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Understanding Public Spending Trends for Infrastructure in Developing Countries

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Abstract

Evidence of public expenditure on infrastructure is extremely sparse. Little is known about the trends and patterns of infrastructure expenditure, and there is no real basis for assessing the adequacy and efficiency of infrastructure spending. Drawing on the World Bank's novel BOOST database, this paper provides a first relatively disaggregated picture of infrastructure spending trends and patterns for a large sample of more than 70 developing countries covering 2010–18, drilling down into expenditure by sector for roads as well as electricity, and distinguishing operating from capital expenditure. Complementary sources of data are tapped to allow comparison between expenditure patterns on and off budget. The study finds that on-budget expenditure on infrastructure has been low both in absolute terms (1 percent of gross domestic product) and relative terms (5 percent of total public spending), as well as declining over time. Overall, infrastructure spending declined by about one-third over 2010–18 (with the road sector bearing the brunt of the decrease), and now lies well below estimates of the required levels, except in a handful of cases. There is evidence that low-income countries, despite lower spending envelopes, attach greater priority to public investment and infrastructure spending than their middle-income counterparts. Econometric analysis suggests that infrastructure spending in low- and middle-income countries has been historically procyclical, although to a lesser degree than total expenditure. In the transport sector, road funds are shown to play a substantial role in funding road maintenance, appearing to improve the adequacy of funding, while attenuating pronounced capital biases in road sector spending, but there is little evidence of efficiency improvements over time.

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Understanding Public Spending Trends for Infrastructure in Developing Countries[1]

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1. Introduction

Infrastructure is key to delivering several essential services and plays a central role in achieving the United Nations' Sustainable Development Goals.[2] Goal 9 explicitly articulates the importance of building resilient infrastructure by promoting innovative sustainable technologies. However, it has been shown that "infrastructure either directly or indirectly influences the attainment of *all* of the Sustainable Development Goals (SDGs), including 72% of the targets" (Thacker et al., 2019).

Developing countries face significant infrastructure needs if they are to deliver on the 2030 policy agenda (Doumbia et al., 2019; World Bank, 2019). There have been few rigorous attempts to quantify these spending needs, and until recently most of them were based on high-level cross-country panel econometric studies (such as Fay and Yepes, 2003), or limited in scope to individual regions or sectors (for instance Foster and Briceno Garmendia, 2009). A more recent study takes a micro-economic approach to modeling individual components of infrastructure needs, which are then built-up into an aggregate picture (Rozenberg and Fay, 2019). This research finds that, when combined with good policy choices, investments of 4.5 percent of GDP, combined with operations and maintenance expenditure of 2.7 percent of GDP, will together enable low and middle-income countries to achieve infrastructure-related Sustainable Development Goals and stay on track to full decarbonization by the second half of the century. These headline estimates can be further disaggregated at the sector level (see table 1).

Table 1: Overview of estimates of infrastructure spending needs for energy and transport

% of GDP of LMICs	Investment needs	Operations and maintenance needs	Total expenditure needs
Energy	2.2	0.6	2.8
Transport	1.3	1.3	2.6
Water	1.0	0.8	1.8
Total	4.5	2.7	5.4

Source: Derived from Rozenberg and Fay, 2019

However, evidence on how much countries are *actually* spending on infrastructure has been sparse. This is due to limitations in the ability of traditional public finance sources – such as the IMF Government Finance Statistics – to provide sufficiently disaggregated measures to isolate infrastructure expenditure. A preliminary attempt to estimate aggregate financing flows to infrastructure in the developing world, leveraging a variety of different data sources, provided a central estimate of 4.0 percent of GDP for public investment in infrastructure by developing countries in 2011 (Fay et al., 2019). While this central estimate of spending is not far short of the projected investment needs above, the aggregate finding belies significant variation in the size of financing gaps across sectors and regions, with significant spending shortfalls estimated for Africa, Middle East, Europe and Central Asia, even as financing exceeds the minimum requirement for East Asia and Pacific.

Subsequent research has shed further light on the sectoral composition of capital spending on infrastructure projects and the extent to which it is delivered through public budgets, state-owned enterprises, or public-private partnerships (World Bank, 2020). This evidence, currently available for 2017 alone, suggests that 80 percent of infrastructure investment is publicly financed and two-thirds of that is channeled through

[2] https://datatopics.worldbank.org/sdgs/sdg-goals-targets.html

state-owned enterprises, with the remainder on-budget. The same study also finds that almost the entirety of infrastructure investment goes to just two sectors: energy (50 percent) and transport (45 percent).

Beyond these high-level estimations of expenditure and spending needs, little is known about infrastructure spending trends and patterns at the global level. This paper fills this gap by analyzing a new source of disaggregated infrastructure spending data covering some 75 countries over a period of 10 years, drawing from the World Bank's novel BOOST database, complemented with data from relevant extra-budgetary channels. On this basis, the study aims to answer the following questions. What have been long term infrastructure spending trends across different types of countries? What are the patterns of infrastructure spending across sectors, functional categories, and institutional channels? Is there evidence of inefficiency, incoherence or cyclicality in infrastructure spending?

The rest of the paper proceeds as follows. The next section describes the data and methodology used to identify the infrastructure public spending trends, while the following one presents the results with a focus on roads and electricity spending. A fourth concluding section discusses the central findings and their policy implications.

2. Data and Methodology

Public expenditure on infrastructure can be classified into three separate categories. The first category is on-budget expenditure, undertaken primarily by central government entities, such as ministries, which is reported in the budget itself and financed from domestic tax revenue mobilization. The second category is development expenditure provided by traditional and new foreign donors to governments and typically channeled outside of the public budget. The third category is off-budget expenditure, undertaken by corporatized or otherwise decentralized state entities, such as power utilities or Road Funds, which is not reported on the budget but can be found in the respective financial accounts.

The World Bank's Public Expenditure Database BOOST compiles information on the level and composition of the first category of on-budget government expenditures for a growing number of emerging and low-income countries at quite a high level of granularity, currently around 75.[3] The sample is heterogeneous ranging from large countries (e.g. Argentina, Brazil, Indonesia, Mexico, and South Africa) to several small islands. It spans all major country income groups, including 22 low-income (LIC), 26 lower-middle income (LMIC), 21 upper-middle income (UMIC), and 8 high-income (HIC) countries, classified according to the level of gross national income per-capita. Due to the relatively small number of high-income countries, no disaggregated analysis is performed for this group. While the sample is not representative by design, with disproportionate representation of Sub-Saharan Africa and Latin America, it does account for about 40 percent of the population and 30 percent of the GDP of low- and middle-income countries globally (Appendix Table A2.2). Moreover, by excluding China and India, which are known to be relatively large spenders on infrastructure and often disproportionately influence global developing country averages, the sample provides a more realistic picture of the infrastructure spending situation across the bulk of emerging nations.

[3] While there are 77 countries covered in BOOST, two had to be dropped. The first is Pakistan, where coverage is limited to the province of Punjab. The second is São Tomé Príncipe, where there were some concerns about data quality and coverage.

The BOOST program was launched in 2010 as a platform for improving, standardizing and curating data collection associated with the World Bank's Public Expenditure Reviews in countries. It tracks well-classified and highly disaggregated budget data derived from engagements with individual countries in a country-specific manner. The BOOST database covers the period 2006 - 2018. The sample is quite unbalanced, with many earlier year observations missing. Furthermore, the available sample shrinks at increasingly fine levels of disaggregation. While aggregate public expenditure is available for over 70 countries, the number shrinks to 61 countries when looking at disaggregated expenditure for roads, and 46 countries for disaggregated expenditure on electricity. Coverage is also uneven depending on the sub-category of data considered, with greater availability of data on investments than on recurrent expenditure, and even less on subsidies. Combining BOOST data with other sources to build a wider picture of on- and off-budget expenditure further reduces the sample due to limited overlap in countries for which multiple data sources are available.

An important issue is differences between countries in the institutional coverage of the budget data provided. While 36 of the countries provide General Government data, which includes expenditure by subnational authorities, the remaining 41 countries provide only Central Government data. Examination of the General Government data shows that for most countries subnational expenditure represents no more than 6 percent of the General Government total, except in federal states. This suggests that pooling General Government and Central Government data is a defensible approximation, particularly for relatively small and unitary states as long as large federations supplying only Central Government data are excluded.[4]

To build up a comprehensive picture of on-budget and off-budget expenditure, it is essential to combine BOOST data with other sources of information that capture development aid as well as domestic spending through off-budget vehicles. When aggregating these different sources of data some possibility of double-counting is introduced, across some though not all of the categories. Wherever possible this issue is examined and any double-counting directly addressed through subtraction. However, due to data limitations this is not always possible. Table A2.5 qualitatively identifies the nature of the risks across each pair of categories. Since double-counting cannot be entirely eliminated, the resulting aggregate estimates must be considered as an upper bound. Given how low the resulting spending envelopes are relative to estimates of spending needs, this does not, however, affect the main conclusions of the paper.

The BOOST database does not capture foreign capital spending such as contributions made by multilateral, bilateral or other donor institutions, because these are typically not channeled through the budget. This source of funding plays an important role in infrastructure financing in the developing world and needs to be incorporated to get a complete picture. The OECD DAC database covers donor and multilateral commitments to developing countries across sectors. The database covers disbursements to 155 countries (from 29 donors) over the period 2005 – 2019. However, the OECD DAC database does not cover financing contributions by Non-Paris Club Members, notably China, which has become a significant source of infrastructure finance for some developing countries (Malik et al., 2021). Therefore, this study also draws upon the College of William and Mary's AidData database that captures over 13,000 officially-financed Chinese projects (by Chinese government institutions and state-owned entities) in five regions (Africa, the

[4] These considerations led to the exclusion of Argentina and Brazil from the BOOST analysis, due to the fact that they are large federal states known to have substantial infrastructure expenditure at the sub-national level, yet only reported central government expenditure to BOOST.

Middle East, Asia and Pacific, Latin America, and the Caribbean) and across 165 countries for the period 2000 – 2017.

In addition, the BOOST database does not capture domestic spending through extrabudgetary vehicles, including State-Owned Enterprises (SOEs) and Road Funds. The research drew upon financial statements of these entities from the World Bank's Power and Transport State-Owned Enterprises (SOE) Database, comprising a panel of systematic standardized data drawn from company financial statements, which is consistent at the observation level and comparable across SOEs and years. The database covers 135 SOEs in the power and transport sectors (including road, rail, and air) across 19 countries. In the case of the road sector, it is known that an important subset of countries has implemented off-budget Road Funds, which capture earmarked revenues from transportation fuel levies and channel them towards road maintenance activities. Expenditure from Road Funds must be considered alongside recurrent budgetary expenditure in order to allow for cross-country comparisons on the adequacy of road maintenance allocations. It was established that 25 countries from the BOOST database have implemented Road Funds, and financial statements were collected for 20 of these, while the remainder of countries with Road Funds were dropped from the more detailed road sector analysis.

Cross-country comparisons of road maintenance expenditure also entail some normalization against the extent of the road network. For this purpose, the International Road Federation database was used, which provides information on road network characteristics across 205 countries. In particular, the total length of the primary and secondary network is used for normalization purposes since tertiary roads are typically a municipal responsibility.[5] The reported share of paved and unpaved roads was also used to adjust maintenance expenditure benchmarks for comparison purposes. The World Bank's ROCKS database provides such regionally differentiated unit cost data for road maintenance activity.

Finally, to get a complete picture of infrastructure expenditure sources, the research also draws upon the World Bank's Private Participation of Infrastructure (PPI) database that covers over 6,400 infrastructure projects in 137 middle- and low-income countries with private sector participation.

One big distinction between both the PPI database and the AidData's Global Chinese Development Finance Dataset versus the others used in the analysis is that the latter provide actual executed expenditure, while the former only record financial commitments at the year of project closing, without recording how this is spent over time. Based on the assumption that infrastructure projects typically take five years from financial closing to complete, commitment data are converted to simulated disbursement data for greater compatibility with other sources. Similarly, AidData is also smoothened by taking five-year moving averages.

Exploratory data analysis is complemented with selective use of econometric techniques. To explore the relationship between infrastructure spending and GDP over time, with a view to assessing the extent of cyclicality, a fixed effects panel data model is estimated and further complemented with a panel vector autoregression (PVAR) analysis. In addition, the efficiency of infrastructure spending is assessed using Data Envelopment Analysis. The details of these techniques are discussed in the relevant sections.

[5] Care was taken to establish whether the institutional responsibility for maintaining primary and secondary road networks in any given country was consistent with the corresponding level of the budget. Road network lengths were averaged over time to address some problematic fluctuations in the data over time.

3. Results

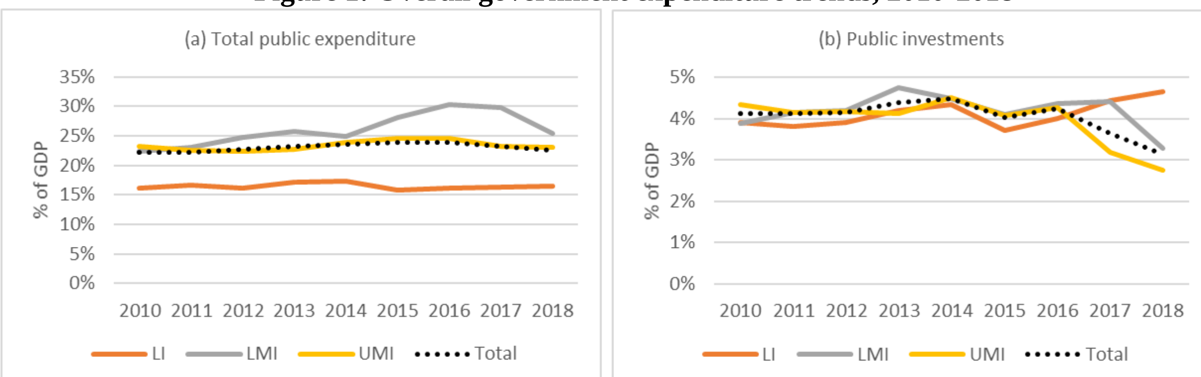
This section presents the results of the analysis, beginning with overall spending on infrastructure, and subsequently drilling down into roads and electricity expenditure in further detail.

3.1 Infrastructure Spending Patterns and Trends

3.1.1 Overall Spending Trends

Government expenditure trends have been relatively stable for low- and middle-income countries over the period 2010-18. On average, middle-income country governments spent about 23 percent of the GDP across all areas of the budget, with this average falling substantially to 16 percent of GDP in the case of low-income countries (Figure 1a).

