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ESTIMATING INFRASTRUCTURE FINANCING NEEDS IN ASIA-PACIFIC LEAST DEVELOPED COUNTRIES, LANDLOCKED DEVELOPING COUNTRIES AND SMALL ISLAND DEVELOPING STATES

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Estimating infrastructure financing needs in Asia-Pacific least developed countries, landlocked developing countries and small island developing States [*]

by
Candice Branchoux, Lin Fang and Yusuke Tateno

Abstract

This paper develops a framework to estimate infrastructure financing needs of the Asia-Pacific least developed countries (LDCs), landlocked developing countries (LLDCs) and small island developing States (SIDS) by 2030. The framework takes into account the financing needs to close existing infrastructure gaps, keep up with growing demands for new infrastructure, maintain existing infrastructure and mitigate the vulnerability of infrastructure to climate-related risks. Based on a panel of 71 developing economies from 1990 to 2015 and the application of unit costs to the level of physical infrastructure stock projected to 2030, the required resources are estimated to amount to 7.6% of GDP per annum on weighted average, which exceeds current levels of infrastructure funding of 5-7% of GDP. This indicates that existing sources of financing are insufficient to meet the large and growing needs of infrastructure financing in these economies. The paper finds that a large proportion of financing needs in LDCs and SIDS arises from the current infrastructure shortages, particularly in the transport and the energy sector, implying that provision of universal access to basic infrastructure services would require large outlays of resources. Results also suggest that LLDCs and some SIDS require over one-third of their spending to be allocated to maintenance and replacement of existing assets, while those in low-lying coastal areas face substantial long-run costs in improving infrastructure to mitigate climate change and protecting it against loss and damages caused by extreme weather events.

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I. Introduction

The Asia-Pacific least developed countries (LDCs), landlocked developing countries (LLDCs) and small island developing States (SIDS) continue to face significant challenges and constraints in achieving inclusive growth and sustainable development. Such challenges and constraints are associated with remoteness, geographic features, availability of resources, demography, weather or, most commonly, a combination of these factors. The result has been limited progress in structural transformation, slower development of productive capacities and heightened vulnerability to external shocks, such as those arising from volatile commodity prices, climate change and natural disasters.

While each of these economies faces its own unique circumstances, one thing they share in common is a significant deficit in physical infrastructure, such as transport, energy, information and communications technology (ICT), and water supply and sanitation (WSS). In many of these economies, particularly in the least developed ones, access to basic infrastructure services is still far from universal: in Afghanistan, Solomon Islands and Cambodia, more than 70 per cent of rural population does not have access to improved water sources and more than half of the population is lacking access to electricity.[1] A lack of physical infrastructure is the principle obstacle to sustainable development as it not only limits opportunities to expand productive capacities and improve connectivity across and among countries, thereby restricting economic growth, but also constrains social development and harms environmental sustainability (ESCAP, 2017).

In addition to the current infrastructure deficit, the Asia-Pacific LDCs, LLDCs and SIDS will face new demand for physical infrastructure stemming from their rising wealth and rapid urbanization. Although population growth is expected to slow down over the medium-term, urban growth pressures will remain in the coming decades, particularly in LDCs and LLDCs. In these economies, only one in three persons lived in urban areas as of 2014, while projections suggest that urbanization will continue and about half of the population is expected to live in urban areas by 2050, aggravating the infrastructure shortage in cities (ESCAP, 2015a). In addition, a rapidly rising middle-income class in LLDCs and an expansion of the transitional income category — defined as people in the income bracket right below the middle-income class — in LDCs will create further demand for public infrastructure services that go beyond basic needs, such as reliable energy and ICT infrastructure.

Inadequate maintenance could also add to the expansion of future infrastructure deficits. Countries tend to prioritize development of new infrastructure over maintenance of existing facilities and end up reducing the useful life of these assets (Roja, 2003; and Kalatzidakis and Kalyvits, 2004). World Bank (2005) estimates that preference towards building new road infrastructure, for instance, has

[1] Data for access to electricity and to improved water sources are for 2012 and 2015, respectively, and compiled from the World Bank (2017).

led investments on maintenance to be only between 20% and 50% of what they should be to effectively maintain the road network. To make matters worse, in countries that have chronically weak public revenues such as LDCs, shortfalls in government review targets are often accompanied by cuts on maintenance spending. The degradation of existing infrastructure not only diminishes the benefits of network development but also results in costly reconstruction projects or repair jobs in the future.

Moreover, climate change will necessitate the development of more sustainable and climate-resilient infrastructure. For instance, in the 2030 Agenda for Sustainable Development, Goal 7 is set to ensure universal access to affordable, reliable, sustainable and modern energy. It aims to increase the share of renewable energy in the global energy mix and specifically addresses the importance of adopting clean energy technology to LDCs, LLDCs and SIDS. It is estimated that developing Asia would need additional investment of $232 billion annually to double their renewable energy consumption by 2030 and $211 billion for energy efficiency improvement in a scenario that is consistent with the 2-degree target of the Paris Agreement (SE4All, 2015). SIDS and other low-lying coastal areas also face substantial long-run costs in improving its infrastructure to mitigate loss and damages caused by climate change or extreme weather events. In Kiribati, operating expenditure related to climate change contingencies, together with new infrastructure maintenance costs, are collectively assumed at around 2–3% of GDP (IMF, 2016).

While it is clear that the Asia-Pacific LDCs, LLDCs and SIDS have to direct significant financial resources to address these issues, quantifying how much is needed for these economies is not an easy undertaking This is partly because information on the magnitude of their past infrastructure investment is often not available. Thus, although some studies have included these economies as the "rest" of the world or of the region, those estimates are typically extrapolated from data for other countries (see, for instance, McKinsey, 2013; and McKinsey, 2016).

The main challenge in estimating financing needs for LDCs, LLDCs and SIDS arises from differences in the nature of infrastructure needs in these economies and other developing countries. In the latter, most needs are a result of either increasing demand for new infrastructure or maintenance and rehabilitation of existing infrastructure. Thus, estimating future levels of infrastructure can be based upon historical trend of infrastructure provision and projections of demand arising from population growth, increasing urbanization and per capita income growth assumptions. However, infrastructure needs in LDCs, LLDCs and SIDS may be more related to supply constraints and resulting infrastructure shortages. Therefore, estimates for these economies cannot be based solely on historical trends and need to include a component of financing needs that would be required to fill the existing infrastructure gaps.

