Infrastructure gap and drivers for growth

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1. Introduction

This conference paper has been written in response to the request by the European Investment Bank (EIB) to outline scenarios for social infrastructure development and provide estimates about a potential investment gap, adding further evidences to the results of the Report of the High-Level Task Force on investing in Social Infrastructure in Europe chaired by Romano Prodi and Christian Sautter published on the first of December 2017.

Infrastructure is at the very heart of economic and social development. It provides the foundations for virtually all modern-day economic activity, constitutes a major economic sector in its own right, and contributes importantly to raising living standards and the quality of life (OECD 2006). While infrastructure in general, accounts for a wide spectrum of capital investments, the following work focuses on the sub class of social infrastructure, and within this on education, healthcare and affordable housing infrastructure.

Maintaining an adequate level of social infrastructure has an important role in economic growth, sustainability and the creation of jobs, as well as ensuring competitiveness (EIB 2017).

Worried by the slowdown in global growth, interest among the academic community and institutional players has reawaken, with several studies that have assessed the size and implications of an infrastructure gap. The gap in social infrastructure is due to a variety of reasons: a lack of strategic long-term planning, poor concept development and inappropriate financing options.

This conference provides a comprehensive review of the literature, both scientific and non-academic, about the infrastructure gap and the contribution of infrastructure to growth.

2. The concept of infrastructure

There is still little consent among academics and researchers on a unanimous definition of infrastructure: the International Finance Corporation (IFC) refers to it "*as electricity, gas, telecoms, transport and water supply, sanitation and sewerage*"[1]. In an Economic Note the African Development Bank (ADB) defines it "*as a country's physical facilities, such as roads, power plants, and bridges*"[2]. The Organization of Economic Co-operation and Development (OECD), in its Statistical Term Glossary, defines infrastructure as "The system of public works in a country, state or region, including roads, utility lines and public buildings."[3]. In the context of this work, infrastructure will be understood in its loosest definition as "the basic physical and organizational structures and facilities needed for the operation of a society or enterprise" as recorded on the Oxford Dictionary.

By contrast, there is wider consensus and formalization regarding its categorizations, divided in (1) hard infrastructure, i.e. physical structures or facilities that support society and economy (Bhattacharyay, 2008, World Bank Group 2010, UN Habitat 2011), split between economic infrastructure and social infrastructure (Bhattcharayay, 2008, WEF 2012, Bottini et al. Forthcoming); (2) personal infrastructure, i.e. the human capital, the stock of knowledge and skills embodied in the workforce; and (3) institutional infrastructure, i.e. the social and institutional capital related to the system of rules that govern a country, such as policy, regulatory, and institutional frameworks, governance mechanisms, systems and procedures, and transparency and accountability of financing and procurement systems (Howes and Robinson, 2006).

Within hard infrastructure, economic infrastructure is an economy's capital stock used to facilitate economic production, or serve as inputs to production (e.g. electricity, roads, and ports) or input to consumption by households (e.g. water, sanitation and electricity) (Fay 2000, UN Habitat 2011).

Social infrastructure is defined as that class of infrastructure that promote health, education and cultural standards of the population – activities that have both a direct

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[1] Available at www.ifc.org/wps/wcm/connect/054be8804db753a6843aa4ab7d7326c0/INR+Note+1+-+The+Impact+of+Infrastructure+on+Growth.pdf?MOD=AJPERES
[2] Available at www.adb.org/about/infrastructure
[3] Available at www.stats.oecd.org/glossary/detail.asp?ID=4511

and indirect impact on the quality of life (Development Bank South Africa (DBSA))[4]. Social infrastructure is recognized for its positive externalities in society, in 1998 the World Bank stated that social capital was the 'glue which holds communities together' (World Bank, 1998). With a more technical definition this paper refers to social infrastructure as the long-term physical assets that facilitate social services (Preqin 2014, Fransen et al. 2017) and encompasses municipal structures (e.g. parks, lightings and recreational spaces), housing (e.g. social dwellings), education (e.g. school buildings, education equipment, ICT), health (e.g. hospital structures, medical equipment), which ameliorate human development, quality of life and living standards (Howes and Robinson, 2006).