Figure 1: Overall government expenditure trends, 2010-2018

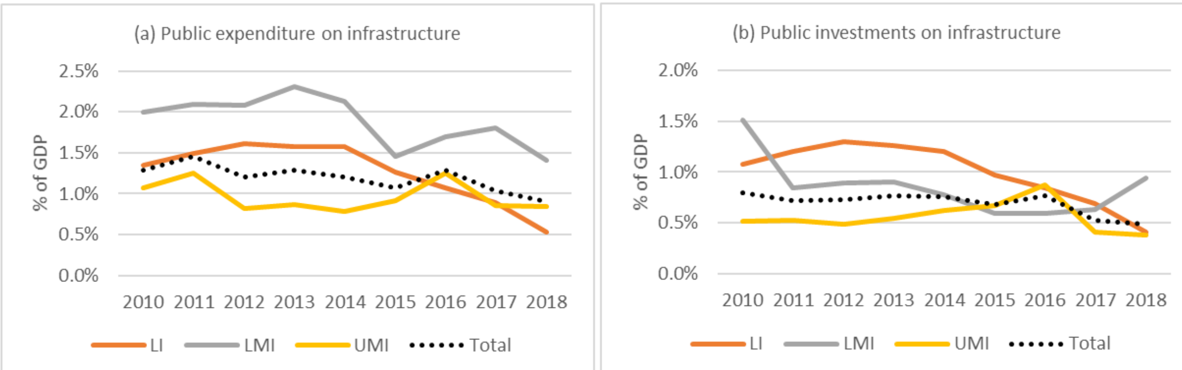


Source: Authors' elaboration based on BOOST database

On-budget public investment over the same period has been around 4 percent of GDP (Figure 1b). While public investment represented less than one-fifth of public expenditure for middle-income countries, low-income countries devote as much as a quarter of their lower spending envelopes to public investment, indicating a higher level of prioritization of capital expenditure and perhaps reflecting more limited baseline asset endowments. Indeed, whereas public investment in middle-income countries has been declining somewhat since 2016 dropping towards 3 percent of GDP, public investment in low-income countries has been climbing steadily since 2015 towards 5 percent of GDP.

Overall, developing country government spending on infrastructure has been low and declining. Indeed, infrastructure spending (narrowly defined to include the two largest sectors energy and transport), has amounted to little more than 1 percent of GDP on average over this period, with a discernible downward trend (Figure 2a). Infrastructure expenditure has been significantly higher for the lower-middle-income country group, where it has fallen from 2.0 to 1.5 percent of GDP between 2010 and 2018, than for the remaining income groups that have seen their expenditure on infrastructure drop from the 1.0-1.5 percent of GDP range in 2010 to the 0.5-1.0 percent range of GDP by 2018. Public investment on infrastructure has also been declining over the period from around 0.7 percent of GDP in 2010 to 0.4 percent of GDP in 2018 (Figure 2b). The decline has been particularly pronounced in low-income countries that had been channeling well over 1 percent of GDP to public investment in infrastructure until 2015. The marked downward trend in infrastructure spending (Figure 2) contrasts with the relatively stable trend for overall public expenditure (Figure 1).

Figure 2: Overall government expenditure trends on infrastructure

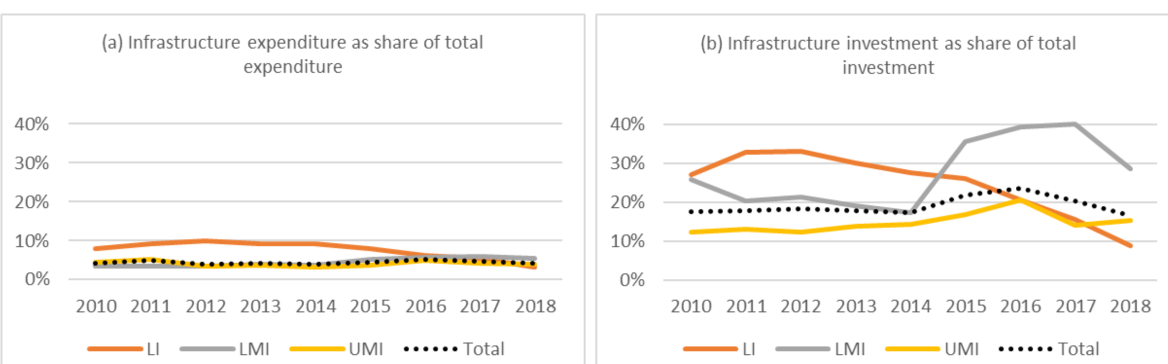


Source: Authors' elaboration based on BOOST database

Consequently, infrastructure accounts for a small and declining share of government expenditure. The overall budget share devoted to infrastructure expenditure over time provides a helpful indication of government's prioritization of infrastructure. Overall, infrastructure spending represents barely 5 percent of total government expenditure (Figure 3a). This perhaps reflects the importance of off-budget vehicles (such as SOEs and PPPs) as channels for infrastructure spending. Notably, however, low-income countries devote a much higher share of their lower absolute budget envelope to infrastructure, as much as 10 percent of total government expenditure at the outset of the period. The fact that baseline infrastructure stocks are typically lower in low-income countries may explain this additional level of budgetary space allocated to infrastructure spending in these countries.

By contrast, the weight of infrastructure in overall public investment is much higher than its share in overall expenditure, representing 15-20 percent of the total, albeit on a declining trend since 2015 (Figure 3b). The remaining public investment budget is devoted to the education, health, agriculture and water and sanitation sectors. At certain points in time, countries may give higher prioritization to infrastructure in their public investment budgets. In particular, low-income countries were devoting as much as 30-35 percent of public investment to infrastructure in the earlier part of the period (2010-14), while lower--middle-income countries devoted 30-40 percent of public investment to infrastructure in the later part of the period (2014-18).

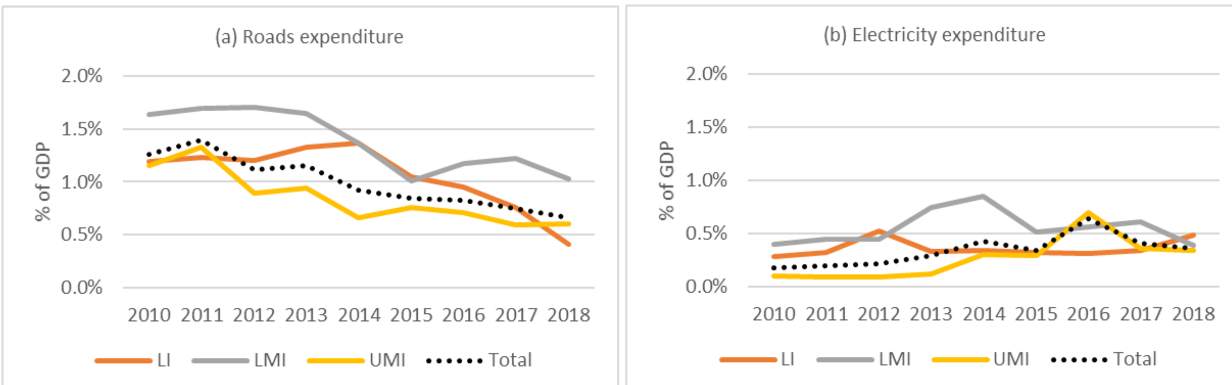
Figure 3: Government fiscal space allocated to infrastructure, 2010-2018



Source: Authors' elaboration based on BOOST database

A further level of disaggregation allows for examination of spending trends at the level of individual infrastructure sectors, focusing on the two largest areas electricity and roads. Total spending on roads, accounting for around 0.8 percent of GDP on average, is substantially higher than total spending on electricity (Figure 4a), which has been closer to 0.3 percent of GDP (Figure 4b). However, while spending on roads has halved over the period 2010-18, spending on electricity has doubled during the same period. Thus, by 2018, spending levels for both roads and electricity were each converging towards 0.5 percent of GDP.

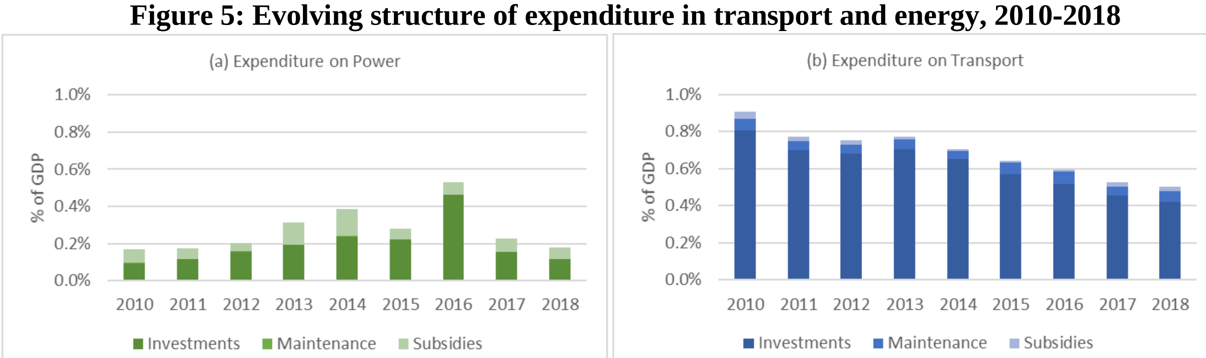
Figure 4: Public expenditure on different infrastructure sectors



Source: Authors' elaboration based on BOOST database

Both transport and energy expenditures are heavily skewed towards investment, with relatively small shares devoted to operating expenditure and subsidies (Figure 5). In the case of roads, 77 percent of on-budget expenditure is investment. However, some countries have established dedicated off-budget Road Funds that are primarily responsible for network maintenance. In the case of electricity, 56 percent of on-budget expenditure is investment. In most countries, operating expenditures are covered by power utilities and financed from tariff revenues.

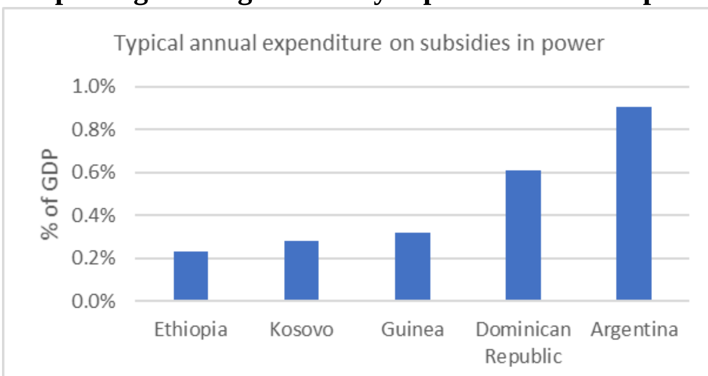
Figure 5: Evolving structure of expenditure in transport and energy, 2010-2018



Source: Authors' elaboration based on BOOST database

Only 18 countries report making subsidy transfers to the electricity sector, which in the majority of cases are transfers to utilities. Subsidies to the electricity sector tend to be relatively small. Only five countries report electricity subsidies in excess of 0.2 percent of GDP (Figure 6). The two countries reporting by far the largest subsidies to the electricity sector are Argentina and Guinea. A word of caution on subsidy data is warranted. The analysis above is based on the subsidies explicitly mentioned in the BOOST database, which are derived by classifying budget items according to the BOOST methodology. While this is quite helpful and the only such database of its kind, different countries follow different reporting mechanisms and there are serious challenges in trying to accurately estimate the overall subsidies in the power sector. For example, looking at BOOST data for Kosovo, on average the country transfers upwards of US$20 million in subsidy to the sector. However, financial statements of the SOEs report receiving on average US$33 million in operational and capital subsidies per year for the same period. Clearly, either the sector utilities are receiving subsidies from extra budgetary sources, or the BOOST data is not capturing all the subsidies. Unfortunately, neither do utility financial statements serve as a reliable source of subsidies in the sector all the time. For example, in Ethiopia, the BOOST data shows average annual subsidies of about US$93 million transferred to the power sector,[6] but the financial statements of the SOEs show no transfer from the government for the same years during the time period (2010-17).

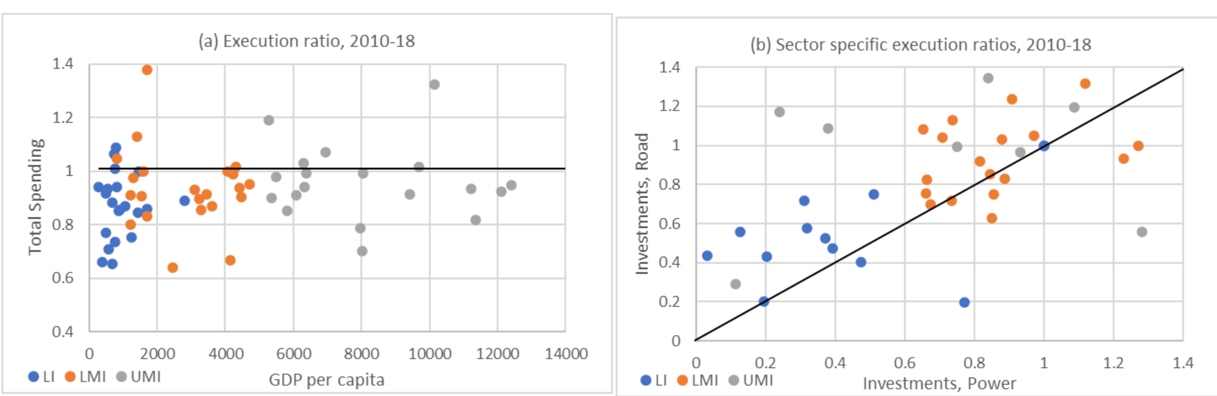
Figure 6: Countries reporting the largest subsidy expenditures in the power sector, 2006-2018



Source: Authors' elaboration based on BOOST database

Finally, the BOOST database provides ample evidence of significant under-execution of budgeted investments in transport, and especially in energy infrastructures (Figure 7). The degree of under-execution is clearly higher in the lower than in the middle-income country groups. Countries also seem to struggle more to execute allocated capital expenditures in the power sector as compared to roads. While the execution ratio for roads is 94 percent, for the power sector it is only 75 percent.

Figure 7: Execution ratios for overall expenditure and Infrastructure sector, 2010-18



Source: Authors' elaboration based on BOOST database

[6] Including the mining sector.

3.1.2 Patterns of Cyclicality

According to Keynesian principles, counter-cyclical fiscal policy provides a means of smoothing out trends in economic fluctuations over time. Most studies in the literature support the economic cyclicality of fiscal policies, but the patterns differ according to a country's stage of development. Government spending has typically been countercyclical in industrial countries and procyclical in developing economies (e.g. Alesina et al, 2008; Gavin and Perotti, 1997; Kaminsky et al., 2004). One strand of the literature relates this phenomenon to the lack of access to international credit markets (Calderón and Schmidt-Hebbel, 2008) by developing countries (especially during recessions) that might constrain their ability to spend during economic downturns. While another strand of the literature attributes this to restrictions on access to domestic markets (Caballero and Khrisnamurthy, 2004) and institutional and political structures (Alesina et al., 2008; Lane, 2003; Talvi & Végh, 2005). In addition, empirical studies indicate the differences in fiscal cyclicality between regions (Gavin and Perotti, 1997), between countries in different income groups (Ilzetzki & Végh, 2008; Kaminsky et al, 2004; Talvi & Végh, 2005), and across time (Fatás & Mihov, 2009; Thornton, 2008).

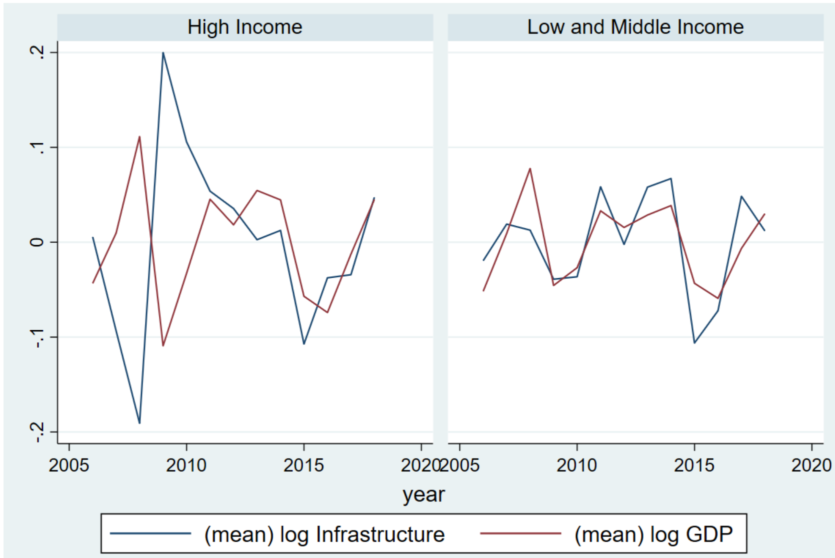
Evidence on the cyclicality of infrastructure spending specifically has been thin due to data limitations. The purpose of this section is to fill this gap with recourse to the BOOST database, which provides data on public investment on infrastructure in the form of capital formation by central and general government. One important limitation of the database for this type of analysis is that it only covers a 13-year time period, which is relatively short for the study of economic cycles. The cyclicality of infrastructure spending patterns is first explored visually, with more sophisticated statistical analysis subsequently applied to examine the evidence on cyclicality. In particular, this shifts the primary focus from the relationship between the business cycle and associated fiscal responses to a dynamic relationship between output growth and government expenditures on infrastructure, which helps to address concerns about endogeneity.