This paper therefore aims to develop a framework to estimate the infrastructure financing needs of the Asia-Pacific LDCs, LLDCs and SIDS taking into account four components: 1) financing that is needed to meet the growing demand for new infrastructure as populations increase and become more urbanized; 2) financing that is needed to effectively maintain existing infrastructure; 3) financing that is needed to fill existing infrastructure shortages; and 4) financing that will be needed for improving infrastructure to mitigate loss and damages caused by climate change or extreme weather events.

The paper contributes to the literature of estimating infrastructure financing needs in the following ways. First, it focuses on a number of 'small' Asia-Pacific countries that have been often omitted from existing analyses or included only as part of the 'rest' of the world due to limited data availability. Second, in addition to the conventional factors of infrastructure financing needs that arise from growing future demand for infrastructure, the paper considers financing that are needed to fill currently existing infrastructure shortages. This component is typically assumed to constitute only a small proportion of total financing needs and thus excluded from analyses. This is a valid assumption to be made as long as countries/sectors assessed are sufficiently developed and have adequate provision of basic services. Since the focus of the paper is on the Asia-Pacific LDCs, LLDCs and SIDS, this assumption has to be relaxed. Finally, this paper considers climate adaptation and mitigation as one of the key drivers of financing needs in these economies, especially in the Pacific. With a notable exception of the latest study by ADB (2017), this component has not been taken into account in the context of estimating infrastructure financing needs and providing universal access to basic infrastructure services.

The methodology developed in this paper partly builds upon the "top-down" approach developed by Fay (2000) and Fay and Yepes (2003) and later extended by Bhattacharyay (2012), Ruiz-Nunez and Wei (2015) and ADB (2017). It first estimates financing needs to meet the growing demand for infrastructure and to effectively maintain existing infrastructure (i.e., the first and second components). Second, for countries or sectors in which universal access to physical infrastructure will not be achieved by 2030, the estimated capital costs of universal access are added (i.e., the third component). Finally, these estimates are adjusted by factoring in the costs of climate mitigation and adaptation (i.e., the fourth component).

The rest of the paper is organized as follows: Section 2 reviews the current state of infrastructure in the Asia-Pacific LDCs, LLDCs and SIDS to demonstrate how universal access to basic services is still limited and narrow in some economies; Section 3 provides the overview of previous studies and methodologies adopted to estimate infrastructure financing needs; Section 4 presents the methodologies used for estimating the four components of infrastructure financing needs; Section 5 provides the results from the estimation of infrastructure financing needs of 29 countries by sector; and Section 6 discusses the policy implication of the findings and draw conclusions.

II. The state of infrastructure in the Asia-Pacific LDCs, LLDCs and SIDS

The infrastructure sectors covered in this paper are (1) transport, (2) energy/electricity, (3) information and communications technology (ICT), and water supply and sanitation (WSS). The review of the state of infrastructure in the Asia-Pacific LDCs, LLDCs and SIDS are based on the following eleven indicators representing the four categories of physical infrastructure:

- Paved roads (total route km per 1,000 people);
- Unpaved roads (total route km per 1,000 people);
- Rail lines (total route km per 1,000,000 people);
- Electric power consumption (kWh per capita);
- Access to electricity (% of population);
- Fixed telephone subscriptions per 100 people;
- Mobile telephone subscriptions per 100 people;
- Access to improved water sources, rural (% of rural population);
- Access to improved water sources, urban (% of urban population);
- Access to improved sanitation facilities, rural (% of rural population); and
- Access to improved sanitation facilities, urban (% of urban population).

Annex 1 provides a list of countries and country groupings used in the paper. Detailed definitions and sources of the infrastructure indicators can be found in Annex 2.

Table 1 offers a review of access to infrastructure services by presenting simple averages by indicator for each of the three country groups, LDCs, LLDCs and SIDS as well as for other Asian developing countries. It reveals that overall access to physical infrastructure is significantly less developed in LDCs than in LLDCs and SIDS, while that in LLDCs and SIDS is still much lower than the average of other Asian developing counties in many aspects. Across the four sectors of infrastructure, LLDCs perform relatively well in transport and energy sectors, while they still have a room for improvement in access to water sources and sanitation facilities, particularly in the rural areas. In SIDS, provision of energy infrastructure services should be ameliorated as more than 30 per cent of the population is still lacking access to electricity. LDCs are severely lacking access to infrastructure services across all sectors. All three groups share a similar pattern for the WSS sector: rural population has a significantly lower accessibility to both water sources and sanitation facilities than urban population.

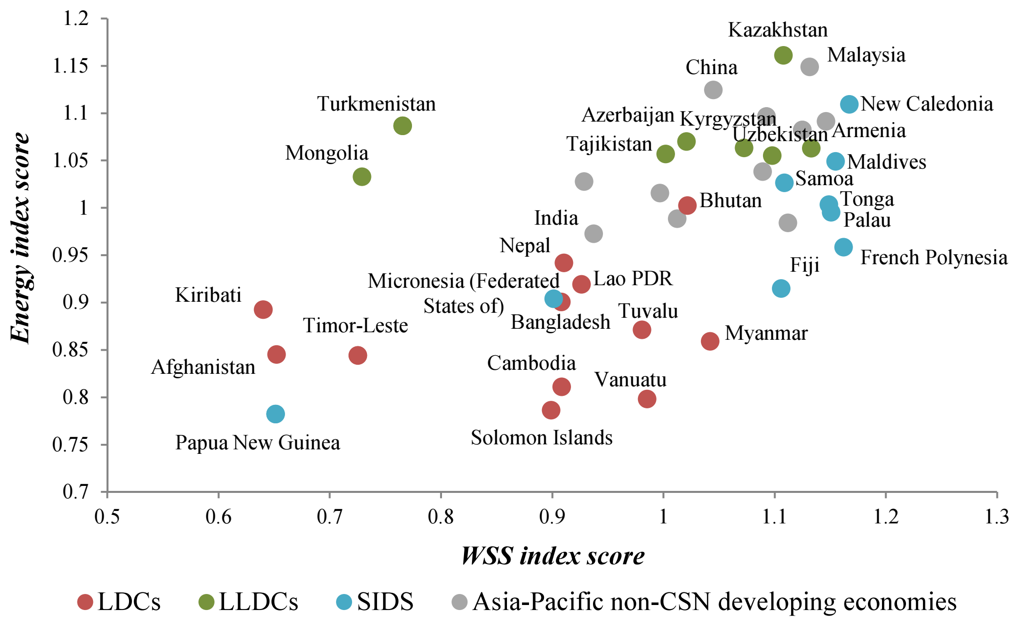
Table 1. Access to infrastructure by country groups