Among social infrastructure, within this work, the following sub categories[5] have been considered:

- Education infrastructure: all long-term physical resources necessary to develop and deliver educational programing, ranging from primary school to tertiary education as well as technical and vocational secondary education and cultural and adult education.
- Healthcare infrastructure: all long-term physical resources necessary for hospital activities, general medical practices, specialist medical practice activities, nursing care activities and residential care activities for mental retardation, mental health and substance abuse as well as the elderly and disabled.
- Affordable housing infrastructure: land needed for construction of dwellings; construction or purchase and remodelling of dwelling units for the general public or for people with special needs.

Even though there is largely agreement on the taxonomy of social infrastructures and recognition of their importance, a univocal definition does not exist. Amidst different definitions there have been studies to track and monitor the need for infrastructure, both for policy considerations and investment decisions. The adoption of myriad approaches and definitions has made it difficult to monitor trends over time on a consistent basis. In addition, very few studies provide detailed forecasts for individual

[4] Availabe at: https://www.dbsa.org/EN/About-Us/Publications/Pages/Research-Documents.aspx

[5] Availabe at: http://ec.europa.eu/eurostat/web/nace-rev2/correspondence_tables

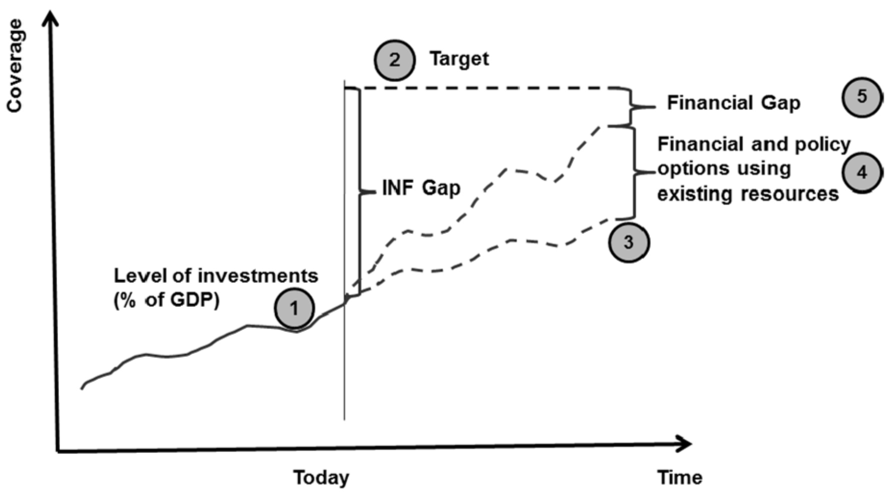
countries and sectors. Lastly social infrastructure estimates have in most cases taken marginal positions.

3. The infrastructure gap

Whereas classifying and evaluating the stock of existing infrastructure is still controversial, many attempted, in academic and grey literature, to estimate the potential gap in infrastructure provision. The infrastructure gap, broadly speaking, is defined as the inadequate level of infrastructure (Bourque 1985, Basile et al. 2001, McKinsey 2013) or as the difference between investment needs and actual spending (WEF 2012; 2014; 2016, EIB 2013).

In the context of this work, we will adopt the definition by the World Bank, according to whom the infrastructure gap is the difference between where a country is today and where a country would like to be in a given point in time (Andrés et al. 2014). Figure 1 shows (1) the current level of infrastructure; (2) where a country will or would like to be in a given point in time; (3) how far business-as-usual scenarios will take the country toward reaching its goal; (4) and (5) financial and policy options using existing resources and investment resource gap that will need to be bridged.

Figure 1: Visual representation of the Infrastructure Gap



Source: Andrés et al. 2014

Estimates have been many at local, national, regional and world-wide level (see appendix 1) and have been calculated with a variety of models that can be categorized in (1) bottom-up microeconomic or micro-engineering models, (2) top-down macroeconomic models and (3) hybrid models.

3.1 Bottom-up models

Microeconomic and micro-engineering models, are both based on bottom up sectorial knowledge, and encompass a wide variety of grey literature, from national project pipelines, that may span from a basic project list identifying local gaps, to comprehensive reports, such as the UK Infrastructure and Projects Authority Report[6], one of the most articulated one in Europe, to sectorial analyses.

