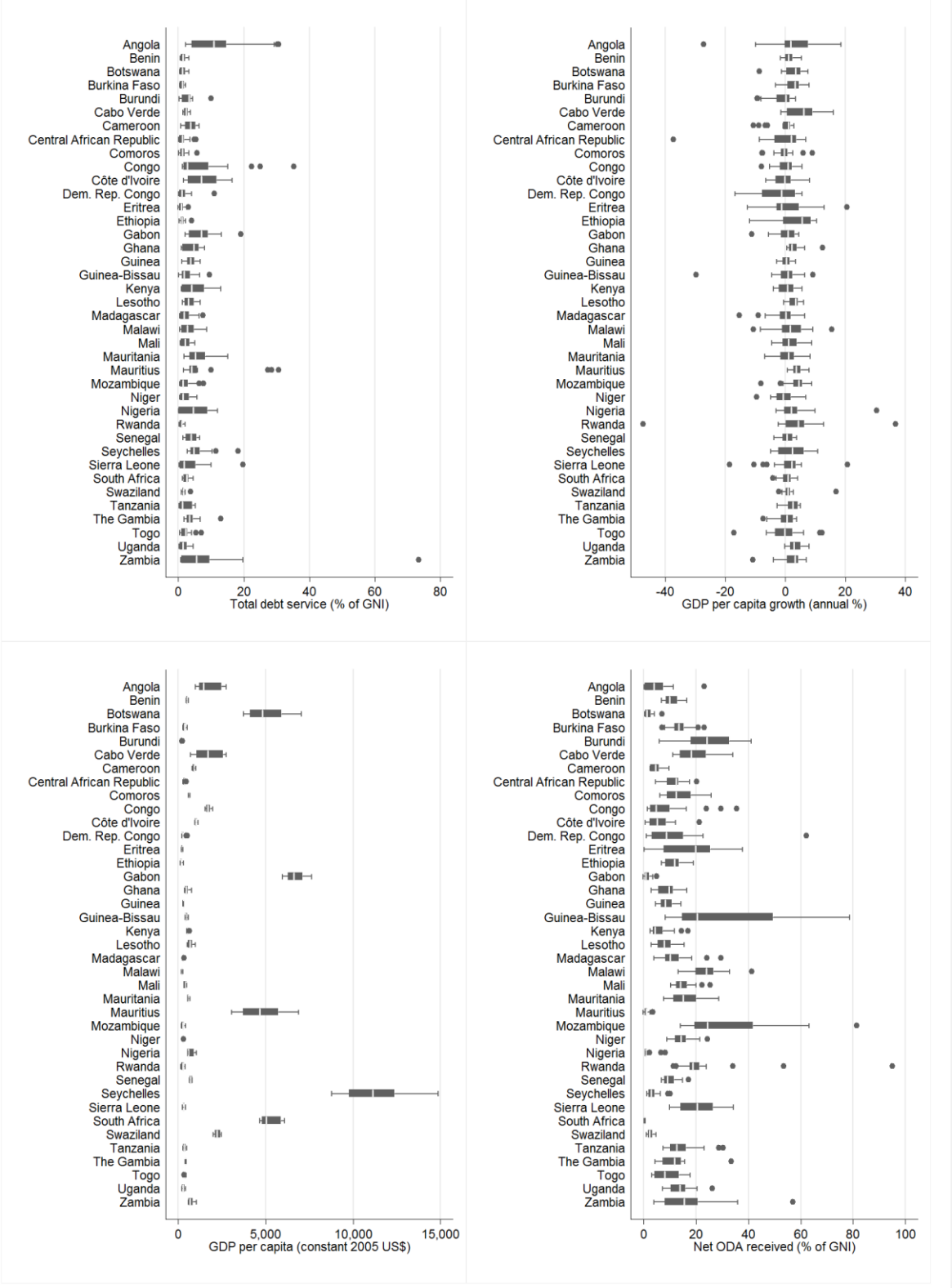
Variable	Description	Sources
Public investment	General government investment (gross fixed capital formation), in constant 2005 international dollars (percentage of GDP)	IMF (2015)
Private investment	Private investment (gross fixed capital formation), in constant 2005 international dollars (percentage of GDP)	IMF (2015)
Natural resource rents	Total natural resource rent is the sum of oil rents, natural gas rents, coal rents (hard and soft), mineral rents, and forest rents	WDI (2015)
Real per capita GDP growth	Annual percentage growth rate of GDP per capita based on constant 2005 US dollars	WDI (2015)
Trade	Trade is the sum of exports and imports of goods and services measured as a share of GDP	WDI (2015)
Aid	Net ODA consists of disbursements of loans made on concessional terms and grants by official agencies of the members of the DAC, multilateral institutions, and non-DAC countries	WDI (2015)
External debt stock	Total external debt is the sum of public, publicly guaranteed, and private non-guaranteed long-term debt, use of IMF credit, and short-term debt. It is normalized by the gross national income	WDI (2015)
External debt service	Debt service is the sum of principle repayments and interest actually paid in currency, goods, or services (percentage of exports of goods, services, and primary income)	WDI (2015)
Polity2	The polity score is computed by subtracting the *p_autocracy* score from the *p_democracy* score; the resulting unified polity scale ranges from +10 (strongly democratic) to −10 (strongly autocratic)	CSP (2014)
Government effectiveness	Reflects perceptions of the quality of public services, the quality of civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies; the score, which is in the standard normal unit, ranges between −2.5 and +2.5, with higher values representing better outcomes	WGI (2015)
Regulatory quality	Reflects perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development; the score, which is in the standard normal unit, ranges between −2.5 and +2.5, with higher values representing better outcomes	WGI (2015)
Rule of law	Reflects perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence; the score, which is in the standard normal unit, ranges between −2.5 and +2.5, with higher values representing better outcomes	WGI (2015)
Control of corruption	Reflects perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as 'capture' of the state by elites and private interests; the score, which is in the standard normal unit, ranges between −2.5 and 2.5, with higher values representing better outcomes	WGI (2015)