Infrastructure indicator	LDCs	LLDCs	SIDS	Other Asian developing countries
Total route km of paved roads per 1,000 people	1.1	4.7	2.1	2.2
Total route km of unpaved roads per 1,000 people	3.0	3.1	5.3	1.0
Total route km of rail lines per 1,000,000 people	10.7	376.6	74.0	52.2
Electric power consumption (kWh per capita)	410.7	2321.5	1851.4	3091.0
Access to electricity (% of population)	49.5	98.6	67.9	96.4
Number of fixed telephone subscriptions per 100 people	3.8	13.0	15.2	17.6
Number of mobile phone subscriptions per 100 people	84.1	115.5	89.4	109.8
Access to improved water sources (% of rural population)	50.2	80.3	84.9	75.4
Access to improved water sources (% of urban population)	77.2	88.8	92.5	87.6
Access to improved sanitation facilities (% of rural population)	69.9	73.3	84.5	92.5
Access to improved sanitation facilities (% of urban population)	85.7	92.2	95.9	97.6

Sources: Authors' calculations based on data from various sources. See Annex 2 for details.
Note: These figures are simple averages and for 2015 data or the latest available year.

What is also evident from observing these infrastructure indicators is the significant variations in access to basic services across countries, even within each of the three country groups. To illustrate the high degree of variations, index scores are calculated for each country and for each of the four sectors of physical infrastructure: each of the eleven infrastructure indicators is first standardized to have a mean value of 1 and a standard deviation of 0.15 and then averaged by country and by sector. As an example, figure 1 presents a scatterplot of the two index scores - one for the energy sector and the other for the WSS sector – of twelve LDCs, eight LLDCs, nine SIDS and thirteen other Asian developing countries. These countries present a great variety of combinations as regard to accessibility to energy and WSS infrastructure. Across the three country groups, LDCs are all located in the bottom-left part of the graph, which reconfirms the presence of severe infrastructure shortages in both sectors in LDCs. LLDCs are all lined up horizontally on the top part of the graph. This implies that all LLDCs provide decent accessibility to energy infrastructure, relative to the Asia-Pacific developing countries average, while access to WSS infrastructure services varies widely by country. In contrast, most SIDS are scattered vertically on the right part of the graph. This indicates that they hold among the best scores in the WSS sector but the pace of development in the energy sector is more disparate. The exceptions to this tendency are the Federal States of Micronesia and Papua New Guinea. These two countries have many dispersed islands and archipelagos and may encounter additional difficulty providing access to energy and WSS infrastructure. Other Asian developing countries are all located at the top-right corner of the graph, with little variation of achievements across countries.

Figure 1. Index scores in the energy and WSS sectors in Asia and the Pacific



Source: Authors' calculation. See Annex 2 for details.
Notes: Annex 1 provides a complete list of countries and country groupings. The figures are based on data from 2015 for the WSS sector and 2012 for the energy sector. The energy index score is calculated, for each country, as the simple average of standardized values of the two energy infrastructure indicators. The WSS index score is the simple average of standardized values of the four WSS infrastructure indicators. Each standardized value is computed to have a mean of 1 and a standard deviation of 0.15 so that the units of these values are consistent.

III. Literature

A wide range of estimates on infrastructure financing needs has been produced in recent years. For instance, ESCAP (2015) estimated that the Asia-Pacific developing region would need to mobilize \$800-900 billion annually for the provision of transport infrastructure services, ICT, water supply and sanitation and electricity access. Bhattacharyay (2012) reported that Asia-Pacific will need to spend approximately \$8 trillion in infrastructure investment for the period 2010-2020 or equivalent to \$800 billion per year in order to maintain current levels of economic growth. Similarly, Fay and Toman (2011) estimated that up to an additional \$1.5 trillion will be necessary annually through 2020 to help low- and medium-income countries establish adequate levels of infrastructure. McKinsey Global Institute (2016) assessed that global infrastructure financing requirements for the period 2016-2030 would be around \$1.6 trillion annually, 60% above the 2000-2015 trends. Most recently, ADB (2017) estimated that, over the period 2016-2030, developing Asia's infrastructure investment needs would reach $26 trillion or $1.7 trillion per annum.

Although these studies agree that bridging infrastructure gaps will require massive investment, their estimates vary significantly as they rely upon various assumptions and definitions. The use of different assumptions, for instance on future infrastructure needs, estimated rates of economic and population growth, assumed increases in rates of urbanization, and policy shocks, necessarily translates itself into wide discrepancies between the estimates. Moreover, as there is no universal database on infrastructure investment, different databases follow their own definitions and cover different aspects of infrastructure investment.

In terms of the methodologies, existing studies can be broadly classified into two categories based on the approaches adopted to estimate infrastructure financing needs: the 'top-down' and the 'bottom-up'.

The 'bottom-up' approach assesses the total infrastructure services demand by reviewing infrastructure investments demand at the project level. The methodology consists of reviewing the implementation costs of individual infrastructure projects and compiling the estimates to obtain the total demand by country and by sector. However, lack of relevant data obscures what is needed at a project level. For instance, data on projects or plans are often not available or confidential so the cost of these projects must be estimated, with varying assumptions based upon costs of past infrastructure projects, which are assumed to be in line with best practice scenarios.

The 'top-down' approach quantitatively estimates infrastructure needs at the national level using econometric analysis techniques. This approach follows the works of Fay (2000) and Fay and Yepes (2003) that developed a model to predict future demand for infrastructure and is later applied in a number of studies, including Bhattacharyay (2012), Ruiz-Nunez and Wei (2015) and ADB (2017). In this approach, the relationships between demand for infrastructure services and economic/demographic variable are established for each sector and extrapolated into the future using predicted growth rates. Once obtained the projections of the infrastructure stock, standardized unit costs based on international best practice norms are applied to estimate the financing requirements for new infrastructure. However, by construction, such projections rely on unit cost estimates and ignore many national and regional specificities as it is assumed that what happened in some countries in the past is a good predictor of what might happen in some other countries in the future (Fay and Toman, 2011). Despite these caveats, the 'top-down' approach still forms the basis for many of the current estimates of multi-country infrastructure financing needs as the data requirements are relatively modest.

IV. Methodology for estimation

A conventional 'top-down' approach to forecast infrastructure financing needs is to apply unit capital costs and unit maintenance costs to projected changes of physical infrastructure stock and to existing stock, respectively. However, earlier sections of this paper have pointed out that many LDCs, LLDCs and SIDS currently lack basic infrastructure and also that some of them will incur climate-related costs. Thus, the methodology developed in this paper takes into account these additional costs of filling those shortages and adapting to climate change.