At global level the most renowned micro studies on the infrastructure gap are the "Infrastructure to 2030" reports by the OECD (2006, 2007, 2012). The three reports cover telecoms, electricity, and transports (road, water, airports, ports, rail corridors as well as oil & gas transport). For each sector or sub-sector, specific micro trends, based on the articulacy of the sector, are identified. (e.g. within the telecommunication sector, the transatlantic sub sector and within this the optical cable subsector. In this last subsector two trends are identified: the long-distance fiber network can be expected to grow in both bandwidth per channel (wavelength) and number of wavelengths (time) per fiber.). Population and income projections are then embedded in each sectorial demand analysis and future investment needs per sector are estimated. Projections have been also adjusted to meet climate change demand in the most recent report (OECD 2017). Regarding Europe, noteworthy, is the European Commission (EC) (2011) estimate on infrastructure needs in transnational energy from a project pipeline priority perspective.

On a national and sectorial basis, a wide variety of academic literature discusses the appropriateness of assessing projects based on Computable General Equilibrium (CGE) models or Cost Benefit Analysis (CBA) models for the quantification of the infrastructure project pipeline. In some cases, models were aggregated and generalized to assess infrastructure needs at regional scale.

Regarding sector specific models, the energy sector is the most studied. The first comprehensive model developed in this field is the renowned MARKAL model now updated to the TIMES model. The TIMES (The Integrated MARKAL-EFOM System)

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[6] Available at: https://www.gov.uk/government/publications/infrastructure-and-projects-authority-annual-report-2017

model was developed in 2004 as part of the IEA-ETSAP's (International Energy Agency- Energy Technology Systems Analysis Program) methodology for energy scenarios development to conduct in-depth energy and environmental analyses. The TIMES models encompass all the steps from assessing primary resources through the chain of processes that transform, transport, distribute and convert energy to the evaluation of the supply of energy services demanded by energy consumers. The economic and engineering relationships between energy "producers" and "consumers" is the basis underpinning TIMES models.[7] The model is able to estimate energy demand, and therefore able to accurately estimate the demand driven need for energy infrastructure across the value chain.

While we acknowledge the existence of this branch of literature on infrastructure needs assessed by micro-engineering models, either based on CGE or CBA, thorough reviews and considerations on the matter are out of the scope of this conference paper.

3.2 Top-down models

Research on macroeconomic models, which explain and predict levels of infrastructure based on macroeconomic variables, stems from the seminal research conducted by Marianne Fay for the World Bank Group in 2000. This work disentangled the primary relationship between macroeconomic variables and the level of infrastructure needed. The model assumes that infrastructure has to classes of users: individuals and companies: the first demand infrastructure as a consumption good, the latter as input into production. The research, originally limited to Latin America, found that economic infrastructure demand is explained by aggregated output, sectorial share of GDP; as well as variables such as density, urbanization and trade.

This line of research was further expanded at a global level (Fay and Yepes 2003) in which it proved its validity through the registered high explanatory power of the model (R squared over 90 percent across infrastructure classes except water). The model was updated with better or more recent data and adapted to different regions for finer results: Yepes (2004) for East Asia and the Pacific, Fay and Morrison (2007) for Latin America, Estache and Yepes (2004) for Sub Saharan Africa, Fedderke and Bogetic,

[7] Available at: http://iea-etsap.org/index.php/etsap-tools/model-generators/times

(2005) for South Africa, Chatterton and Puerto (2005), for South Asia and Bhattacharyay (2010) for the Asia Pacific.

Theory underpinning these works was left basically untouched until Oxford Economics (2017) under a G20 initiative, developed the Global Outlook on Infrastructure making use of stochastic frontier modeling techniques. This allowed the introduction of 'quality-adjusted' performance measures allowing the determination of the spending required for a country to match the performance of its best performing peers. The main theoretical contribution to the Fay (2000) model is the shift in the definition of infrastructure need. Previously it was understood as the need to match the demand required for consumption by individuals and the demand required to satisfy production needs. It's now interpreted dynamically, as the level necessary to raise the game across the board. Need is evaluated by comparing what peers are doing: countries with similar characteristics are expected to dedicate a similar amount of resources to infrastructure and while countries converge to higher levels of infrastructure the entire model adapts to the new frontier.

To the best of our knowledge, no macroeconomic model has been applied to social infrastructure.