To begin with, the bivariate correlation coefficient is reported as a simple way of capturing how government expenditure on infrastructure per capita responds to changes in GDP per capita, without delving into underlying drivers. Figure 8 visually illustrates the cyclical movements between total spending on transport and energy per capita, and GDP in per capita terms for both developing and high-income countries. The visual evidence clearly suggests a countercyclical pattern for high-income countries, with infrastructure expenditure (blue) increasing relative to the expected trend when economic output (red) declines. On the other hand, GDP and infrastructure expenditure cycles seem to follow a procyclical pattern in developing countries. Procyclicality is particularly accentuated following the Global Financial Crisis of 2008–10, perhaps reflecting the depth of the crisis.

The nature of this relationship between GDP and infrastructure spending also varies across developing regions, but emerges as procyclical in most cases (Figure 9). Dependence of natural resources in many countries in these regions limits economic diversification and hence the ability to run countercyclical policies. Oil price fluctuations and volatility seem to lead to particularly large changes in infrastructure spending in oil-dependent MENA countries. However, this impact is not immediate (exhibiting a one to two year lag). For instance, world crude oil prices declined from USD 97.2 per barrel in 2008 to USD 61.5

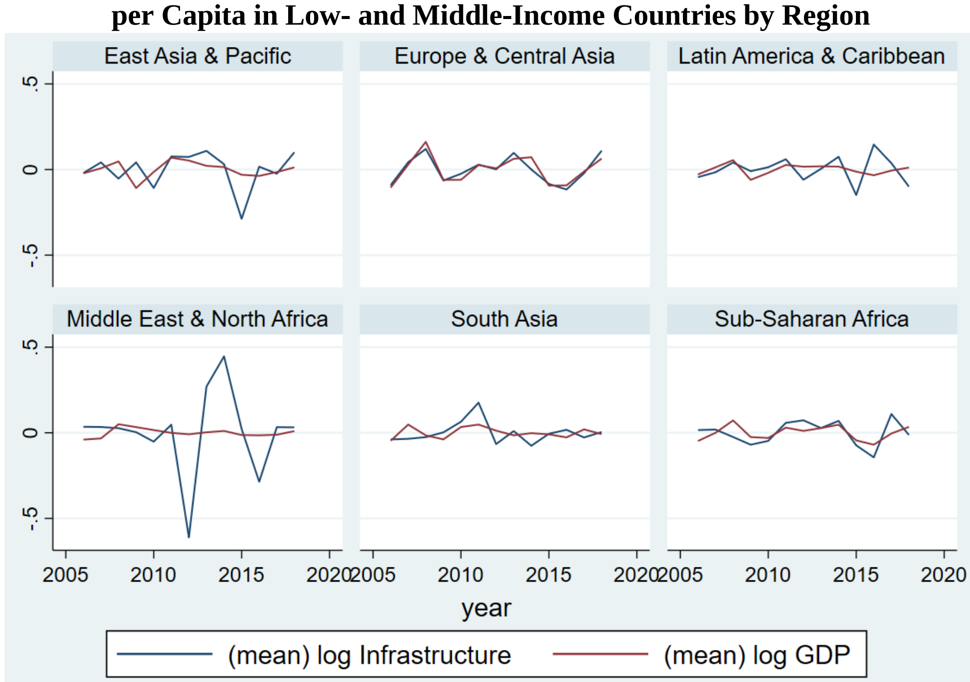
per barrel in 2009.[7] Oil rents (% GDP)[8] declined from 32.4 to 19.9 in the MENA region during the same period, which may explain the sharp decline in infrastructure expenditure growth between 2010 and 2012.

Figure 8: Relationship between GDP per capita and Infrastructure Expenditure growth per capita



Source: Authors' elaboration based on World Bank's BOOST database

Figure 9: Relationship between GDP per capita and Infrastructure Expenditure Growth per Capita in Low- and Middle-Income Countries by Region



Source: Authors' elaboration based on World Bank's BOOST database

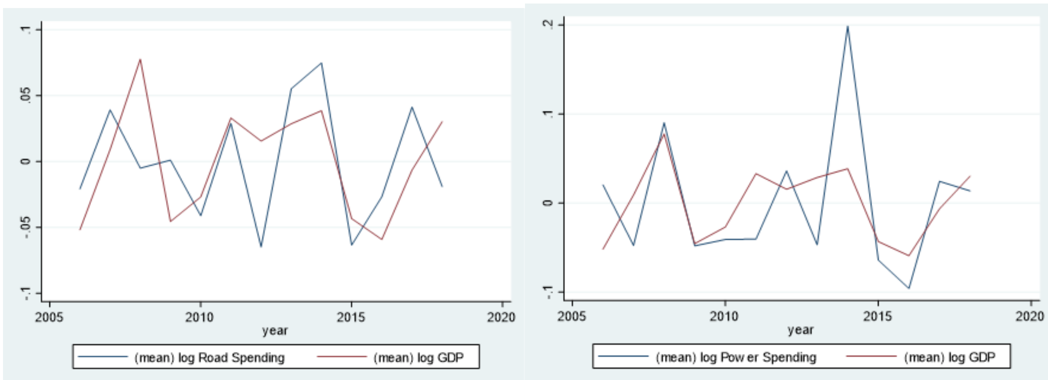
[7] https://ourworldindata.org/

[8] The difference between the value of crude oil production at world prices and total cost of production.

It is also interesting to explore whether infrastructure expenditure follows a similar trend for different types of infrastructure. Movements between the GDP and infrastructure expenditure for roads and power for the period 2006 to 2018 each show procyclical behavior in developing countries (Figure 10).

Figure 10: Relationship between GDP per capita and Infrastructure Expenditure Growth per Capita by Sector in Low and Middle-Income Countries

(a) Road Spending (b) Power Spending



Source: Authors' elaboration based on World Bank's BOOST, Road Funds, and PPI Databases

To complement the visual analysis, the degree of cyclicality between sectors and across regions is assessed using simple correlation coefficients (Table 2). The results clearly show that total public expenditure is positively correlated with GDP (suggestive of procyclicality) in almost all regions, with the degree of correlation particularly pronounced for Europe and Central Asia as well as East Asia and Pacific. Although infrastructure spending remains positively correlated with GDP for almost all regions, particularly Europe and Central Asia, correlations are typically lower than for aggregate public expenditure, with the exception of Middle East and North Africa. Furthermore, spending on individual sectors, like electricity and roads, is less procyclical than infrastructure spending as a whole and even becomes negatively correlated (suggestive of modest countercyclicality or at best stability) for Latin America and the Caribbean as well as East Asia and Pacific.

Table 2: Cyclicality of Expenditures in Low- and Middle-Income Countries across regions, 2006 – 2018

Region	Correlation (Total Spending, GDP)	Correlation (Infrastructure, GDP)	Correlation (Road, GDP)	Correlation (Power, GDP)
South Asia	0.11	-0.02	0.05	-0.03
Latin America and Caribbean	0.20	0.09	-0.08	-0.05
East Asia and Pacific	0.52	0.11	-0.08	-0.16
Sub-Saharan Africa	0.24	0.14	0.15	0.14
Middle East and North Africa	-0.07	0.26	0.10	0.07
Europe and Central Asia	0.72	0.54	0.41	0.16
High Income Countries	0.48	0.01	-0.02	-0.001
All Sample	0.34	0.16	0.09	0.09

Source: Authors' elaboration based on World Bank's BOOST, Road Funds, and PPI Databases

Note: All indicators are in per capita terms and in logarithm.

A more rigorous investigation of this question can be conducted using a fixed effects panel data model, where the dependent variable is the logarithm of real government spending per capita, at varying levels of disaggregation. (For full methodological details see Appendix A1.1.) The results indicate that coefficients for GDP growth are positive and statistically significant for total, infrastructure and transport expenditures for developing countries, pointing to procyclicality (Table 3). Following the literature, lagged terms are used to attenuate the potential endogeneity concern, without fully eliminating it (del Granado et al., 2013). Therefore, while the results provide suggestive evidence for a procyclical pattern of infrastructure expenditure, a causal effect cannot be claimed.[9] Consistent with the simple correlation analysis, the size of the coefficients is smaller for energy and disaggregated roads spending than for public spending as a whole and lacks statistical significance when disaggregated for the transport and power sectors. It is also important to note that coefficients are less than unity implying a less-than-proportionate response to output fluctuations.

Table 3: Cyclicality of Infrastructure Expenditures in Developing Countries

DepVar: Expenditure	Total	Infrastructure	Transport	Road	Energy	Power
GDP growth per capita	0.440***	0.448**	0.493*	0.356	0.265	0.617
	(0.101)	(0.242)	(0.321)	(0.331)	(0.425)	(0.439)
lagged Fiscal Balance	0.003**	0.0007	0.005**	0.005*	-0.003	-0.014*
	(0.001)	(0.001)	(0.002)	(0.002)	(0.003)	(0.007)
Terms of Trade growth	0.007	0.029	0.455	0.075	-0.135	0.186
	(0.133)	(0.298)	(0.300)	(0.427)	(0.498)	(0.345)
N.Obs.	720	672	672	696	684	528
R-squared	0.13	0.05	0.04	0.03	0.02	0.04
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Country Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes

Robust Standard errors in parentheses.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

An alternative approach is to use a panel vector autoregression (PVAR) technique to examine the dynamic relationship between government expenditure and output growth. The VAR approach addresses the problem of endogeneity that fixed effect models have by allowing endogenous interaction between system variables. (For further details on the methodological underpinnings see Appendix A1.2.)

Figure 11 depicts the response of infrastructure spending to output shocks for the low- and middle-income countries. The responses of the total, infrastructure, road, and power spending to an increase in output are positive. However, the output multipliers are close to zero in the first year and low in the following years. A 1 percent increase in GDP per capita does not have a statistically significant impact at 5 percent level[10] on the initial infrastructure spending per capita. It increases the infrastructure spending per capita by 0.008 percent after 1 year. This is the largest response and is temporary. There is no quantitative impact after five

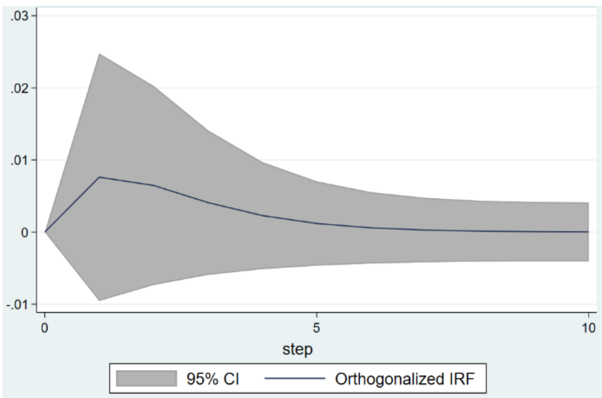
[9] In related studies, Konuki and Villafuerte (2016) show that output shocks drive fiscal policy. Similarly, based on quarterly data for 49 countries for the period 1960 –2006, the findings of Ilzetsky and Vegh (2008) support that output causes government spending when properly instrumented.

[10] Response of power spending to GDP shock is statistically significant at 10 percent level with an impact multiplier of 0.058.

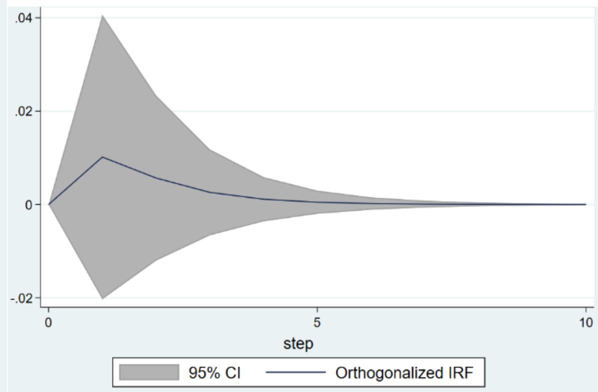
years. A 1 percent increase of GDP per capita generates a cumulative increase of infrastructure spending per capita of 0.02 percent in the long run that is defined as 10 years in our case (Figure 11b). Given the magnitude does not much surpass 0.1, the cumulative effect is very small indicating a weak form of procyclicality.

Figure 11: Impulse Response Functions for Low- and Middle-Income Countries

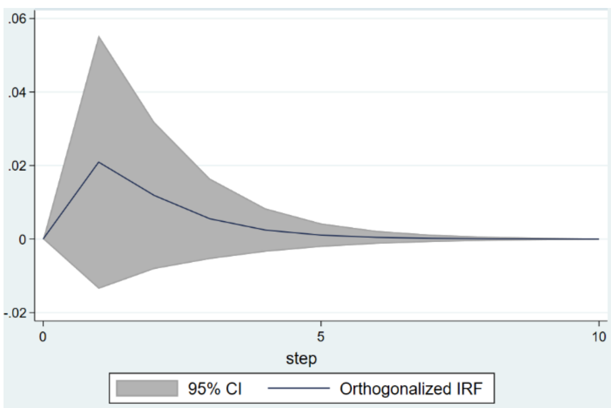
a. Response of Total Spending to GDP shock



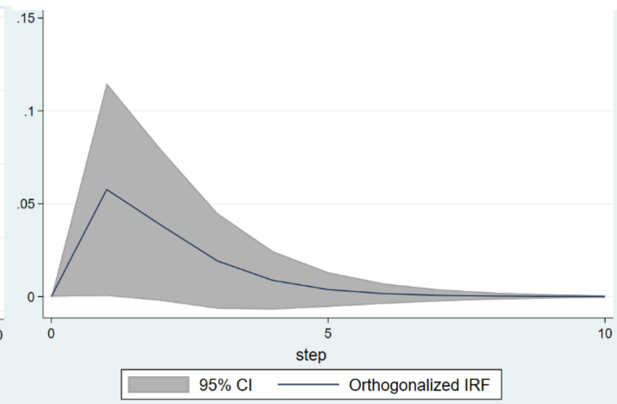
b. Response of Infrastructure Spending to GDP shock



c. Response of Road Spending to GDP shock



d. Response of Power Spending to GDP shock



Source: Authors' elaboration based on BOOST, Road Funds, and PPI Databases

Note: We choose a PVAR specification that satisfies the Hansen's J statistics that tests for overidentification criterion, and the IRF confidence intervals are computed using 1000 Monte Carlo draws from the distribution of the fitted reduced-form panel VAR model.

Table 4 compares output multipliers for different types of expenditures including total, road and power. This is based on the computation of: (i) the impact multiplier that measures the response of spending to an output shock at the initial period; (ii) the peak multiplier that measures the largest response of spending to the GDP shock; and (iii) the cumulative multiplier that captures the long-term effect by dividing the sum of changes in the output variable over the entire period. An increase in GDP is likely to have a greater impact on power spending than road spending, but, overall, even the cumulative impacts after ten years are small in absolute terms.