It is assumed that the annual financing needs by 2030 are decomposed and expressed as follows:

$$F_{i,t} = \sum_j F_{i,t}^j \text{ and}$$

$$F_{i,t}^j = \max\left(\frac{I_{i,T}^j - I_{i,t}^j}{T-t}, 0\right) \times c_i^j + I_{i,t}^j \times m_i^j + \max\left(\frac{U^j - I_{i,T}^j}{T-t}, 0\right) \times c_i^j$$

where $F_{i,t}$ represents the total annual financing needs for country *i* at time *t*; $F_{i,t}^j$ indicates financing needs for infrastructure type *j*; $I_{i,t}^j$ is the infrastructure stock of type *j* in country *i* at time *t*; U^j denotes the infrastructure stock of type *j* required to provide universal access; c_i^j and m_i^j are the annual unit capital costs and unit maintenance costs of infrastructure of type *j* in country *i*; and *T* is a targeted time period by which universal access should be provided.

The three terms of $F_{i,t}^j$ represent the first three components of annual financing needs, respectively: the first term indicates the costs induced by the construction of infrastructure stock to meet the rising demand driven by demographic evolution, economic growth and urbanization by 2030; the second term represents the maintenance cost of the existing stock of infrastructure; and the third term signifies the additional financial cost required to palliate the existing infrastructure shortages by 2030. The fourth component of annual financing needs, which is associated with additional costs required for climate change mitigation and adaptation, will be factored in into each of the three terms of $F_{i,t}^j$ through the annual unit capital cost c_i^j and unit maintenance cost m_i^j.

The same set of infrastructure indicators reviewed in Section 2 is also used for estimating infrastructure financing needs. These indicators range from 1990 to 2015, except for that covering mobile phone subscriptions which only starts in 2004. Due to limited availability of data, three year-averages have been used instead of yearly data. This transformation also captures the fact that infrastructure development is a slow process. Linear intra/extrapolations have been performed to fill in the missing values and thus obtained a balanced data panel.

The methodology developed in this paper first estimates the component of financing needs that correspond to the growing demand for new infrastructure based on the 'top-down' approach described above. This is done so by projecting the demand for infrastructure to 2030 under the assumption that infrastructure services are both demanded as consumption goods by individuals and as inputs into the production process by firms, in accordance with the work of Fay (2000), Fay and Yepes (2003), Bhattacharyay (2012) and Ruiz-Nunez and Wei (2015). Once the new demand is projected to 2030, financing needs can be calculated by applying it to a set of unit cost estimates.

The projection of each indicator to 2030 is performed using an OLS regression with fixed effects on a sample of 71 developing economies of which 29 Asia-Pacific LDCs, LLDCs and SIDS. In theory, the use of GMM-IV estimator would be more adapted than OLS given the presence of the lagged variable in the model. However, ADB (2017) found that its explanatory power was actually lower than OLS and that the performance in out-of-sample forecasting was uneven and unsatisfactory. The future infrastructure demand can thus be described by the following process:

$$I_{i,t}^{j} = \alpha_0^j + \alpha_1^j I_{i,t-1}^{j} + \alpha_2^j y_{i,t} + \alpha_3^j A_{i,t} + \alpha_4^j M_{i,t} + \alpha_5^j U_{i,t} + \alpha_6^j P_{i,t} + \alpha_7^j D_i^j + \alpha_8^j t,$$

where $I_{i,t}^{j}$ is the infrastructure stock of type j needed in country i at time t; $y_{i,t}$, $A_{i,t}$ and $M_{i,t}$ represent, respectively, the GDP per capita and shares of agriculture and manufacture value added in GDP; $U_{i,t}$ and $P_{i,t}$ stand for the urbanization rate and the population density; D_i^j is the country fixed effect; and t a time trend, used to capture time effect. All the variables in the equation are expressed in natural logarithm to linearize the model.

The definitions and data sources of the independent variables and their projections are displayed in Annex 3 and Annex 4, respectively, and the regression results can be found in Annex 5. Due to the absence of future estimations for GDP composition, the shares of agriculture and manufacture value added in GDP are assumed to be constant since 2015.

Table 2 presents the unit costs the paper employs. For transport, the estimated unit costs for paved roads, unpaved roads and railways per kilometer are obtained from various studies, such as Collier, Kirchberger and Söderbom (2015), ADB (2012), Fay (2000), Ruiz-Nunez and Wei (2015) and Eliste and Ivailo (2015).

Table 2. Unit capital cost of physical infrastructure

Sector	Unit cost in 2010 US dollars
Paved roads, per kilometer	200,000 for a 6-7m wide road (two lanes)
Unpaved roads, per kilometer	50,000
Rail lines, per kilometer	1,200,000
Electricity generation, per kilowatt of generating capacity	1,400 for fossil fuel-based electricity generation, 2,200 for hydro power-based, and 1,800 for mixed sources, depending on the composition of current generating capacity mix
Access to electricity, per person	Unit cost of electricity generation per kilowatt multiplied by the average power consumption of people who have access to electricity
Fixed telephone, per subscription	250
Mobile telephone, per subscription	100 in urban area and 160 in rural area
Access to water supply, per person	75.5 in rural area and 151 in urban area
Access to sanitation, per person	117 in rural area and 190.5 in urban area

Sources: ESCAP based on various sources.

The estimates for annual unit capital costs for electricity generation are based on World Bank and IEA (2015) and IEA (2016). It is assumed that newly installed generating capacity would use an energy source that is used predominantly in respective countries. For instance, in Afghanistan, Bhutan, Lao PDR, Kyrgyz Republic, Nepal and Tajikistan, where more than 80% of electricity is generated from hydroelectric sources, it is assumed that new capacity would be also based on hydroelectric power. Similarly, in Azerbaijan, Bangladesh, Kazakhstan, Maldives, Mongolia, Solomon Islands, Tonga, Vanuatu, Turkmenistan, Kiribati, Palau, Tuvalu, New Caledonia, Timor-Leste and Federated States of Micronesia, where more than 80% of electricity is generated from coal, gas or oil sources, new capacity would be also fossil fuel-based. Countries in which electricity is generated from mixed sources are assumed to face the averages of the costs faced by the first two groups. The data on the energy mix for individual countries' electricity generation are taken from UNIDO and ICSHP (2013) and IEA (2014). The unit cost for providing access to electricity is the unit costs for electricity generating capacity multiplied by the average power consumption of people with access to electricity. This calculation makes the estimates for access to electricity country-specific, depending on the current composition of energy sources for electric power generation and the projected power consumption.