3.3 Hybrid models

Grey literature produced several models, combining sectorial approaches to macroeconomic evaluations. The McKinsey Global Institute (2013) estimated the global infrastructure need by studying what is required to keep pace with anticipated growth, the report applies the limited 70 percent "rule of thumb" approach[8], and does not estimate what would be needed to meet a range of broader aspirations. The model uses capital stock values as a proxy of current infrastructure stock and estimates need by projecting global infrastructure through demand drivers in different infrastructure categories sourced from the (OECD 2006, 2007, (IEA), and Global Water Intelligence (GWI), cross checked with historical spending investment for roads, rail, ports, airports, power, water, and telecommunications infrastructure (which averaged about 3.8 percent of global GDP).

[8] The McKinsey Global Institute examined the value of infrastructure stock using a perpetual inventory model for 12 countries for which comprehensive historical spending data are available. This analysis showed that, with a few exceptions such as Japan (arguably an "over-investor" in infrastructure), the value of infrastructure stock in most economies averages around 70 percent of GDP.

A second widely referred to model is the World Economic Forum (WEF) (2012; 2013; 2014) model in which the investment in infrastructure gap is based on OECD (2006; 2007; 2012) expenditure estimates as percentage of GDP. Sector trends were generalized to find an average annual investment need for 2010-2030 of about 3.9 percent of GDP. In 2014 the WEF report was expanded to encompass also social infrastructure, replicating the same model. Most recent among the hybrid models is the Oliver Wyman (2017) report yet based on WEF (2012, 2013, 2014) estimates.

Regarding Europe, the European Investment Bank (EIB) (2013) collected, separated out and updated investment in infrastructure gaps with estimates from (OECD 2006, 2007, 2012; EC 2011 and McKinsey 2013).

4. Infrastructure and growth

Whereas there is, to the best of our knowledge, only two lines of research in macroeconomic models studying the drivers of demand for new infrastructure (Fay 2000; Oxford Economics 2017), literature linking infrastructure and growth is fairly large. In the past 30 years, many tried to understand the relation between infrastructure and macroeconomic variables.

Most of these studies can be categorized in: those who focuses on the contribution of (1) infrastructure stock to growth expressed as percentage points of GDP or GDP per capita (Canning 1998; Basile et al 2001; Calderón and Servén 2004; Égert et al. 2009; Calderon et al. 2011; Broyer et al. 2013; EC 2014) those focused on (2) public investment decisions (Aschauer 1989; Blaeny et al 2001; Leeper, et al. 2010, IMF 2014, ECB 2017) and their impact on productivity and growth, and the role of political decision process (Cadot et al. 2006) on the level of infrastructure. See appendix 2.

Some of the literature stated previously disentangles the relationship between infrastructure and growth to assess also the role of social infrastructure. Bleaney et al. (2001) found no evidence that education and health infrastructure expenditure have smaller impact on growth compared to other expenditures. The relationship between health expenditures and growth is found to be virtually identical to that for other productive expenditures (the regression coefficient connecting the two is estimated at 0,33 ceteris paribus.), while the coefficient of education expenditures is greater at 0,48, although the difference between the two is not significant. Aschauer, (1998) finds that public-sector hospitals, have an elasticity of 0.06 to GDP, proving a small but positive relationship between the investment in healthcare infrastructure and growth. The category 'other buildings', that among others contains also affordable housing has an estimated elasticity of 0.04 slightly smaller but still positive. Lastly the stock of educational buildings has an estimated elasticity which is negative and insignificant.

While to the best of our knowledge there is no other literature accounting for the impact of social infrastructure on growth, a wide set of literature focuses on the role of social infrastructure in economic development with national or regional studies. Additionally, multiple lines of literature studied, more broadly, the relationship between resources invested in education, healthcare and affordable housing and their outcome on society and the economy, with non-unanimous results.

5. Drivers of social infrastructure

The demand for social infrastructure is not only a matter of economic growth and past scarce resources investments. It is also the result of changes at the demographic level (Fay 2000, OECD 2006, 2007, 2012, Oxford Economics 2017 Fransen et al. 2017) infrastructure capacity has to grow in line with population growth. A country that faces major population increases is likely to need to invest more heavily to provide for that population boost than one in which the population is expected to stagnate. Moreover, changes in the composition of the population are likely to have impact on the level of infrastructure. EU Member States report, among OECD countries, longer life expectancy and lower fertility rates.

In addition to these trends, technology is harnessing rapid innovations, high mobility of large groups of population is shaping new systems, while climate change is shifting priorities (OECD 2017). All of this has profound implications for social systems, the investment in social welfare, social infrastructure and service provision (Fransen et al. 2017). While this work will not account for mobility and technological spillovers, it will partially account for climate change investment needs.