Thus, the overall evidence on the dynamics of government infrastructure spending in low- and middle-income countries points to a relatively weak procyclical pattern, compared to other areas of expenditure.

Table 4: Comparison of Output Multipliers from PVAR

	Impact multiplier	Peak multiplier	Cumulative multiplier (after 10 years)
Total Spending	0.008	0.008	0.023
Infrastructure Spending	0.010	0.010	0.020
Road Spending	0.021	0.021	0.043
Power Spending	0.058	0.058	0.130

Note: All spending is in per capita terms

3.2 Roads

3.2.1 Road Spending Adequacy

Attention now turns to a more disaggregated analysis of spending trends at the sector level. In the case of roads, on-budget road expenditure does not tell the full story. While many countries do channel roads expenditure directly through the budget, a significant minority – particularly in Sub-Saharan Africa – have also established off-budget road funds that are typically resourced through earmarked fuel levies and used primarily to support road maintenance activities. This makes it particularly important to integrate road fund expenditure in any cross-country comparison of road sector spending or any assessment of its adequacy. In addition, several off-budget channels of expenditure potentially make a significant contribution to road sector funding. To begin with, OECD donor agencies (FCDO, JICA, MCC etc.) and multilaterals (WB, AfDB, ADB etc.) often fund or finance major investment projects in the sector, as increasingly do Non-Paris Club donors (notably China). In addition, a subset of countries has pursued toll road projects through public private partnerships, thereby tapping an additional source of finance for road investments.

For a better understanding of the sources of expenditure in the sector, budget expenditure needs to be combined with road fund statements, donor contributions and information on PPPs to build up a more comprehensive picture of financial flows. Due to constraints in data availability from different sources, the sample size shrinks to 49 countries where data is available and can be brought together from multiple sources to provide the full picture of road sector spending.[11]

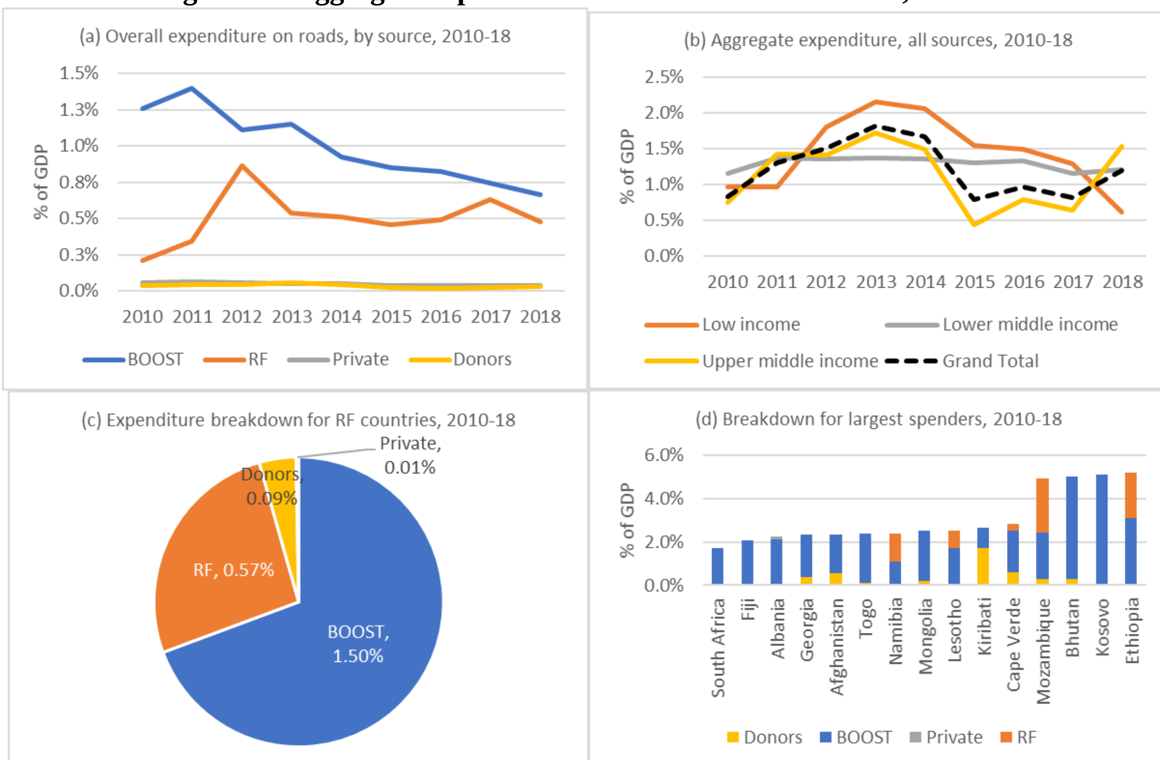
The relative importance and time trends for the different sources of road expenditures differ remarkably (Figure 12a). Budget expenditure was historically by far the largest source, but has fallen dramatically over the period 2010-18, and is now similar in overall magnitude to the resources from Road Funds, which have been more stable over time at just over 0.5 percent of GDP. Contributions from donors and private sector financiers have been steady but very small in magnitude, amounting to no more than 0.1 percent of GDP combined. Overall, public investment accounts for around 70 percent of road sector spending, with Road Funds making-up another 26 percent, donors a further 4 percent, and the private sector providing only a negligible amount (Figure 12c).

As anticipated, addition of off-budget expenditures significantly increases the estimate of resources allocated to the road sector. Whereas total on-budget spending on roads for the reported countries averages around 1 percent of GDP during the time period 2010-18, total spending on roads rises to 1.2 percent of

[11] There is some potential risk of double counting to the extent that Road Agency expenditure may be dedicated to paying shadow tolls or availability payments to private road concessionaires. However, given the limited scope of toll road concessions, and the fact that these are more typically funded directly from toll revenue collected, the issue of double counting looks to be relatively insignificant in the roads sector.

GDP when all sources are taken into account (Figure 12b). The overall trend in aggregate road spending is subject to fluctuation, declining steeply after 2013 and partially recovering since 2015. Between 2012 and 2017, low-income countries devoted substantially higher shares of GDP to roads expenditure than middle-income countries, peaking at 2 percent of GDP in 2013. Reliance on different types of road sector spending does differ substantially across countries (Figure 12d). While most rely primarily on budget spending, Road Funds make a major contribution for some (Ethiopia, Mozambique), but not all (Malawi), of the countries that have them. Kiribati is one of the few countries showing particularly high donor-dependency for road sector spending.

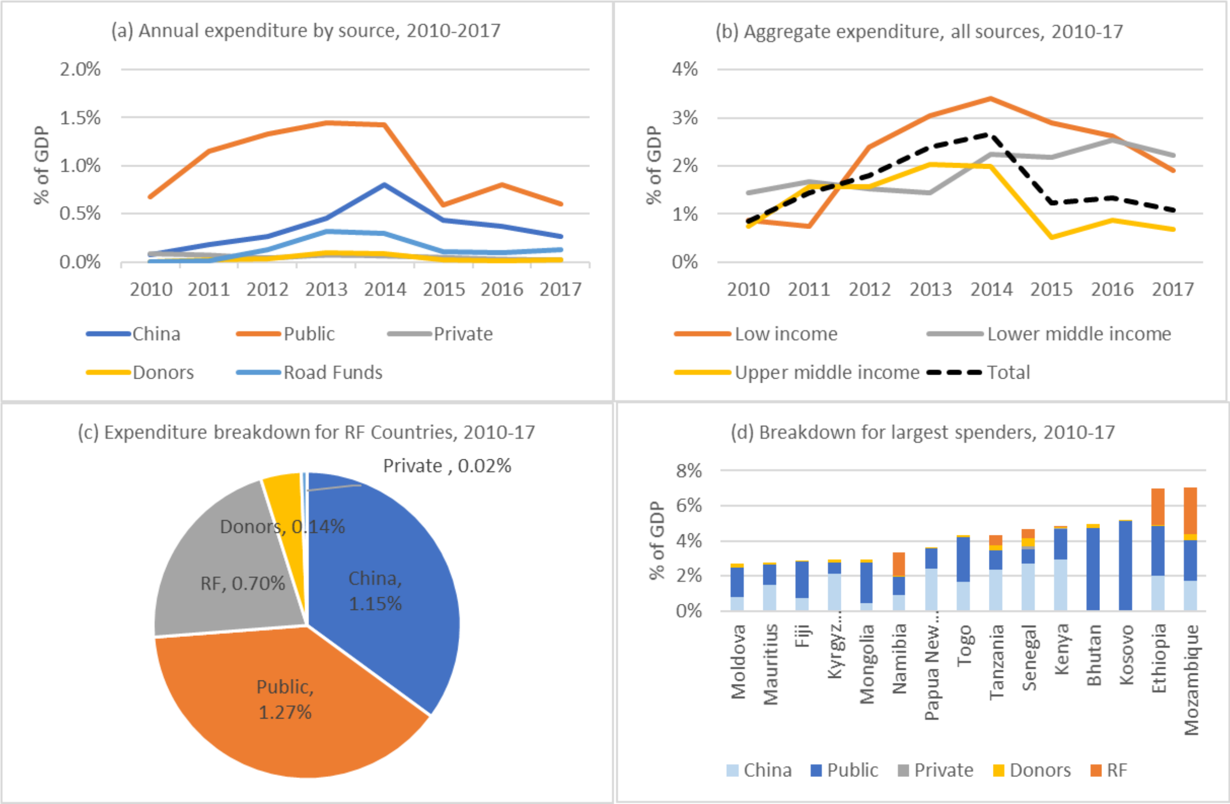
Figure 12: Aggregate expenditure on roads from all sources, 2010-18



Source: Authors' elaboration based on BOOST, Road Funds, OECD-DAC, and PPI Databases

Due to limitations in data comparability, the foregoing analysis does not consider Chinese financing flow to the roads sector in low- and middle-income countries. For a smaller subset of 36 countries, and a slightly shorter time period from 2010-2017, it is possible to compare the magnitude of Chinese flows to other sources of spending. In this case, the public sector continues to lead as the largest source of expenditure, with average spending over the period 2010-17 of around 0.87 percent of GDP overall. However, spending from Chinese sources moves into second place contributing 0.34 percent of GDP, mostly in low income countries, followed by road funds (0.13 percent), with negligible contributions from other sources. At the level of individual countries, there are a handful where China is by far the largest contributor for the road sector (notably Kenya, Senegal, and Tanzania), while in most other cases it is exceeded by public sources (Figure 13(d)).

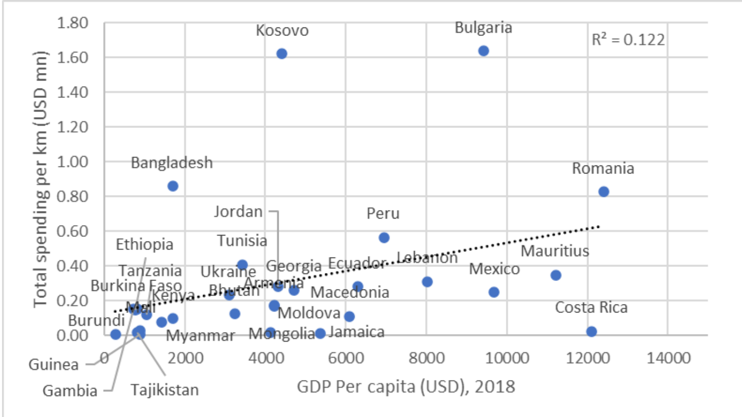
Figure 13: Chinese spending in the road sector



Source: Authors' elaboration based on BOOST, Road Funds, OECD-DAC, AidData and PPI Databases

Road spending broadly reflects the scale of each country's road network and its GDP per capita. Normalizing total road expenditure by the scale of the primary and secondary network, provides a measure of unit spending per kilometer combining both capital and operating expenditure. There is some consistency in the level of spending reported per kilometer with an inter-quartile range from US$200,000 to US$400,000. Spending per kilometer increases somewhat at higher levels of GDP per capita, producing a correlation of 0.122 (Figure 14). A handful of higher spending outlier countries are primarily from Eastern Europe. Also noteworthy is the significant number of countries – such as Costa Rica, Jamaica and Mongolia – that report negligible levels of expenditure on roads, under $50,000 per kilometer of the primary and secondary network.

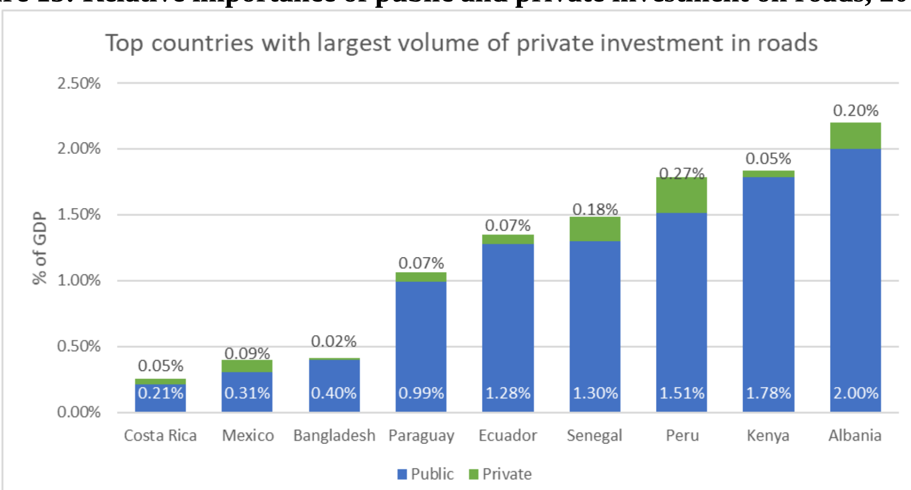
Figure 14: Correlation between spending per kilometer and GDP per capita



Source: Authors' elaboration based on BOOST, Road Funds, OECD-DAC. Aid Data and PPI Databases

PPPs make a relatively small contribution to road sector expenditure. Only a handful of countries have succeeded in attracting any significant amount of PPP financing for roads. Even in these cases, private investment at best comes to just 0.25 percentage points of GDP annually, and typically accounts for no more than 5-10 percent of total investment on roads (Figure 15). Mexico is exceptional in relying on private investment for almost a quarter of total road investment over this time period, although overall road sector investment in the country appears to have been relatively low in absolute terms.

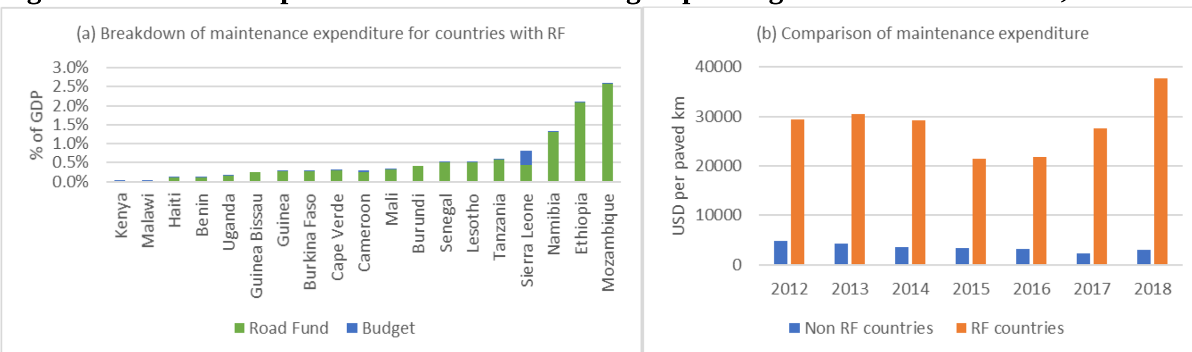
Figure 15: Relative importance of public and private investment on roads, 2006-18



Source: Authors' elaboration based on BOOST, and PPI Databases

Road Funds, on the other hand, do contribute significantly to the road maintenance expenditure of those countries which have them. About 25 of the countries studied were found to have Road Funds. Data on Road Fund expenditure was captured for 19 of these countries, with the remainder being dropped from the sample. For these countries, Road Funds expenditure typically amounts to 0.52 percent of GDP, and contributes some 85 percent of total expenditure on road maintenance (Figure 16 a).