Unit costs for fixed and mobile telephone per subscription are borrowed from Ruiz-Nunez and Wei (2015) and ADB (2017), while for WSS indicators, country-level unit costs estimated by WHO (2012) are applied. For water supply, a household connection and piped and treated household water supply for all are assumed, respectively, in rural and urban areas. For sanitation, a provision of a septic tank is assumed in a rural area, while sewerage with treatment for all is considered for an urban area. The unit costs used for Kiribati, Federated States of Micronesia, New Caledonia, Palau and Tuvalu are unavailable in the original study so the averages of SIDS are applied.

The second component of financing, which is needed for maintenance of existing infrastructure, is calculated by applying depreciation rates to the predicted total value of infrastructure stocks. The paper assumes a depreciation rate of 2% for paved roads, rail lines, 1% for unpaved roads, 2-3% for power, depending upon current energy mix, and 3% for telecommunication. For water and sanitation, depreciation rates vary across countries, depending upon the technologies used and whether the facilities are located in rural or urban areas. While rates of 2-13% for water and 10-17% for sanitation are assumed for most countries, some LDCs and LLDCs face substantially higher rates of up to 48% for water and up to 39% for sanitation (WHO, 2012).

The third component of financing, that is needed to fill existing infrastructure shortages, is calculated as the cost of reaching the ‘unserved’ by 2030 based on the same set of unit costs used to estimate the first component. While there is no obvious ‘optimal’ level of infrastructure that can be used to define the level up to which infrastructure gaps need to be filled, this framework uses as a normative target *universal access* to electricity and water and sanitation by 2030. Thus, for access to electricity and for the four indicators of WSS, the targets are to provide everyone with access to these types of infrastructure by 2030. For electricity, the targeted annual power consumption per capita is defined using the maximal value between countries’ 2030 power consumption projection and the current average of other Asian developing economies (3,091 kWh per capita annually). The number of people that will not have access to these services in 2030 is calculated based on the projected stock of infrastructure obtained above and the projection of population and urbanization rate.

Since defining universal access to public transportation and telecommunications is less obvious, the average penetration rates or densities in other Asian developing countries are used as the normative target for LDCs, LLDCs and SIDS. Thus, the target for ICT and transport indicators is to reach by 2030 the average level of other Asian countries in 2015. The amount of stock needed to reach this objective is calculated for each country by taking the difference between the average infrastructure stock of other Asian developing countries in 2015 and the previously projected values of infrastructure indicators in 2030. The same set of unit capital cost assumptions presented at table 1 is then applied to get the amount needed to provide universal access by 2030.

The last component, related to climate change, covers three elements: 1) additional capital and maintenance costs of energetic transition to renewable sources for electricity generation; 2) costs of protecting infrastructure against changes in rainfall and temperature due to climate change and 3) costs of protecting infrastructure in SIDS from extreme weather events.

The first element is to access additional financing needs for new electricity-generating capacity to be only from green sources. While the first three components of financing needs are estimated based on the assumption that countries will continue to rely on electricity generation sources that they are primarily reliant on at the moment, this additional element considers the case where some countries face higher unit costs. Since hydropower is clean energy, additional financing needs to adopt renewable energy technologies will be incurred only by a group of countries that predominantly use traditional fuels and mixed energy sources. Considering the fact that hydropower is among the most prevalent renewable energy technologies today and also that hydropower is usually more affordable than other renewable energy technology types, the estimation of this element applies the hydropower unit cost to all new provision of electricity.

It should be noted however that some countries, including Kiribati, Maldives, Palau, Tonga and Tuvalu, have limited hydropower potential and would necessarily face higher costs for shifting their current energy mix towards renewables such as solar and wind. For example, the Model for Electricity Technology Assessment, developed by the Energy Sector Management Assistance Program of the World Bank,[2] assumes that solar/wind technologies would cost more than twice as much as hydropower electricity generation, even after taking into account the recent cost reduction in these types of clean energy technology. In this light, the estimation of this component of financing needs should be interpreted as a lower bound of the actual requirements for countries with limited hydropower potential.

The second element is associated with the needs to integrate climate resilience into infrastructure. It is assumed that climate proofing will increase capital and maintenance costs of providing infrastructure. Taking paved roads for example, activities such as upgrading concrete mix and improving the structure of drainage to strengthen their capacity to manage heavy rainfalls would increase the capital investment cost. Following ADB (2014), this paper assumes that at least 5% of total capital investment is required as cost of protecting infrastructure against changes in rainfall and temperature. Some atoll countries such as the Federated States of Micronesia and Kiribati face higher costs which climb up to 21% of total expenditures. Besides, additional 0.5-1.5 percentage points of maintenance cost for new and existing infrastructure is also employed for all CSN.

Finally, the third element is to incorporate costs of protecting infrastructure in SIDS from increased tropical cyclone wind intensity. Following The World Bank (2016), this paper estimates the adaptation cost to be 5% of replacement cost. While sea level rise, coastal erosion, sea and river flooding induced by climate change do require huge amount of investment to mitigate losses, the estimation of related costs would be beyond the scope of this study, since the various engineering solutions such as sea walls building and beach nourishment cannot be incorporated into the discussion of four infrastructure sectors. Thus, the actual financing requirements in SIDS concerning climate resilience would be much higher than the estimation provided in this paper.

[2] See www.esmap.org/node/3051 (accessed on 24 February 2017).

V. Results

The estimation results indicate that financing requirements to cover the four components from 2018 to 2030 in the Asia-Pacific LDCs, LLDCs and SIDS would be \$700 billion or \$54 billion a year in 2010 dollars (table 3). This represents a weighted average of 7.6% of the total GDP per annum, which exceeds current levels of infrastructure funding of 5-7% of GDP.[3] Across the three country groups, financing needs of LDCs are by far the largest, both in terms of volume (\$38 billion) and share of GDP (12.6% of GDP). Those of LLDCs and SIDS are estimated approximately at 3.8% and 6.4% of their respective GDP. At the sectoral level, the energy sector accounts for the largest share of overall investment needs, while the needs are also sizeable for transport infrastructure in LDCs and SIDS. Detailed results for each country are presented in Annex 6.

Table 3. Annual infrastructure financing needs, 2018-2030, at 2010 prices

	LDCs		LLDCs		SIDS		Total	
	Millions of dollars	% of GDP	Millions of dollars	% of GDP	Millions of dollars	% of GDP	Millions of dollars	% of GDP
Transport	12,772	4.3%	4,746	1.3%	711	2.3%	18,230	2.6%
Energy	15,968	5.4%	5,261	1.4%	705	2.3%	21,934	3.1%
ICT	5,914	2.0%	2,159	0.6%	319	1.0%	8,391	1.2%
WSS	2,934	1.0%	2,291	0.6%	193	0.6%	5,418	0.8%
Total	37,588	12.6%	14,457	3.8%	1,928	6.4%	53,973	7.6%

Source: Authors' estimation.