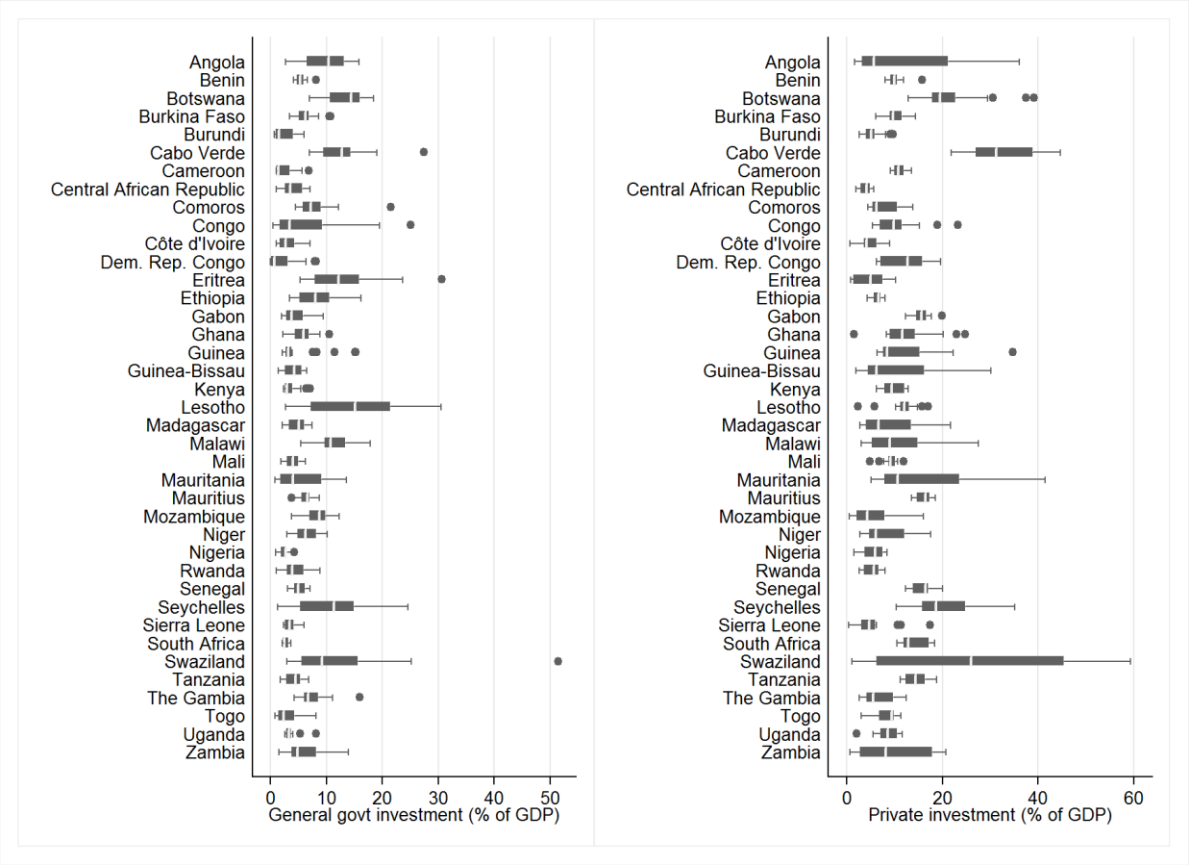
Note: GDP, gross domestic product; ODA, official development assistance; DAC, development assistance committee; IMF, International Monetary Fund.