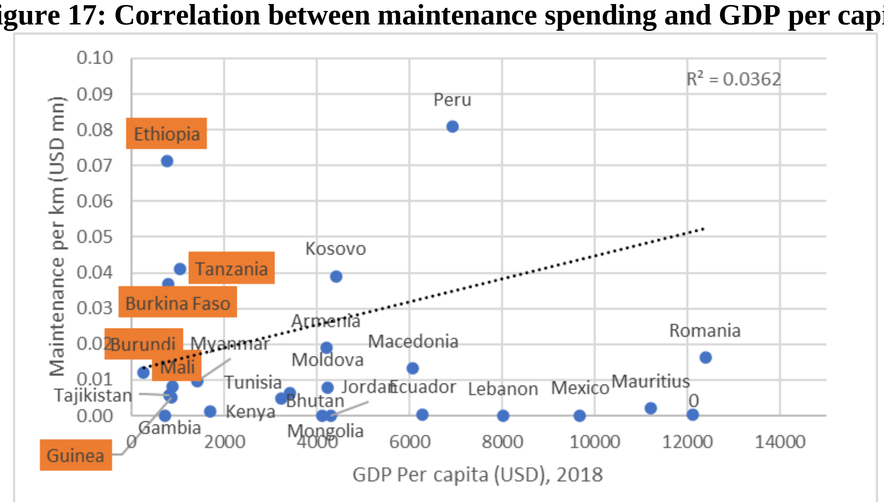
Figure 16: Relative importance of on- and off-budget spending for road maintenance, 2006-18



Source: Authors' elaboration based on BOOST and IRF databases.

Countries with Road Funds in place tend to devote more resources to road maintenance than their peers without them (Figure 16 b). Examining overall on and off-budget maintenance expenditure shows that countries with Road Funds are among those devoting the greatest resources to road maintenance across the entire sample (Figure 17).[12] In fact, the average maintenance spending per kilometer for countries with Road Funds is $27,000 compared to $3,000 for countries without Road Funds. Despite countries with Road Funds being relatively poor, their level of spending effort on road maintenance far exceeds that of higher income countries and is consistent with national income levels several times higher than their own. This phenomenon serves to dilute any correlation between unit spending on road maintenance and GDP per capita, yielding a negligible correlation of 0.036 (Figure 17).

Figure 17: Correlation between maintenance spending and GDP per capita



Note: Countries with Road Funds are highlighted in orange
Source: Authors' elaboration based on BOOST and IRF databases

Road spending is strongly skewed towards capital expenditure, even among countries that have adopted Road Funds to boost maintenance expenditure. The scatterplot illustrates that the vast majority of countries

[12] There is a possibility that BOOST data does not record or capture the complete maintenance expenditure. Some maintenance expenditure could be recorded as capital expenditure due to the reporting mechanism of the various countries.

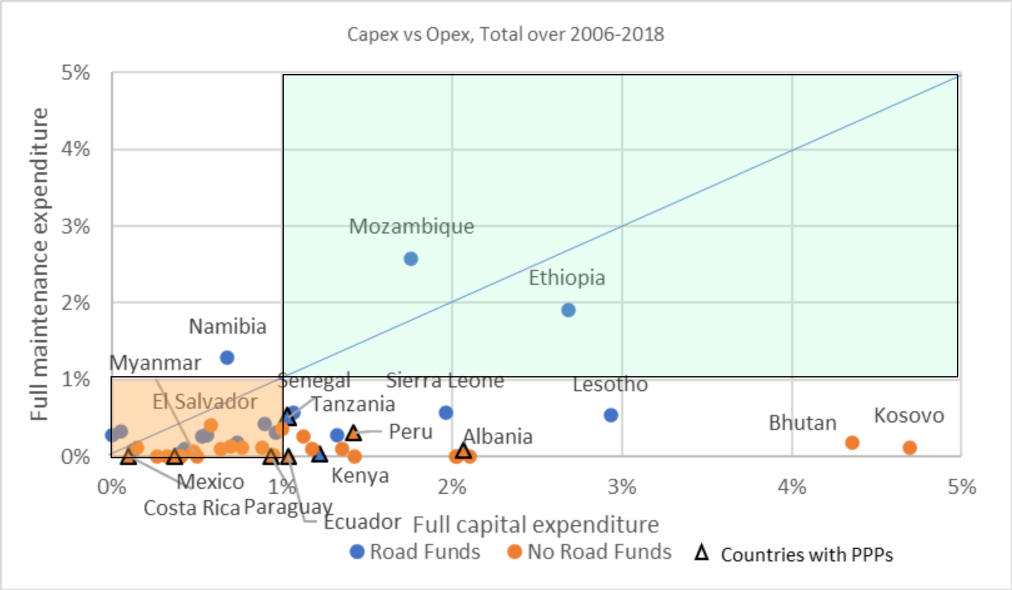
prioritize construction of new or upgraded roads over preservation of existing roads, spending around six times as much on investment as maintenance. Some countries appear to neglect road maintenance almost completely (such as Gabon, The Gambia, Jordan, Mexico and Paraguay). Even countries with Road Funds, while they may spend more on maintenance than their peers, still seem to dedicate more resources to investment than maintenance overall (such as Cameroon, Kenya, Senegal, Mozambique and Namibia). Mozambique and Ethiopia are among the few countries reporting both high and balanced levels of expenditure between road investment and road maintenance.[13]

Only a minority of countries are dedicating adequate resources to either investment in or maintenance of roads. An important question is whether spending levels are adequate to meet development targets. High level estimates of spending needs for roads suggest that countries may need to spend similar amounts, of the order of 1 percent of GDP, on both capital and operating expenditure for roads (Rozenberg and Fay, 2019). These spending adequacy thresholds are represented by the green box in Figure 18, meaning that countries appearing in the green box are spending adequate amounts on both investment and maintenance. Strikingly, Ethiopia and Mozambique are the only two countries that fall into this category. Additionally, the red box represents the area where countries are neither spending enough on investment nor maintenance, and the majority of countries appear in this area. Namibia is the only country that spends adequately on maintenance, but not on investment. A larger group of countries, including some with Road Funds, spend adequately on investment but not on maintenance.

Countries with PPP programs for toll roads (represented as black triangles in Figure 18 tend to exhibit a particularly high level of capital bias in road spending allocation decisions. Countries with Road Funds (represented by blue circles in Figure 18) are more likely to allocate adequate resources to the road sector, either on maintenance and/or investment, than those without. Nevertheless, the presence of a Road Fund is not of itself a guarantee that maintenance expenditure will be *enough*. Countries like Lesotho and Sierra Leone, for instance, do not appear to capture adequate resources through their Road Funds to support full maintenance requirements.

[13] The above estimates are based on the BOOST, Road Fund and OECD-DAC data and do not include any maintenance expenditure undertaken by toll roads as this data is not available. However, based on the earlier analysis of Road Funds, this is likely to be relatively small overall.

Figure 18: Overall adequacy of capital and operating expenditure on roads, 2006-18[14]



Source: Authors' elaboration based on BOOST database

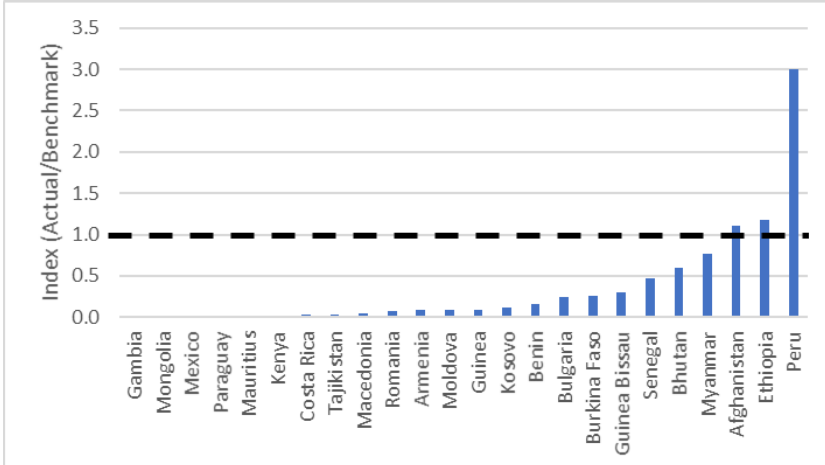
For a majority of countries, maintenance expenditure lies well below engineering benchmarks. A different approach to gauging the adequacy of expenditure on road maintenance is to benchmark maintenance spending per kilometer against benchmark engineering estimates of the cost of road maintenance.[15] The ratio of the actual maintenance expenditure per kilometer of the total (primary plus secondary) network to the benchmark is reported in Figure 19. The vast majority of countries come nowhere close to the spending benchmark. A few of countries, (notably, Afghanistan, Bhutan, Ethiopia and Myanmar), are spending relatively close to the benchmark, while Peru stands out for spending almost three times the benchmark level.

Of course, spending levels are only one preliminary indication that maintenance may be adequate and is no guarantee of adequate maintenance given that resources may be poorly spent. The next section therefore turns to the issue of measuring the efficiency of expenditure.

[14] Only BOOST data are used as the breakdown for the other sources is not available.

[15] The World Bank's ROCKS database reports historic unit costs of paved road maintenance differentiated by geographic region. On this basis, a country-specific unit cost maintenance norm is computed taking the regional figure on paved road maintenance costs per kilometer from ROCKS and adjusting for the share of paved roads in each country's primary and secondary network, assuming that the annual maintenance cost for unpaved roads is approximately one-fifth of that for paved roads.

Figure 19: Ratio of maintenance expenditure per kilometer to customized benchmarks



Source: Authors' elaboration based on BOOST and ROCKS databases

3.2.2 Road Spending Efficiency

While the level of road sector expenditure looks to be wanting, it is also relevant to ask whether the resources that are actually spent are also efficiently used. The combination of disaggregated roads sector expenditure data with data about the scale and quality of the road network in countries makes it possible to apply Data Envelopment Analysis (DEA) to measure the extent to which road sector expenditure lies on the efficiency frontier (Andrejic et al., 2016).

Following the most recent literature, the quantitative indicators that we use to measure output are the change in network length for paved, unpaved roads (in km).[16] The relevant change in length comprises the sum of primary and secondary networks, whose financing is a central government responsibility for the countries concerned. Urban roads and rural roads, which are typically managed at the municipal level, are not considered.

Capital expenditure (CAPEX) and operating expenditure (OPEX) (US$ per km) are used as input variables, each of which is calculated by dividing the total capital and operational expenditures (investments) of the project by the total length of roads measured in kilometers, respectively. This refers to expenditure from the central government budget, including where relevant expenditure from off-budget national Road Funds used as a vehicle to fund road maintenance. Using CAPEX and OPEX as two separate variables allows the model to reflect the possible trade-offs between these costs (Jamasb et al, 2004). This is because OPEX, in the form of road maintenance, is needed to preserve road assets and reduce the need for future CAPEX, in the form of reconstruction. At the same time, the need to respect road maintenance norms on existing assets limits the resource available for further expansion and upgrading of the road network. When, for instance, OPEX is used as a single input variable, then Coelli (2000) suggests that output variables should be independent of CAPEX or otherwise adjusted based on the relative share of total costs. The sub-sample

[16] We consider the changes in network length as output variables, rather than total lengths, since the total length of the network at the start of the period reflects public expenditure prior to the 2006-2018 period of investigation. In addition, we explore the possibility of including road quality as an additional output variable, using the Road Quality Index from the World Economic Forum. This data is available for 2010 onwards and for selected countries, limiting the scope of the analysis. Table A2.3 reports the results when change in road quality is also included to analysis as an output variable for this reduced period 2010-2018.

panel data for 18 countries on input and outputs covered the period between 2006 and 2018. Data vary considerably across countries. While the median CAPEX per kilometer is USD 550 in Costa Rica, it is USD 71,872 in Guatemala. Similarly, Tanzania has the median OPEX per kilometer value of USD 0.41 while the OPEX by km is 7,065 in Bulgaria.

The particular form of DEA adopted is the input-oriented Envelopment Model, which minimizes input while keeping outputs at their current level. The technique estimates a productivity Malmquist index (Malmquist, 1953), which decomposes the change of productivity into technological change (TECCH) and efficiency change (EC), with the latter further decomposed into pure efficiency change (PECH) and scale efficiency change (SECH). The latter term captures economies of scale recognizing that a process may become more efficient simply by increasing the scale of production. A Malmquist Index (or any of its components) greater than one indicates improvement in productivity whereas values less than or equal to one denote stagnation. (Refer to Appendix 2 for further methodological details.)

The overall results for the sample, reported in Table 5, indicate that on average there has been a very slight improvement in productivity, with a Malmquist index of 1.03, and this improvement is almost entirely attributable to technological change rather than any efficiency gain. Curiously, a 6 percent improvement in pure efficiency (1.06) has been almost entirely offset over the sample by an equivalent deterioration in scale efficiency (0.95). However, the average results conceal a wide variation in country results.

DEA shows substantial dispersion in efficiency performance by country (Figure 20). Some nine countries show an improvement of overall road sector productivity in excess of 3 percent, and as high as 70 percent in the case of Mauritius. In most of these cases (such as Ethiopia, Mexico, Paraguay, and Peru), the observed productivity improvements are driven by technological progress. Only a handful of countries (Macedonia and Mauritius) boosted productivity primarily through efficiency gains, and in most cases, these were attributable to a change in the scale of production.

It is striking that one third of the countries saw road sector productivity decline by 10 percent or more. In each case, this was attributable to a loss of efficiency large enough to overwhelm mainly positive technological trends. In the case of Afghanistan and Niger, both of which saw a massive decline in efficiency of 70-98 percent, scale effects seem to have played the largest role.

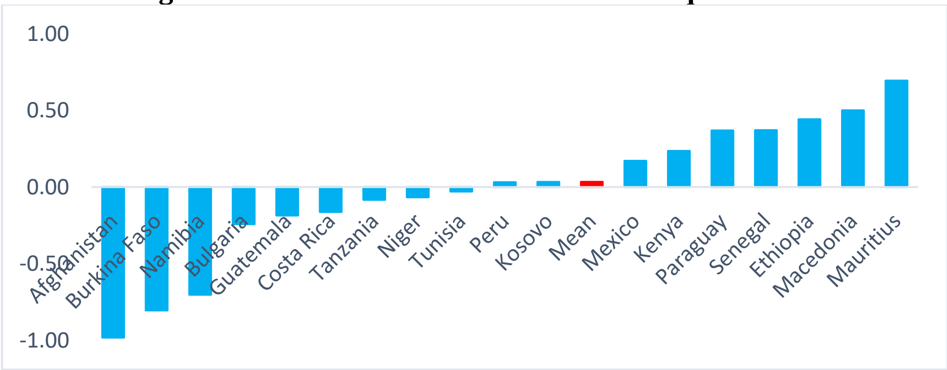
Figure 22 shows the summary of annual means of total productivity change (Malmquist Index) and its components, technical change, and efficiency change (decomposed into pure efficiency and scale efficiency) for the whole sample over the period 2006 - 2018. The pattern in Figure 22 shows that efficiency change (the product of pure efficiency and scale efficiency) and technology change move in opposite directions in general, diluting the overall growth in total productivity. The chart also indicates that movements in the indices can be quite volatile, with a large spike for technological progress in 2012, and smaller spikes for other indices at different points in time.