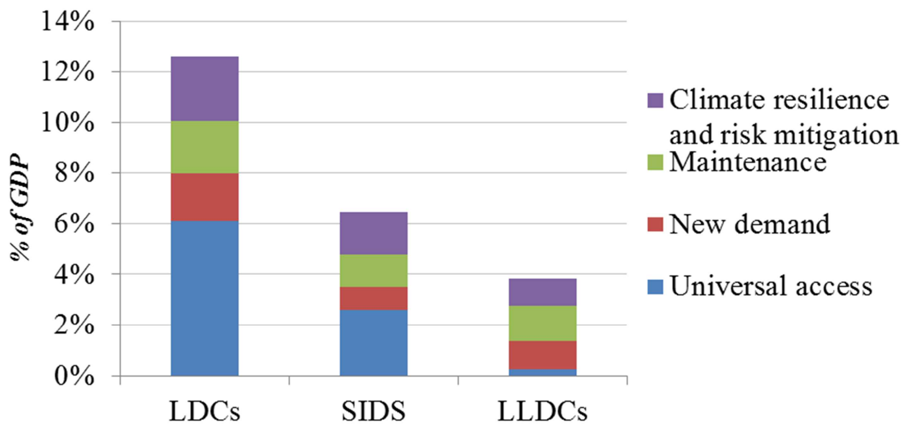
Figures 2 and 3 present the composition of annual financing needs for each of the three country groups and their break down by sector. They indicate that the largest share of infrastructure financing needs in LDCs and SIDS arise from their infrastructure shortages, particularly in the transport sector and the energy sector. In Afghanistan, Nepal and Solomon Islands, the provision of universal access to basic infrastructure services accounts for more than 50% of the total estimated financing requirements. These findings, while justifying the inclusion of this component of financing needs into the estimation framework, indicate that provision of universal access to basic infrastructure services would require large outlays of resources in these counties.

For LLDCs, results suggest that more than one third of the spending should be allocated to effectively maintain existing assets. SIDS also face large financing needs for maintenance of transport infrastructure and additional needs for the development of more sustainable and climate-resilient infrastructure. The former finding is closely in line with PRIF (2013) in which the cost of infrastructure maintenance was found to be high and one of the major financing challenges for SIDS.

[3] Estimates for current levels of infrastructure funding in the Asia-Pacific LDCs, LLDCs and SIDS are given by ESCAP (2017).

On average, financing equivalent to 1.7% of GDP will be required to achieve energetic transition and to protect infrastructure against extreme weather events. Results of LDCs (2.5% of GDP) are mainly driven by countries that are also SIDS, particularly Timor-Leste and Kiribati where financing needs to cover the climate-change related component represent, respectively, additional 4.1% and 3.7% of GDP. In LLDCs, the energy sector accounts for a half of this component, reflecting the fact that more than 70 per cent of electricity is generated from coal, oil or gas sources in most of these countries (World Bank, 2017).

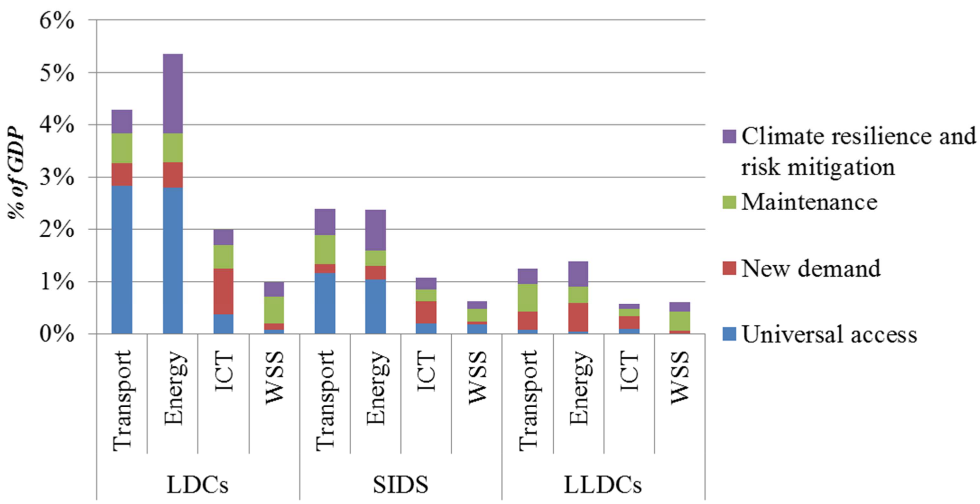
Figure 2. Annual infrastructure financing needs by country group and component, as a percent of GDP, 2018-2030



Source: Authors' estimation.

Note: The figures reported correspond to averages of the high and low estimates.

Figure 3. Annual infrastructure financing needs by country group, component and sector, as a percent of GDP, 2018-2030



Source: Authors' estimation.

Note: The figures reported correspond to averages of the high and low estimates.

VI. Conclusions

This paper presented estimations of infrastructure financing requirements over 2018-2030 accounting for needs to close existing infrastructure gaps, keep up with growing demands for new infrastructure, maintain existing infrastructure and mitigate the vulnerability of infrastructure to climate-related risks. Based on to the assessments for 29 countries for which relevant data are available, the paper finds that the Asia-Pacific LDCs, LLDCs and SIDS would need to spend on average 7.6% of their GDP per annum to cover the above four components. Given the limited resource availability and the large scale of investment needed, these economies will face significant challenges in accessing sufficient and appropriate financing from a public and private, as well as domestic and external sources.

The estimates presented in this paper are higher than those of other studies in Asia-Pacific, such as 6.5% of GDP estimated by Bhattacharyay (2012) and 5.9% of GDP by ADB (2017). While our estimates could be considered as an upper bound of regional financing needs, these discrepancies in estimates can be explained largely by the difference in countries of study interest as well as the difference in components of financing needs considered. This paper, focusing only on the region's LDCs, LLDCs and SIDS, did not include high- or most of upper-middle income countries. Since, in general, the lower the income level of a country, the higher the infrastructure financing needs, our estimates should be, by default, larger than other studies that provide region-wide or world-wide comprehensive assessments. In addition, the estimation of this study included financing needs required to provide universal access, which turned out to be the largest one for LDCs and SIDS. However, this component is usually assumed to be sufficiently small, especially in relatively rich countries, and excluded from analysis. Without these factors, our estimates would become highly consistent and comparable with other studies.