Source: Authors' compilation based on CSP (2014), IMF (2015), WDI (2015), and WGI (2015).

Figure A1: Boxplot for each of the variables in our main model before log transformation




Angola
Benin
Botswana
Burkina Faso
Burundi
Cabo Verde
Cameroon
Central African Republic
Comoros
Congo
Côte d'Ivoire
Dem. Rep. Congo
Eritrea
Ethiopia
Gabon
Ghana
Guinea
Guinea-Bissau
Kenya
Lesotho
Madagascar
Malawi
Mali
Mauritania
Mauritius
Mozambique
Niger
Nigeria
Rwanda
Senegal
Seychelles
Sierra Leone
South Africa
Swaziland
Tanzania
The Gambia
Togo
Uganda
Zambia
0
20
40
60
80
Total debt service (% of GNI)
-40
-20
0
20
40
GDP per capita growth (annual %)
0
5,000
10,000
15,000
GDP per capita (constant 2005 US$)
0
20
40
60
80
100
Net ODA received (% of GNI)



Note: GDP, gross domestic product; GNI, gross national income; ODA, official development assistance; govt, government.

Source: Authors' compilation using data from study analysis.

Appendix B: Robustness check

Table B1: Long-run estimates for the public investment model

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Real GDP growth ($GGDP_{t-1}$)	–0.020	–0.018	–0.014	–0.017	–0.007	–0.003	–0.002
	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)	(0.02)	(0.02)
Rents ($\ln RR_{t-1}$)	–0.019	0.025	0.0191	0.018	0.030	0.047	0.357**
	(0.05)	(0.04)	(0.05)	(0.05)	(0.03)	(0.04)	(0.15)
Private investment ($\ln PI_{t-1}$)		0.326**	0.304**	0.300**	0.154	0.135	0.115
		(0.13)	(0.13)	(0.14)	(0.11)	(0.11)	(0.11)
Aid ($\ln Aid_{t-1}$)			0.144	0.149	0.202**	0.209**	0.265***
			(0.11)	(0.12)	(0.08)	(0.08)	(0.09)
External debt ($\ln ED_{t-1}$)			–0.237*	–0.242	–0.313**	–0.290*	–0.351**
			(0.13)	(0.17)	(0.14)	(0.15)	(0.15)
Debt service ($\ln DS_{t-1}$)				0.048	–0.026	–0.025	–0.046
				(0.15)	(0.12)	(0.12)	(0.12)
Trade ($\ln TD_{t-1}$)					0.521***	0.581***	0.562***
					(0.15)	(0.14)	(0.13)
Institution ($\ln Pol_{t-1}$)						0.161	0.910**
						(0.23)	(0.41)
$\ln Pol_{t-1} \times \ln RR_{t-1}$							–0.395**
							(0.18)
Effect of rents							0.139**
							(0.062)
N	890	890	882	880	864	841	841

Note: Standard errors are in parentheses; *, **, and *** denote significance at 10, 5, and 1 per cent, respectively.

Source: Authors' compilation using data from study analysis.

Table B2: FE and pooled OLS estimates for public investment model, yearly data

Variable	FE	FE	Pooled	Pooled
Real GDP growth ($GGDP_{t-1}$)	0.016*** (0.00)	0.009*** (0.00)	0.032*** (0.01)	0.016*** (0.01)
Rents ($\ln RR_{t-1}$)	0.162*** (0.05)	0.214** (0.08)	–0.114*** (0.01)	–0.033 (0.05)
Private investment ($\ln PI_{t-1}$)		0.056 (0.04)		–0.040 (0.04)
Aid ($\ln Aid_{t-1}$)		0.195*** (0.04)		0.277*** (0.03)
External debt ($\ln ED_{t-1}$)		–0.259*** (0.05)		–0.361*** (0.06)
Debt service ($\ln DS_{t-1}$)		0.032 (0.04)		0.029 (0.04)
Trade ($\ln TD_{t-1}$)		0.325*** (0.10)		0.679*** (0.06)
Institution ($\ln Pol_{t-1}$)		0.358* (0.21)		0.101 (0.14)
$\ln Pol_{t-1} \times \ln RR_{t-1}$		–0.185* (0.10)		–0.021 (0.06)
Constant	1.526*** (0.21)	0.717 (0.51)	1.684*** (0.05)	–0.289 (0.31)
Effect of rents		0.046** (0.046)		
N	891	842	891	842
R^2-adjusted	0.54	0.61	0.10	0.34

Note: FE, fixed effect; OLS, ordinary least square. Standard errors are in parentheses; *, **, and *** denote significance at 10, 5, and 1 per cent, respectively.