Table 5: Malmquist Index summary by country means

Country	Total Factor Productivity Change (TFPCH)	Technological Change (TECCH)	Technical Efficiency Change (EC)	Of which: Scale Efficiency Change (SECH)	Of which: Pure Efficiency Change (PECH)
Afghanistan	0.02	1.22	0.01	0.02	0.90
Bulgaria	0.76	0.94	0.81	0.71	1.13
Burkina Faso	0.20	0.41	0.48	0.49	0.97
Costa Rica	0.84	1.18	0.71	0.74	0.96
Ethiopia	1.44	1.51	0.96	0.90	1.06
Guatemala	0.81	1.20	0.68	0.63	1.07
Kenya	1.24	0.97	1.27	1.01	1.26
Kosovo	1.03	1.08	0.95	0.70	1.36
Macedonia	1.50	0.55	2.75	2.08	1.32
Mauritius	1.70	0.78	2.18	2.01	1.09
Mexico	1.17	1.17	1.00	1.00	1.00
Namibia	0.30	1.13	0.26	0.26	1.00
Niger	0.93	0.74	1.26	1.26	1.00
Paraguay	1.37	1.41	0.97	0.95	1.02
Peru	1.03	1.13	0.91	1.24	0.74
Senegal	1.37	0.94	1.46	1.20	1.23
Tanzania	0.92	0.97	0.95	0.88	1.07
Tunisia	0.97	0.98	0.99	1.34	0.74
Mean	1.03	1.04	1.00	0.95	1.06

Source: Authors' elaboration based on BOOST data. This table presents the results for the input–oriented Malmquist index and its components for the period 2006 – 2018.

Figure 20: Mean Deviations from the Malmquist Index



Source: Authors' elaboration based on BOOST database. Mean deviation is calculated by subtracting 1 from the Malmquist Index presented in Table 5.

Figure 21: Total Factor Productivity Change over Time for Selected Countries

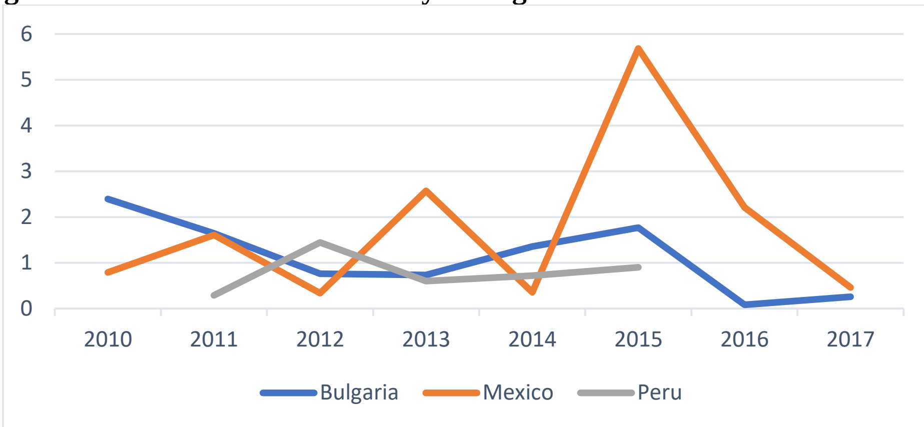
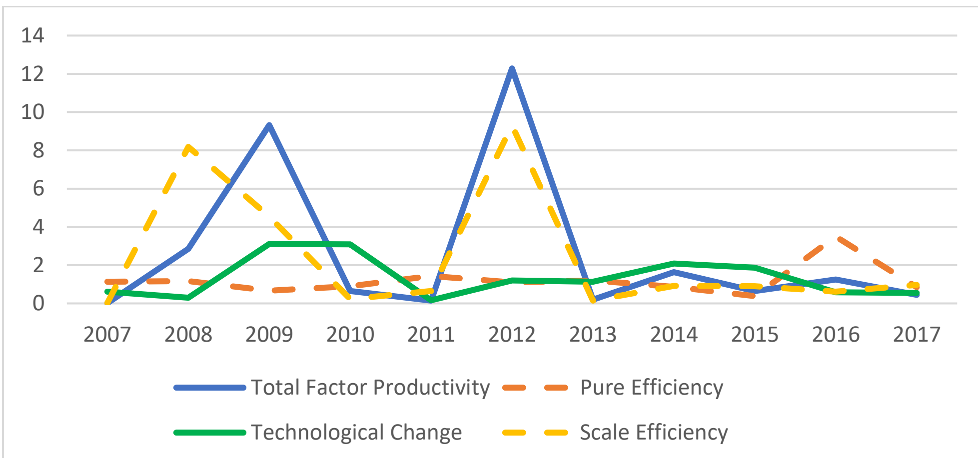


Figure 22: Malmquist Indices and Sub-Components Over Time



Source: Authors' elaboration.

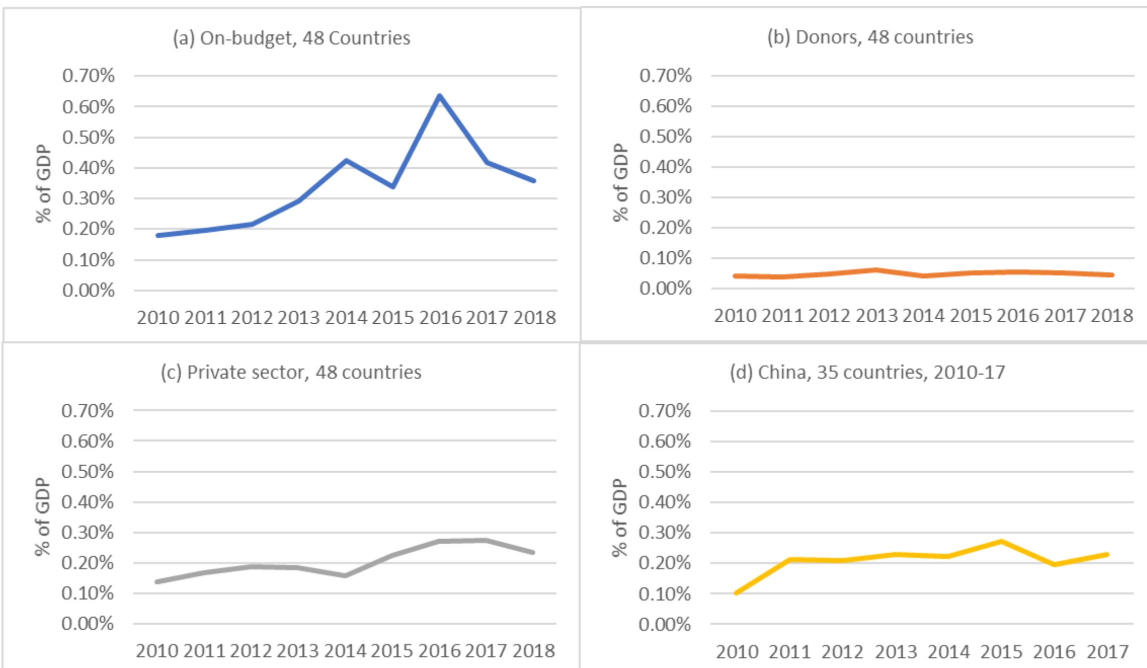
3.3 Electricity Spending Trends

As with roads, budgetary expenditure on electricity fails to fully capture resource flows to the sector due to widespread reliance on off-budget vehicles. Due to the prevalence of electric utilities, many of which are state-owned enterprises across the developing world, budget spending on electricity only tells a small part of the expenditure story for the sector. During the last 25 years, there has also been a substantial scale-up in PPPs, particularly for power generation projects. Finally, donors – from the OECD and beyond – have also contributed to spending in the sector, especially in the lower income country group. This means that budget expenditure needs to be combined with data from utility financial statements, as well as public private partnerships and donor engagements, to build-up a comprehensive picture of financial flows to the electricity sector.

By integrating off-budget data sources, a more complete picture can be provided. Over the period 2010-2018, public expenditure for the reporting 48 countries averages 0.35 percent of the GDP with a clear rising trend (Figure 23a). The private sector contributed 0.21 percent of GDP towards expenditure, while OECD donors contributed just 0.05 percent of GDP in the power sector during the same period (Figure 23b, c).

For a subset of 35 countries, it is possible to look at Chinese spending, another crucial source of expenditure in the sector, alongside the other sources of infrastructure spending considered so far (except for SOEs). Based on the AidData database from 2010-2017, Chinese spending in the sector amount to 0.21 percent of GDP (Figure 23d). During the same time period and in the same countries, public sector spending totals to 0.31 percent of GDP while the private sector contributes 0.22 percent with OECD donors lagging far behind in this subset of countries with just 0.04 percent of the total spending. This finding is in contrast to the roads sector, where Chinese sources were found to far exceed contributions by the private sector. Over the 2010-17 period, most of the Chinese investments in the power sector took place in the low-income countries.

Figure 23: Average aggregate expenditure on electricity across sources during 2010-2018



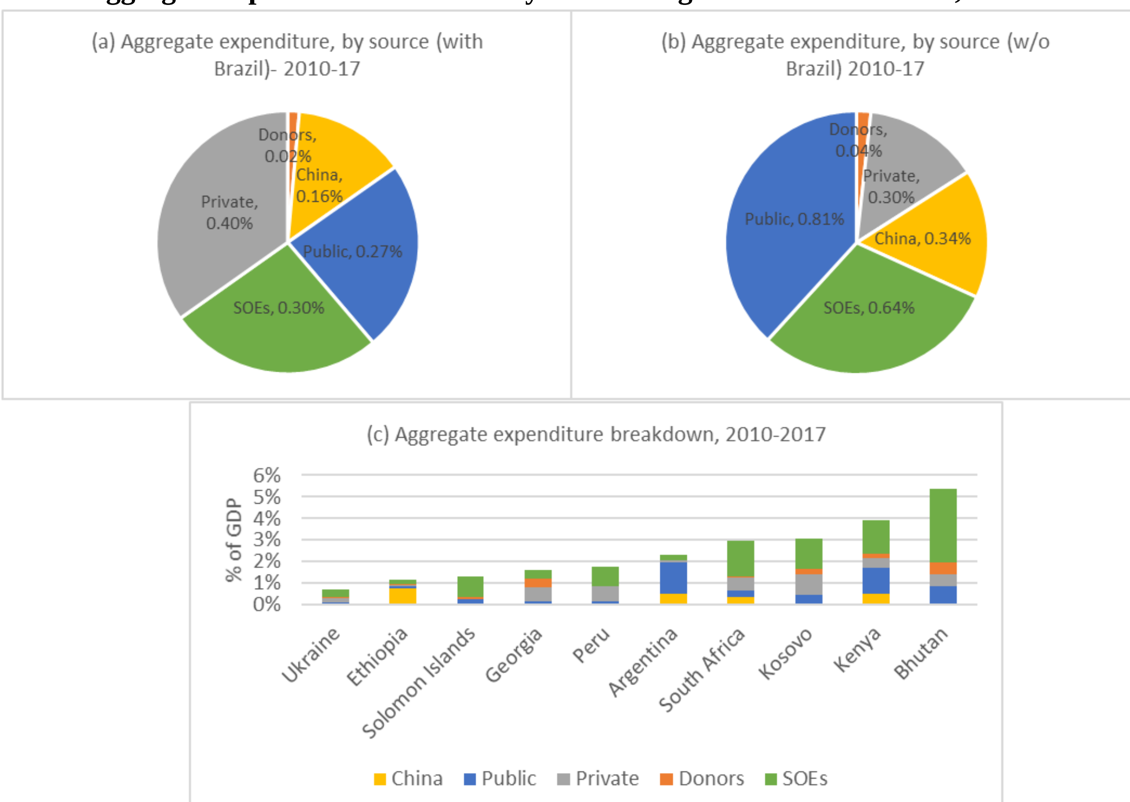
Source: Authors' elaboration based on BOOST, OECD-DAC, AidData and PPI databases

To allow for a more meaningful comparison of the relative magnitude of different sources of expenditure at the country level, attention is next limited to a sub-sample of 11 countries for which all four sources of data are consistently available. In aggregating data across sources, special care must be taken to avoid double-counting, which may arise either if budgetary transfers are made to state-owned enterprises, or if state-owned enterprises pay public private partnerships through power purchase agreements. However, data limitations, especially around confidentiality of PPAs, do not always make it possible to separate this data. While combining these four different sources of funding accounts for a very large part of expenditure in the sector, it does not account for all of it, as data on spending by private utilities, where these exist, was not available.

State owned utilities are an important source of spending in the sector and the picture presented in Figure 23 does not include this spending. While getting data for all SOEs in the power sector for the 48 countries is not feasible, for a subset of 11 countries data is available from the state-owned utility's financial statement as well. Inclusion of utility expenditure on electricity leads to substantially higher estimates of expenditure. Whereas average on-budget spending on electricity for the reporting 11 countries is 0.27 percent of GDP during the time period 2010-17, total spending on electricity rises to 1.14 percent of GDP when all sources

(Public, Private, Donors, China and SOEs) are taken into account. Brazil[17] is an outlier due to its large PPP program, and given its scale, when included in the average tips the results so that PPPs (0.40 percent) become the largest share of electricity expenditure, followed by SOEs (0.30 percent) and the budget (0.27 percent). However, if Brazil is excluded, for the remaining 10 countries the public sector leads with 38 percent of total spending (0.81 percent of GDP), followed by utilities (0.64 percent), then the private sector (0.30 percent) and donors (0.04 percent of GDP) accounting for less than 2 percent of the total spending. However, the pattern of expenditure varies substantially across countries, from those more heavily reliant on PPPs (such as Brazil and Peru) and those more heavily reliant on SOEs (such as Kenya and South Africa). However, the analysis above does not include private sector utilities.

Figure 24: Aggregate expenditure on electricity considering Chinese investments, 2010 - 2017

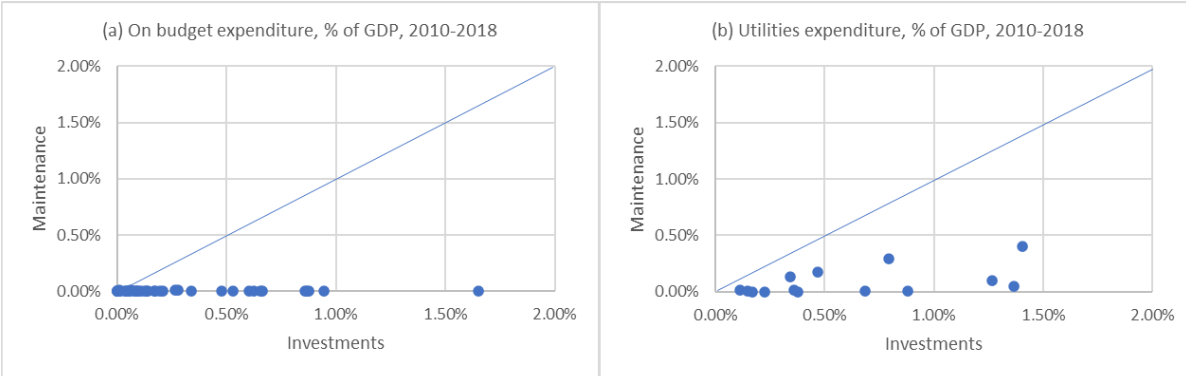


Source: Authors' elaboration based on BOOST, SOE, OECD-DAC, AidData and PPI Databases

Similar to the roads sector, spending in the power sector is skewed towards capital expenditure. This is understandable given the capital-intensive nature of the sector and the fact that almost all developing countries are still in the process of building out their systems. On-budget expenditure on maintenance is almost negligible, with only utilities showing some spending (Figure 25).