While the methodology proposed in this paper has many limitations as in other similar studies, it still provided several insights as to where and how much financing is needed for infrastructure development in 'small' economies of the Asia-Pacific region. LDCs, while recording remarkable progress in some countries in recent years, still require large outlays of resources to provide basic infrastructure services for all. LLDCs and SIDS are faced by high cost of maintenance, mostly in their transport sector. Finally, the upgrading of infrastructure for climate proofing and climate adaption would require additional investment across the region and sectors, but especially in countries with a high reliance on fossil fuels for electricity generation and also in those that are susceptible to climate change impacts and other extreme weather events.

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Annex 1. List of countries and country groups

LDCs	LLDCs	SIDS	Other Asian developing countries	Developing countries
Afghanistan*	Armenia	Fiji	China	Algeria
Bangladesh	Azerbaijan	French Polynesia	India	Argentina
Bhutan*	Kazakhstan	Maldives	Indonesia	Benin
Cambodia	Kyrgyzstan	Micronesia	Iran	Botswana
Kiribati**	Mongolia	New Caledonia	Malaysia	Brazil
Lao PDR	Tajikistan	Palau	Pakistan	Cameroon
Myanmar	Turkmenistan	Papua New Guinea	Philippines	Chile
Nepal*	Uzbekistan	Samoa	Republic of Korea	Colombia
Solomon Islands**		Tonga	Singapore	Cote d'Ivoire
Timor-Leste**			Sri Lanka	Egypt
Tuvalu**			Thailand	Gabon
Vanuatu**			Turkey	Ghana
			Viet Nam	Jordan
				Kenya
				Mexico
				Morocco
				Mozambique
				Namibia
				Nigeria
				Paraguay
				Peru
				Saudi Arabia
				Senegal
				South Africa
				Tunisia
				Uruguay
				Yemen
				Zambia
				Zimbabwe

Notes: (*) For simplicity, LDCs that are also LLDCs (Afghanistan, Bhutan and Nepal) belong to the LDC group only. (**) Similarly, LDCs that are also SIDS (Kiribati, Solomon Islands, Timor-Leste, Tuvalu and Vanuatu) belong to the LDC group only. In this way, these three groups are mutually exclusive (non-overlapping).

Annex 2. Definition and sources of the infrastructure indicators

Type of physical infrastructure	Name of indicator	Definition	Sources
Transport	Paved roads (total route km per 1000 people)	Paved roads are those surfaced with crushed stone (macadam) and hydrocarbon binder or bituminized agents with concrete or with cobblestones.	World Bank Development Indicators, ADB, CIA Factbook
	Unpaved roads (total route km per 1000 people)	Total road network excluding the paved road network. Total road network includes motorways highways and main or national roads secondary or regional roads and all other roads in a country.	
	Rail lines (total route km per 1 000 000 people)	Rail line is the length of railway route available for train service, irrespective of the number of parallel tracks.	World Bank, Transportation, Water, and Information and Communications Technologies Department, Transport Division.
Energy	Power consumption (kWh per capita)	Electric power consumption measures the production of power plants and combined heat and power plants less transmission, distribution, and transformation losses and own use by heat and power plants.	IEA Statistics, OECD/IEA
	Access to electricity (% of population)	Access to electricity is the percentage of population with access to electricity.	World Bank, Sustainable Energy for All (SE4ALL) database from World Bank, Global Electrification database.
ICT	Fixed telephone subscriptions per 100 people	Fixed telephone subscriptions refers to the sum of active number of analogue fixed telephone lines, voice-over-IP (VoIP) subscriptions, fixed wireless local loop (WLL) subscriptions, ISDN voice-channel equivalents and fixed public payphones.	International Telecommunication Union, World Telecommunication/ICT Development Report and database.
	Mobile telephone subscriptions per 100 people	Refers to the subscriptions to a public mobile telephone service and provides access to Public Switched Telephone Network (PSTN) using cellular technology, including number of pre-paid SIM cards active during the past three months. This includes both analogue and digital cellular systems (IMT-2000 (Third Generation, 3G) and 4G subscriptions, but excludes mobile broadband subscriptions via data cards or USB modems. Subscriptions to public mobile data services, private trunked mobile radio, telepoint or radio paging, and telemetry services should also be excluded. This should include all mobile cellular subscriptions that offer voice communications.	
Water supply and sanitation	Access to improved water sources, rural (% of rural population)	The improved drinking water source includes piped water on premises (piped household water connection located inside the user's dwelling, plot or yard), and other improved drinking water sources (public taps or standpipes, tube wells or boreholes, protected dug wells, protected springs, and rainwater collection).	World Bank Development Indicators
	Access to improved water sources, urban (% of urban population)		
	Access to improved sanitation facilities, rural (% of rural population)	Improved sanitation facilities are likely to ensure hygienic separation of human excreta from human contact. They include flush/pour flush (to piped sewer system, septic tank, pit latrine), ventilated improved pit (VIP) latrine, pit latrine with slab, and composting toilet.	
	Access to improved sanitation facilities, urban (% of urban population)		

Annex 3. Definition and sources of the independent variables

Name of indicator	Definition	Sources
GDP per capita (constant 2010 US$)	GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant 2010 U.S. dollars.	World Bank Development Indicators
Agriculture, value added (% of GDP)	Agriculture corresponds to ISIC divisions 1-5 and includes forestry, hunting, and fishing, as well as cultivation of crops and livestock production. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources. The origin of value added is determined by the International Standard Industrial Classification (ISIC), revision 3. Note: For VAB countries, gross value added at factor cost is used as the denominator.	
Manufacturing, value added (% of GDP)	Manufacturing refers to industries belonging to ISIC divisions 15-37. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources. The origin of value added is determined by the International Standard Industrial Classification (ISIC), revision 3. Note: For VAB countries, gross value added at factor cost is used as the denominator.	
Urban population (% of total)	Urban population refers to people living in urban areas as defined by national statistical offices. It is calculated using World Bank population estimates and urban ratios from the United Nations World Urbanization Prospects.	
Population density (people per sq. km of land area)	Population density is midyear population divided by land area in square kilometers. Population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship--except for refugees not permanently settled in the country of asylum, who are generally considered part of the population of their country of origin. Land area is a country's total area, excluding area under inland water bodies, national claims to continental shelf, and exclusive economic zones. In most cases the definition of inland water bodies includes major rivers and lakes.	

Notes: Due to the absence of data, agriculture value added (% of GVA) and manufacture value added (% of GVA) have been used instead of GDP composition for French Polynesia and Samoa. Likewise, for French Polynesia and New Caledonia, GDP per capita (current USD) has been used instead of GDP per capita (2010 USD).