Source: Authors' compilation using data from study analysis.

Table B3: System GMM and FE estimates for the public investment model using five-year averages

Variable	GMM	GMM	FE	FE
Government investment (lnGI_{t-1})	0.616*** (0.08)	0.588*** (0.09)		
Real GDP growth ($GGDP_{t-1}$)	0.036* (0.02)	0.014 (0.02)	0.044** (0.02)	0.020 (0.02)
Rents (lnRR_{t-1})	0.031 (0.02)	0.246** (0.12)	0.138 (0.11)	0.518* (0.27)
Private investment (lnPI_{t-1})		0.126 (0.10)		0.127 (0.16)
Aid (lnAid_{t-1})		0.103* (0.05)		–0.042 (0.13)
External debt (lnED_{t-1})		–0.085 (0.09)		–0.348** (0.16)
Debt service (lnDS_{t-1})		–0.031 (0.06)		0.221 (0.15)
Trade (lnTD_{t-1})		0.101 (0.11)		0.275 (0.34)
Institution (lnPol_{t-1})		0.446 (0.27)		1.720* (0.86)
lnPol_{t-1}×lnRR_{t-1}		–0.259** (0.13)		–0.641* (0.33)
Constant	0.502*** (0.12)	–0.313 (0.61)	1.308*** (0.49)	–0.172 (1.78)
Effect of rents		0.094* (0.047)		0.143 (0.119)
R^2-adjusted			0.52	0.58
Test (*p* value)				
Hansen (diff.)	0.473	0.048		
Instrument count	6	12		
N	117	113	117	113

Note: GMM, generalized method of moment (based on Blundell and Bond 1998). Standard errors are in parentheses; *, **, and *** denote significance at 10, 5, and 1 per cent, respectively. Robust standard error, based on Windmeijer's (2005) finite-sample correction, is used to calculate the standard errors. Hansen (diff.) represents the Hansen test for exogeneity of instruments.

Source: Authors' compilation using data from study analysis.

Table B4: System GMM estimates using expenditure on education and health

Variable	Log education	Log health
Education expenditure (ln$Educ.Exp_{t-1}$)	0.918*** (0.02)	
Real GDP growth ($GGDP_{t-1}$)	–0.0003 (0.00)	0.002* (0.00)
Rents (lnRR_{t-1})	–0.046** (0.02)	–0.017** (0.01)
Private investment (lnPI_{t-1})	0.035** (0.02)	0.002 (0.01)
Aid (lnAid_{t-1})	0.003 (0.01)	–0.001 (0.00)
External debt (lnED_{t-1})	–0.026** (0.01)	–0.009 (0.01)
Debt service (lnDS_{t-1})	0.006 (0.01)	0.005 (0.01)
Trade (lnTD_{t-1})	0.017 (0.02)	–0.018 (0.01)
Institution (lnPol_{t-1})	–0.078** (0.04)	–0.039 (0.02)
lnPol_{t-1}×lnRR_{t-1}	0.061*** (0.02)	0.020** (0.01)
Health expenditure (ln$Health.Exp_{t-1}$)		0.935*** (0.02)
Constant	0.128 (0.14)	0.253*** (0.09)
Effect of rent	–0.012* (0.006)	–0.006* (0.003)
Test (*p* value)		
AR2	0.102	0.837
Hansen (diff.)	0.393	0.711
Instrument count	12	12
Groups	33	38
N	293	664

Note: GMM, generalized method of moment (based on Blundell and Bond 1998). Standard errors are in parentheses; *, **, and *** denote 10, 5, and 1 per cent, respectively. Robust standard error, based on Windmeijer's (2005) finite-sample correction, is used to calculate the standard errors. We consider per capita real GDP growth as endogenous and use only the second lag as instruments. We also use the first lag of all other independent variables as their respective instruments. *AR2* denotes second-order autocorrelation. Hansen (diff.) represents the Hansen test for exogeneity of instruments.

Source: Authors' compilation using data from study analysis.