[17] Brazil and Argentina are included in the 11-country sample as we have on-budget data for central government and the SOE financial statements for SOEs where the central government has a majority stake. As an overall spending estimate for the country, this is probably an underestimation given the federal nature of the countries. But the purpose of the comparison here is to compare the various sources rather than the overall level of spending.

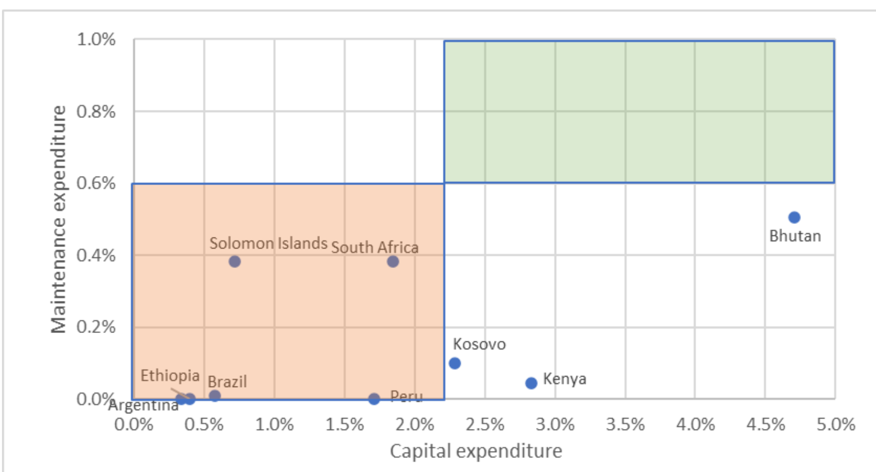
Figure 25: Comparison of typical power utility expenditure with on-budget electricity expenditure



Source: Authors' elaboration based on BOOST and SOE database

However, it is important to see if countries are dedicating adequate resources in terms of investments or maintenance in their power sectors. High level estimates of spending needs for the power sector mentioned above indicate that countries need to invest about 2.2 percent of GDP and spend about 0.6 percent of GDP for maintenance. The green box in Figure 26 represents these thresholds, meaning countries in the green box are dedicating adequate resources to the power sector. There is detailed comparable information for just eight countries from BOOST, utility database, OECD DAC and the PPI database.[18] Combining these data, it becomes clear that no country is in the green zone (Figure 26). Only Kenya, Bhutan and Kosovo manage to invest over the 2.2 percent threshold but do not meet the 0.6 percent threshold for maintenance. All other countries are in the red zone where they are under both investment and maintenance thresholds (represented by the red box in Figure 26). In addition to the observed under-spending on both investment and maintenance, the ratio of capital to maintenance expenditure continues to exhibit a capital bias for all countries except the Solomon Islands.

Figure 26: Overall adequacy of capital and operating expenditure in the power sector, 2010-2018



Source: Authors' elaboration based on BOOST, PPI and SOE database

[18] For the OECD DAC database we do not have breakdown information on the disbursements and assume it to be capex. As mentioned earlier, the data does not include any private sector utility. We also do not include Chinese data in this analysis as detailed breakdown is not available.

4 Discussion and Policy Implications

Drawing on a variety of new and existing data sources, this paper has aimed to shed light on the patterns and trends of public spending on infrastructure in low- and middle-income countries.

Overall, public expenditure on infrastructure in the developing world was found to be low and declining, reaching its lowest levels since 2010 at just below 1 percent of GDP in 2018. Infrastructure accounts for a low and stable share of no more than 5 percent of total government expenditure. However, investment in infrastructure accounts for a somewhat higher share of 15 percent of overall public investment; albeit reaching higher shares of around 30 percent for some countries during limited time windows.

There is evidence that low-income countries, despite their lower overall levels of public expenditure, were inclined to devote significantly higher shares of public expenditure and public investment to infrastructure at least up until 2015, but with a marked decline subsequently. Over the period 2010-18, there has been a marked sectoral shift in public expenditure for infrastructure, with spending on roads halving over this period even as spending on electricity has doubled.

It is striking that these numbers are much lower than previous high-level aggregated estimates of developing country infrastructure spending presented in Fay et al. (2019). However, there are important differences in the methodology that can adequately explain the differences. First, this analysis is limited to actual spending data and does not rely on any estimates involving assumptions or extrapolations. Second, the current data set does not include any of the known high infrastructure spending countries such as India and China, which due to their large size tend to inflate global estimates of infrastructure spending. In that sense, the current research provides a higher resolution more accurate understanding of spending patterns in the developing world outside the largest middle-income countries.

Low levels of public expenditure on infrastructure are further exacerbated by low budget execution ratios. Comparing budget allocations to executed amounts shows that countries manage to execute 94 percent of the budget allocation for capital projects in roads but only 75 percent in power. There are marked differences according to income group, with middle-income countries (executing 99 percent of budget for roads and 82 percent for power), doing substantially better than their low-income counterparts (executing just 64 percent in roads and 39 percent in power).

When it comes to roads expenditure, the main sources of funding are government budgets, and for some countries Road Fund resources and official financing from China, with the private sector and donors contributing relatively modest amounts. Relatively few countries have been able to tap PPP resources for the road sector, and even where they have, these have typically accounted for no more than 5-10 percent of total road investment.

The vast majority of countries were found to exhibit a strong capital bias, allocating about six times as much expenditure to construction of new roads as to preservation of existing roads; a 50:50 balance would be closer to recommended norms. Countries adopting Road Funds were found to allocate substantially more to road maintenance on average than those without – nine times as much on a per kilometer basis – and this is particularly remarkable when their relatively low level of income is taken into account. Countries with Road Funds were also less likely to exhibit capital bias, or at least exhibit less pronounced capital bias, than those without. However, even then, the presence of a Road Fund did not necessarily seem to guarantee that an *adequate* resource envelope would be allocated to maintenance. Countries with road sector PPPs seemed to exhibit even stronger capital bias than those without.

Data Envelopment Analysis suggests that the productivity of road sector spending has barely improved over time, despite modest technological progress. This is due to a countervailing deterioration in technical efficiency that largely wipes out these gains. Countries that did see some improvement in productivity often did so as a result of scale effects rather than pure efficiency gains.

Turning to the electricity sector, budget expenditures were found to account for just 25 percent of the resource allocation to the sector. Investment in electricity is dominated by SOE or PPP financing, while operating expenditure comes almost exclusively from SOE revenues. Chinese financial flows have made a material contribution in some cases. Again, there is significant evidence of capital bias in observed spending patterns.

Regarding the adequacy of infrastructure spending relative to high-level estimates of what would be needed to deliver on 2030 development goals, actual spending looks well below the benchmarks in the majority of cases. Only two countries, Ethiopia and Mozambique, were found to have dedicated adequate resources to both the construction and preservation of roads. Similarly, only a handful of countries – including Bhutan, Kenya and Kosovo – are investing in the power sector at recommended levels. Overall budgetary expenditure on infrastructure looks to be no more than 0.7 percent of GDP; although this rises to around 2.5 percent of GDP when all off-budgetary sources are taken into account, still just a fraction of the estimated 4.5 percent of GDP minimum requirement. At the more disaggregated sector level, both capital and operating expenditures for both roads and electricity were found to lie below spending norms for the vast majority of countries studied.

Finally, while data for the turbulent post-2018 period is not yet available, infrastructure spending was already low and declining in many low- and middle-income countries prior to the global pandemic of 2020-21. The paper presents significant evidence regarding the procyclicality of infrastructure spending in low- and middle-income countries, which suggests that the explosion of competing demands for health and social safety net expenditures during this economic crisis is likely to have placed infrastructure spending under even further strain.

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Appendix 1

Statistical Approaches to Measurement of Cyclicality of Public Expenditure

Two different statistical approaches are used to examine the extent of cyclicality in public expenditure: fixed effects panel data model and panel vector autoregressive model (PVAR). The main advantage of the former approach is that it allows to control for time invariant omitted variables. However, the estimation equation can only be considered an expenditure reaction function and provides conclusive evidence if output is exogenous with respect to fiscal policy as discussed by Rigobon (2004). On the other hand, PVAR allows to estimate the dynamics between infrastructure expenditure and output growth. It also comprises intertemporal effects of each variable. For this reason, PVAR models have been increasingly used in the literature to derive the fiscal multipliers. Data frequency and availability of long time series data strengthen the validity of results in this model. While the high frequency long time series mostly available for developed countries such as the U.S., estimates based on shorter time series constraints to analyze the impact of fiscal policy shocks in developing countries and emerging economies. It is also important to note that the panel data estimation indicates the average size of fiscal multipliers while the impact of government expenditure shocks might depend on key country characteristics such as the exchange rate regime, public indebtedness, and trade liberalization. The methodological underpinning for each method is described below.

A1.1 Fixed Effects Panel Data Model

A more rigorous investigation of the cyclicality of public expenditure can be conducted using a fixed effects panel data model, where the dependent variable is the logarithm of real government spending per capita (at varying levels of disaggregation).[19] Following literature on the cyclical behavior of public spending (e.g., del Granado et al., 2013; Gavin and Perotti, 1997; Clements et al., 2007; Jaimovich and Panizza, 2007), main controls include lagged fiscal balance, the log terms of trade, the lagged level of capital expenditure per capita, and the log of real GDP per capita. Lagged fiscal balance captures available fiscal space to run countercyclical policy. In other words, it captures the potential effect of borrowing constraints on infrastructure spending. Countries with high initial fiscal deficits usually have lower access to capital markets during economic downturns due to high risk of default. As a result, their spending patterns are expected to be procyclical. The close connection between the budget and the foreign sector in low- and middle-income countries makes them more vulnerable to external shocks relative to high income countries. Log of terms of trade captures the effects of external shocks on fiscal cyclicality.

$$\Delta \log(Expenditure_{c,t}) = \delta_1 \Delta\log(GDP_{c,t}) + \delta_2 Fiscal\ Balance_{c,t-1} + \delta_3 \Delta\log(ToT_{c,t}) + \alpha_{c,t} + u_{c,t} \quad (1)$$

[19] For this kind of analysis, normalization of expenditure by population is preferable to normalization by GDP, as the latter does not provide an unambiguous reading of the cyclical stance of fiscal policy. This is because the presence of GDP in the denominator tends to shift the measure in the direction of procyclicality when variables are in percentage terms (Kaminsky, Reinhart and Vegh, 2004; Jaimovich and Panizza, 2007).

where *Expenditure* denotes the per capita expenditure of infrastructure and its components in country *c* at time *t*, *GDP* is the gross national income per capita (in USD), *Fiscal Balance* is the overall fiscal balance as a percentage of GDP. *ToT* denotes an index of country's terms of trade, a is county-year fixed effect, and u is the error term.

δ_1 measures the degree of cyclicality of public spending. In other words, it is the elasticity of government spending with respect to output growth. A positive value of $\delta_1$indicates a procyclical behavior while negative value implies countercyclical behavior.

A1.2 Panel Vector Autoregressive Models

An alternative approach is to use a panel vector autoregression (PVAR) technique to examine the dynamic relationship between government expenditure and output growth. The VAR approach addresses the problem of endogeneity that fixed effect models have by allowing endogenous interaction between system variables.

For this approach, we use the Hodrick-Prescott (HP) filtering technique to remove short-term fluctuations. This allows us to extract the cyclical (stationary) component and trend (non-stationary) component. Following Ravn and Uhlig (2002), we adjust the filter parameter by multiplying it with the fourth power of the observation frequency ratios. For annual data, this implies a value of 6.25. In addition, as before, all indicators are converted to per capita terms since scaling to per capita terms make the countries in panels more comparable.

The HP filtering technique is used for all indicators and missing data are generated by interpolation. Blanchard and Perotti (2002) suggest that fiscal decisions in practice lag one period against shocks to macroeconomic variables. The intuition is simple. Planning and budgeting processes are not affected by downturns immediately. But having a lag takes into account the transmission of the shock. In high income economies, for instance, countercyclical responses are common. Since the impact of shocks is likely to be absorbed in advanced economies, the negative impacts of downturns may not appear immediately.

Following Blanchard and Perotti's (2002) methodology, we estimate the below Panel Vector Autoregressive (PVAR) model for our sample countries for the period 2010 - 2018.

$$X_{c,t} = A(L)X_{c,t} + \gamma_c + \epsilon_{c,t}$$

where c represents countries and t is the time. X is the vector of the endogenous variables of the model, A(L) is a matrix polynomial with L the lag operator, γ_c is fixed effects, and $\epsilon_{c,t}$ is the vector of errors.

Appendix 2

Statistical Approaches to Measuring Efficiency of Expenditure

Data Envelopment Analysis – a non-parametric technique which aims to estimate the efficiency frontier based on a panel of input and output variables – can be applied to examine the efficiency of road sector expenditure. In particular, we make use of the DEA based Malmquist index, since it is used to measure both the efficiency of units in a certain year and the change in efficiency over time.

Our work draws upon a significant literature on the evaluation of efficiency for different elements of transportation infrastructure. Sarmento, Renneboog, and Matos (2017) provides a summary of the applications of DEA including airports (e.g., Suzuki, Nijkamp, Rietveld, & Pels, 2010; Curi, Gitto, & Mancuso, 2010; Suzuki, Nijkamp, Pels, & Rietveld, 2014), railways (e.g., Yu & Lin, 2008; Roets & Christiaens, 2015), highways (Li and McNeil, 2014; Odeck 2008; Ozbek et al, 2010; Welde and Odeck, 2011; Daito and Geiford, 2014), and seaports (e.g., Panayides et al., 2009; Odeck & Brathen, 2012).

DEA is extensively applied for efficiency evaluation. By analyzing completing and efficiency conditions of the Colombian highway and railway systems, Correa (2012) finds that railway has higher efficiency in resource configuration. Karlaftis (2004) shows the positive correlation between the efficiency of 256 transportation systems in North America and the benefits. A brief overview of the literature on highway efficiency is presented in Table A2.1.

Data Envelopment Analysis (DEA) is a non-parametric technique to estimate the production frontier. It serves as a benchmark and computes the relative distance between each unit and the frontier. The ideal frontier is constructed by using observed input and output data. The distance can be interpreted as the economic performance of the units in the sample. DEA allows multiple input-outputs to be considered at the same time without any assumption on data distribution. DEA is a multi-factor productivity analysis model that can be used to measure the relative efficiencies of a homogenous set of decision-making units (DMUs). In other words, it measures the efficiency of each DMU (countries in our case) within a group relative to the observed more efficient unit within that group.

The selection of input and output variables in DEA is regarded as an important step. However, there is a lack of consensus on which variables best describe the existence of a roads network. In general, transportation literature use labor (number of employees), capital (transport cost, total expenditure, rehabilitation general maintenance, routine maintenance etc.), environment and energy indicators (transport risk, road condition, network area density, gasoline/diesel/fuel consumption etc.), facilities (freight vehicles, total number of passenger seats, network length, total area served etc.), and other factors (travel time, rehabilitation in kilometers, public maintenance etc.) related to production as input variables. The mostly used outputs can be grouped into three categories: operational outputs (length of network, transportation capacity, rapid response capability etc.), financial outputs (revenue, routing expenditure on maintenance etc.), and environmental and safety outputs (accident per vehicle, CO2 emission, pollution etc.).