Annex 4. Sources of the projections of the independent variables

Name of indicator	Sources
Urban population (% total population)	United Nations, World Urbanization Prospects
Population density	
Population	
GDP per capita (2010 USD)	Economic Research Service of the United States Department of Agriculture

Notes: The projections of GDP per capita for French Polynesia, Kiribati, New Caledonia, Palau, Timor-Leste and Tuvalu have been obtained by using the average growth rate of Asia Pacific SIDS (Fiji, Maldives, Federated States of Micronesia, Papua New Guinea, Samoa, Solomon Islands, Tonga and Vanuatu).

Annex 5. Regression results

	Paved roads	Unpaved roads	Rail lines	Power consumption	Access to electricity	Mobile phones	Fixed telephones	Water sources rural	Water sources urban	Sanitation facilities rural	Sanitation facilities urban
Lagged variable	0.7930***	0.6787***	0.8215***	0.8137***	0.9062***	0.5430***	0.7954**	0.7271***	0.9119***	0.8107***	0.9403***
	(0.0293)	(0.0332)	(0.0191)	(0.0170)	(0.0145)	(0.0391)	(0.0297)	(0.0115)	(0.0079)	(0.0094)	(0.00732)
GDP per capita	0.0307	0.1006	-0.0062	0.1584***	0.0128	-0.3840	0.1350*	0.0356**	0.0063	0.0525***	0.0080***
	(0.0580)	(0.0766)	(0.0182)	(0.0292)	(0.0081)	(0.2888)	(0.1750)	(0.0170)	(0.0040)	(0.0095)	(0.0031)
Urbanization	0.1945	0.0990	0.0597	-0.0189	0.0111	0.3521	0.4764	0.1463***	0.0296***	0.0037	-0.0030
	(0.1239)	(0.1662)	(0.0388)	(0.0574)	(0.0169)	(0.6823)	(0.1750)	(0.0353)	(0.0082)	(0.01976)	(0.0065)
Population density	0.0162	-0.1387	-0.1738***	-0.0152	0.0526**	0.0619	0.6649	0.0593	0.0218**	0.1115***	0.0357***
	(0.1496)	(0.2042)	(0.0502)	(0.0703)	(0.0222)	(0.7886)	(0.2070)	(0.0430)	(0.0103)	(0.0242)	(0.0079)
Manufacture	0.0473	-0.0262	-0.0118	0.0496***	0.0078	-0.3149**	-0.1308**	-0.0315***	-0.0039	-0.1625***	0.0022
	(0.0384)	(0.0503)	(0.0121)	(0.0192)	(0.0053)	(0.1420)	(0.0526)	(0.0111)	(0.0026)	(0.0063)	(0.0020)
Agriculture	-0.0907**	0.0130	0.0011	0.0014	0.0059	-0.4406**	0.0230	-0.0019	-0.0007	0.0141*	-0.0003
	(0.4488)	(0.0626)	(0.0141)	(0.0216)	(0.0065)	(0.1905)	(0.0607)	(0.0128)	(0.0030)	(0.0073)	(0.0024)
Period	-0.0069	0.0056	0.0019	0.0085*	-0.0009	0.0271	-0.4145***	0.0003	-0.0014**	-0.0030*	-0.0020***
	(0.0094)	(0.0127)	(0.0030)	(0.0045)	(0.0013)	(0.0499)	(0.0137)	(0.0027)	(0.0006)	(0.0016)	(0.0005)
Constant	-0.8474	-0.4127	1.1584***	0.0090	0.0381	2.4860	-1.3903	0.1025	0.1651***	-0.1759	0.0905*
	(0.7952)	(1.0342)	(0.2831)	(0.3762)	(0.1114)	(4.2535)	(1.0824)	(0.2324)	(0.0535)	(0.1331)	(0.0510)
Rho	0.6456	0.7142	0.9767	0.6997	0.8812	0.8961	0.7237	0.9022	0.9248	0.9607	0.9644

Notes: Standard errors are in parentheses. The levels of significance are as follows: *** p<0.01, ** p<0.05 and * p<0.1.

Annex 6. Composition of annual financing needs, by country and sector, % of GDP, 2018-2030

Country	Transport	Energy	ICT	WSS	Total
Afghanistan	9.9%	12.3%	3.1%	1.1%	26.4%
Armenia	0.7%	0.9%	0.5%	0.7%	2.8%
Azerbaijan	0.7%	0.9%	0.4%	0.5%	2.5%
Bangladesh	3.9%	4.9%	1.8%	0.7%	11.3%
Bhutan	3.4%	3.2%	0.6%	0.2%	7.5%
Cambodia	4.3%	5.2%	1.8%	1.4%	12.7%
Fiji	1.4%	1.2%	0.4%	0.7%	3.7%
French Polynesia	0.5%	0.5%	0.1%	0.2%	1.3%
Kazakhstan	0.7%	0.9%	0.2%	0.3%	2.1%
Kiribati	4.3%	4.2%	1.3%	1.6%	11.5%
Kyrgyz Republic	7.0%	4.5%	1.8%	2.6%	15.8%
Lao PDR	3.6%	3.6%	1.8%	1.2%	10.2%
Maldives	0.7%	0.7%	0.2%	0.1%	1.7%
Micronesia (F.S. of)	2.4%	2.3%	0.7%	0.8%	6.2%
Mongolia	2.4%	1.3%	0.7%	0.7%	5.1%
Myanmar	2.9%	3.9%	1.9%	1.4%	10.1%
Nepal	6.6%	8.1%	3.4%	1.1%	19.3%
New Caledonia	0.7%	1.5%	0.1%	0.2%	2.6%
Palau	0.5%	1.2%	0.3%	0.4%	2.4%
Papua New Guinea	4.3%	4.1%	2.1%	1.0%	11.5%
Samoa	1.8%	1.7%	0.5%	0.6%	4.8%
Solomon Islands	6.0%	5.8%	1.8%	1.7%	15.3%
Tajikistan	4.2%	6.3%	3.3%	2.6%	16.4%
Timor-Leste	5.7%	6.3%	2.3%	1.9%	16.3%
Tonga	1.8%	1.8%	0.7%	1.0%	5.3%
Turkmenistan	2.8%	1.3%	0.3%	0.4%	4.8%
Tuvalu	1.5%	1.6%	0.6%	0.9%	4.6%
Uzbekistan	1.6%	2.6%	1.7%	1.3%	7.2%
Vanuatu	2.9%	3.0%	1.0%	1.0%	7.8%
Weighted average	**2.6%**	**3.1%**	**1.2%**	**0.8%**	**7.6%**

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