The lack of balanced panel data is one of the main constraints of this study. While different methodologies are used in the literature; these include adding fake decision-making units (Yang and Pollitt, 2012) and reassembling the data into several balanced sub-panels (Li, 2009), all have shortcomings. More recent studies combine alternative concepts such as sequential production possibility and global productivity index to deal with the unbalanced data concern. We prefer the most well-known conventional Productivity Index suggested by Färe et al (1994) since it allows for the identification of the inefficient units in terms of change in technical efficiency or technological change. However, it is important to note that the Malmquist index only indicates the change in efficiency (increase or decrease). It does not identify its causes (Cooper et al, 2011).

Table A2.1: Survey of selected papers evaluating highway efficiency using Data Envelopment Analysis

Author(s)	Data	Study Period	Inputs	Outputs	Main Finding(s)
Choi & Jung (2017)	Highway infrastructure cases in 48 U.S. states	2000-2008 2012-2013	Highway investment, Highway maintenance	Length of lanes, Daily vehicles-miles traveled	Efficiency has a significant effect on effectiveness of highway management
Daito & Geiford (2014)	53 highways in the United States		Project costs, Construction duration	Number of lanes, Length in miles	US private highway projects were not more efficient than non-private counterparts
Li et al. (2016)	Highway transportation in the Beijing-Tianjin-Hebei, Yangtze River Delta, and Pearl River Delta in China		Highway mileage, Average highway network density per person, Network area density, Population density	Average GDP per person, Unit area GDP, Passenger and cargo transportation capacity, Urbanization rate	The highway transportation efficiency scores differ across regions indicating that government must apply different strategies for each region
Odeck (2008)	18 companies in Norway	2001 – 2004	OPEX, Payments to managers	Annual traffic, Number of lanes	Productivity increases due to companies using more efficient methods to collect revenue
Ozbek et al. (2010)	Highway maintenance in Virginia, USA		19 cost maintenance inputs (climate, traffic, cost, etc)	7 outputs including changes in highway or bridge conditions, and pollution	
Sarmento et al. (2017)	7 Portuguese highway projects	2003 - 2012	Operating and maintenance costs, Total assets, Number of employees	Daily average traffic on a highway, Revenues	The average productivity of Portuguese highways decreased over time due to drop in technological efficiency
Welde & Odeck (2011)	20 companies in Norway	2003 – 2008	OPEX	Annual Traffic	There is potential for efficiency improvement, no evidence of economies of scale

Source: Compiled by the authors

As in almost all empirical models, a small number of DMUs might create concerns for the degrees of freedom when measuring productivity. We address this concern by following Cooper et al (2011). They suggested degrees of freedom is not a concern if the following equation holds: $n \geq \max\{m \times s, 3(m+s)\}$ where n is the number of DMUs (countries, n= 32), m represents the number of inputs (CAPEX and OPEX), and s is the number of outputs (paved and unpaved roads in km). This implies that the number of countries should be greater than 12 (=3(2+2)). In addition, we study a period of 13 years (2006 – 2018). This gives us a sufficient number of observations to estimate productivity changes.

We use the input-oriented Envelopment Model by estimating a productivity Malmquist index (Malmquist, 1953). The input-oriented model determines the minimum input for which the observed production of the i^{th} DMU is possible given the observed outputs (Hoff, 2007). In other words, an input-oriented model determines frontiers to minimize the inputs while keeping the outputs at their current levels.

The traditional Envelopment Model with constant returns to scale (CRS) assumes that outputs should be maximized, and inputs should be minimized (Li, Xiao, McNeil, & Wang, 2011). Unlike this, estimating a Malmquist index allows for variable returns to scale. While DEA only looks at a specific year's efficiency, the Malmquist index measures productivity changes over a certain period and decomposes them into efficiency and technology changes.

The Malmquist index measures the difference of each unit to the efficiency frontier over time. For instance, our sample in this study starts in 2006. The efficient frontier is calculated for 2006 and 2007. The first value of the index for 2007 is the difference in deviations to the efficiency frontier. The details for the calculation of the distance function to the efficiency frontier are the following.

The below equations are for the calculation of the distance function to the efficiency frontier.

$$MI^t = \frac{E^t(x^{t+1}, y^{t+1})}{E^t(x^t, y^t)} \qquad (1)$$

$$MI^{t+1} = \frac{E^{t+1}(x^{t+1}, y^{t+1})}{E^{t+1}(x^t, y^t)} \qquad (2)$$

MI is the Malmquist Index in periods t and t+1; x and y are inputs and outputs. $E^t(x^{t+1}, y^{t+1}), E^t(x^t, y^t)$, $E^{t+1}(x^t, y^t),\ and\ E^{t+1}(x^{t+1}, y^{t+1})$ refer to output distance functions that evaluate change in the technology in periods t, t, t+1 and t+1 relative to technology in periods t+1, t, t, and t+1 respectively. The geometric mean of equations (1) and (2) defines the Malmquist Index (MI) that can further be decomposed into efficiency change and technical change following Färe et al. (1992).

$$MI = \frac{E^{t+1}(x^{t+1}, y^{t+1})}{E^t(x^t, y^t)} \ \left[\frac{E^{t+1}(x^{t+1}, y^{t+1})}{E^t(x^t, y^t)} \times \frac{E^{t+1}(x^{t+1}, y^{t+1})}{E^t(x^t, y^t)} \right]^{1/2} \qquad (3)$$

$$MI = Technical\ Efficiency\ Change\ (EC) \times Technology\ Change (TC)$$

The first term in equation (3) represents the technical efficiency change between two periods. It captures whether the observation gets closer the frontier over time while the frontier (technology) shift is captured by the geometric mean of the terms in the bracket. Technical efficiency change (or simply called as efficiency change, EC) is usually defined as the "catching-up" effect. If EC is equal to 1, then there is no change in efficiency between two periods. While EC values greater than 1 indicates that the distance of observation to the frontier gets closer, the reverse occurs for values less than 1.

Technological change (TC) is associated with the "displacement effect" or "frontier-shift", and as a results the set of production possibilities frontier changes over time. When TC is equal to one, technological frontier stays the same. If TC is greater than 1, there is technological progress; and if it is less than 1, there is technological regress.

Overall, if the Malmquist index is greater than 1, then there is a growth in productivity. Values less than 1 indicates a decline in productivity (deterioration) and value of 1 denotes productivity stagnation or no change in productivity.

The technical efficiency (EC) can be decomposed into two components: pure efficiency change (PECH) and scale efficiency change (SECH). While the pure efficiency change is related to the learning process in the decision-making units, the scale efficiency change indicates the success to produce in optimal scale.

Table A2.2: List of Countries in the Sample by Income Group and Region

High Income		Upper Middle Income		Lower middle income		Low Income	
Country	**Region**	**Country**	**Region**	**Country**	**Region**	**Country**	**Region**
Croatia	Europe & Central Asia	Fiji	East Asia & Pacific	Indonesia	East Asia & Pacific	Papua New Guinea	East Asia & Pacific
Poland	Europe & Central Asia	Albania	Europe & Central Asia	Kiribati	East Asia & Pacific	Belarus	Europe & Central Asia
Chile	Latin America & Caribbean	Bulgaria	Europe & Central Asia	Mongolia	East Asia & Pacific	Haiti	Latin America & Caribbean
Trinidad & Tobago	Latin America & Caribbean	Macedonia	Europe & Central Asia	Myanmar	East Asia & Pacific	Afghanistan	South Asia
Uruguay	Latin America & Caribbean	Romania	Europe & Central Asia	Solomon Islands	East Asia & Pacific	Bangladesh	South Asia
Oman	Middle East & North Africa	Argentina	Latin America & Caribbean	Timor-Leste	East Asia & Pacific	Benin	Sub-Saharan Africa
Saudi Arabia	Middle East & North Africa	Brazil	Latin America & Caribbean	Armenia	Europe & Central Asia	Burkina Faso	Sub-Saharan Africa
Seychelles	Sub-Saharan Africa	Costa Rica	Latin America & Caribbean	Georgia	Europe & Central Asia	Burundi	Sub-Saharan Africa
		Dominican Republic	Latin America & Caribbean	Kosovo	Europe & Central Asia	Ethiopia	Sub-Saharan Africa
		Ecuador	Latin America & Caribbean	Kyrgyz Republic	Europe & Central Asia	Gambia, The	Sub-Saharan Africa
		Jamaica	Latin America & Caribbean	Moldova	Europe & Central Asia	Guinea	Sub-Saharan Africa
		Mexico	Latin America & Caribbean	Tajikistan	Europe & Central Asia	Guinea-Bissau	Sub-Saharan Africa
		Paraguay	Latin America & Caribbean	Ukraine	Europe & Central Asia	Liberia	Sub-Saharan Africa
		Peru	Latin America & Caribbean	El Salvador	Latin America & Caribbean	Malawi	Sub-Saharan Africa
		St. Lucia	Latin America & Caribbean	Guatemala	Latin America & Caribbean	Mali	Sub-Saharan Africa
		Lebanon	Middle East & North Africa	Jordan	Middle East & North Africa	Mozambique	Sub-Saharan Africa
		Equatorial Guinea	Sub-Saharan Africa	Tunisia	Middle East & North Africa	Niger	Sub-Saharan Africa
		Gabon	Sub-Saharan Africa	Bhutan	South Asia	Senegal	Sub-Saharan Africa
		Mauritius	Sub-Saharan Africa	Pakistan	South Asia	Sierra Leone	Sub-Saharan Africa
		Namibia	Sub-Saharan Africa	Angola	Sub-Saharan Africa	Tanzania	Sub-Saharan Africa
		South Africa	Sub-Saharan Africa	Cameroon	Sub-Saharan Africa	Togo	Sub-Saharan Africa
				Cabo Verde	Sub-Saharan Africa	Uganda	Sub-Saharan Africa
				Kenya	Sub-Saharan Africa		
				Lesotho	Sub-Saharan Africa		
				Mauritania	Sub-Saharan Africa		
				São Tomé and Príncipe	Sub-Saharan Africa		

Note: Based on World Bank country classifications by income level: 2018-2019

Table A2.3: Malmquist Index summary by country means – considering quality of road infrastructure

Country	Total Factor Productivity Change (TFPCH)	Technical Efficiency Change (EC)	Technological Change (TECCH)	Scale Efficiency Change (SECH)	Pure Efficiency Change (PECH)
Bulgaria	0.88	0.78	1.13	0.54	1.44
Costa Rica	0.83	1.00	0.83	1.00	1.00
Ethiopia	1.03	0.85	1.21	0.95	0.89
Guatemala	0.56	0.70	0.80	0.72	0.98
Kenya	1.02	1.26	0.81	1.03	1.22
Macedonia	1.82	5.14	0.35	3.67	1.40
Mauritius	0.96	0.74	1.29	0.64	1.16
Mexico	1.14	1.00	1.14	1.00	1.00
Namibia	1.00	0.02	1.00	0.02	1.00
Paraguay	1.62	1.00	1.62	1.00	1.00
Peru	0.85	0.91	0.93	1.13	0.81
Senegal	1.41	1.13	1.25	1.03	1.10
Tunisia	1.09	1.69	0.65	1.74	0.97

Figure A2.4: Mean Deviations from the Malmquist Index

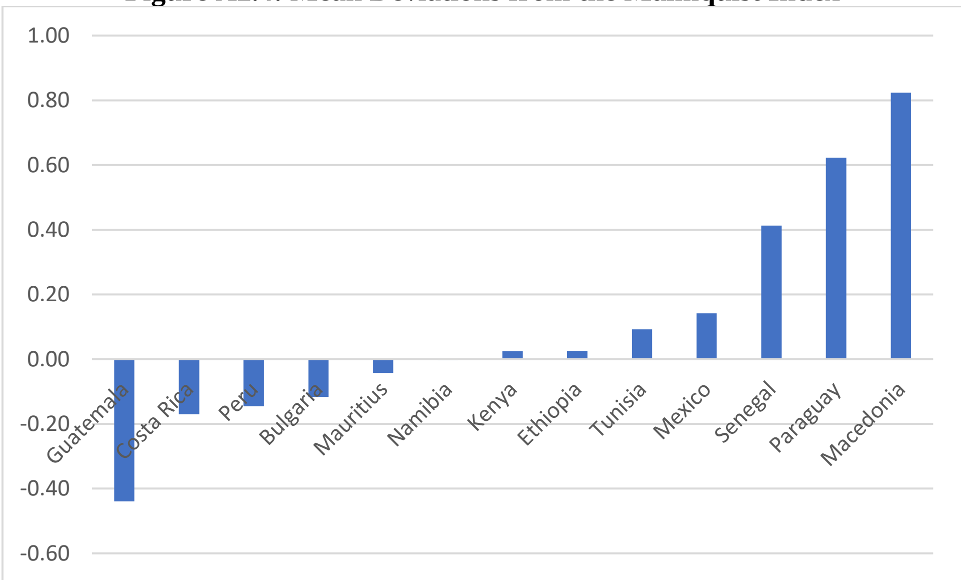

Table A2.4: Analysis of Coverage Shares to Gauge Representativeness of BOOST Sample

No. of BOOST Countries Included in Numerator	Total No. Of Countries Included in Denominator	Population Share (%)	GDP Share (%)
All (N = 77)	All (N=205)	27.4	11.4
All except HICs (N=69)	All except HICs (N=132)	39.4	27.2
LICs only (N=22)	LICs only (N=30)	73.1	82.9
MICs only (N=47)	MICs only (N=102)	24.4	23.2
MICs only (N=47)	MICs only excluding BRICS (N=97)	57.9	71.4
EAP only (N=8)	EAP only (N=34)	14.7	4.5
MENA only (N=5)	MENA only (N=20)	15.5	30.3
ECA only (N=14)	ECA only (N=55)	16.8	5.4
LCR only (N=16)	LCR only (N=39)	83.8	86.5
SAR only (N=4)	SAR only (N=8)	22.7	17.7
SSA only (N=30)	SSA only (N=46)	53.8	57.5

Note: This table compares the sample of countries included in the BOOST dataset, and various sub-samples thereof, with the wider global situation to gauge representativeness. All calculations are based on 2018.

Abbreviations: East Asia and Pacific (EAP), Middle East and North Africa (MENA), Europe and Central Asia (ECA), Latin America and Caribbean (LCR), Sub-Saharan Africa (SSA), Brazil – Russia – India – China – South Africa (BRICS). Calculations are based on World Bank country classifications by income level: 2018 – 2019.

Table A2.5: Analysis of Potential for Double-Counting Between Data Sources

	Budget expenditure	Foreign aid	SOEs	PPPs
Foreign aid	None, as BOOST database excludes development budget items coming from foreign aid.			
SOEs	Possible, transfers to SOEs may be on budget, but are only sometimes identified as such in SOE accounts.	Possible, foreign aid may be transferred to SOEs, but are only sometimes identified as such in SOE accounts.		
PPPs	Possible, payments to PPPs may come from the budget, but are not separately identified in BOOST.	Possible, but less common, as foreign aid may be transferred to PPPs whose accounts are not available.	Possible, as payments to PPPs may come from SOEs, but are not separately identified in SOE accounts.	

Note: This table identifies the possible channels and reasons for double-counting between different sources of public finance for infrastructure.