In the consideration of the role played by demographics, starting in 2008 there has been a growing acknowledgment by the European Commission, as well as the European Council and all other institutional players, on the need to tackle resolutely the impact of aging populations on European Social Models. This EU wide effort culminated with the publication of the EU Ageing Report series (2009, 2012, 2015).

The EU population is projected to increase (from 507 million in 2013) of almost 5 percent by 2050, when it will peak (at 526 million) and will thereafter decline slowly[9].

In terms of drivers of changes in composition the Ageing Report (2015) provides a worrying scenario: while total fertility rates are projected to rise for the EU as a whole, they are expected to remain below the natural replacement rate. At the same time, the projections show large and sustained increases in life expectancy at birth. In the EU, life expectancy at birth is expected to increase between 6/7 percent, making Europe older. The Ageing Report (2015), which studied three population evolution scenarios (baseline, lower fertility and lower mortality scenarios) for EU Member States, also provides detailed projections for many other macroeconomic drivers: (1) potential GDP (real growth rate), (2) health care spending as percentage of GDP changes and (4) education spending as percentage of GDP.

These projections, might they be demographic or economic, feed into a variety of policy debates at EU level and National level. In particular, because of their EU wide scope, three policies have been considered within this work as drivers of infrastructure change: the European Commission's Europe 2020 Strategy, the 2030 Agenda for Sustainable Development by the United Nations to which the EU has committed both in its internal and external policies and the EU Energy Efficiency Directive.

Box 1: Europe 2020 Strategy

Europe 2020 Strategy was presented in 2010 by the Barroso Commission[10], and is based on the following three priorities: (1) smart growth: developing an economy based on knowledge and innovation, (2) sustainable growth: promoting a more resource efficient, greener and more competitive economy and (3) Inclusive growth: fostering a high-employment economy delivering social and territorial cohesion. The 2020 headline targets are monitored by Eurostat with nine targets: of which two for education.

- Reducing Early leavers from education and training (percentage of population aged 18-24) to less than 10 percent of the considered population;
- Raising tertiary educational attainment (percentage of population aged 30-34) to at least 40 percent of considered population.

[9] Available at: http://ec.europa.eu/eurostat/web/population-demography-migration-projections/population-projections-data

[10] Availabe at: http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A52010DC2020

Moreover, while these targets are not directly linked to infrastructure level (Eurostat 2012), significant variations in the share of 18-30 in education might shape the level of education infrastructure, and changes to this share of population might raise the needed of high quality education infrastructure.

Regarding affordable housing Eurostat monitors one target:

- Lifting at least 20 million people out of the risk of poverty and social exclusion.

Again, this indicator does not refer directly to affordable housing infrastructure but has rather a broader strategy for reducing poverty and social exclusion.

The above targets were adopted at National level and adapted to specific situations [11].

Box 2: 2030 Agenda for Sustainable Development

In 2015, the United Nations General Assembly adopted the universal, integrated and transformative 2030 Agenda for Sustainable Development, along with a set of 17 Sustainable Development Goals (SDG) and 169 associated targets. Soon after the EU adopted the Agenda (EC 2016) committing to implement the SDGs, pointing out that all 17 goals are already talked by EU policies, yet for completeness and comparability Eurostat developed a granular set of indicators to monitor the achievement of these goals[12]. Among the many two goals are relevant to this study:

- Goal 3: "Ensure healthy lives and promote well-being for all at all ages": The Commission (EC 2016) confirms that it will help Member States to reach the SDG targets[13]. Regarding infrastructure Eurostat tracks the self-reported unmet need for medical care, in particular (1) unmet need due to distance and (2) unmet need due to the waiting list. While both levels are small (less than 1 percent) across most EU Member States, reducing this un met need to 0 percent will be adopted as a target for 2030.
- Goal 4: "Ensure inclusive and equitable quality education and promote life-long learning opportunities for all". For goal 4 most of the indicators are oriented towards education policies rather than infrastructure, and no targets are set. In this work we will keep the

[11] Availabe at: http://ec.europa.eu/eurostat/documents/4411192/4411431/Europe_2020_Targets.pdf

[12] Availabe at: http://ec.europa.eu/eurostat/web/sdi/indicators

[13] Targets are: reducing chronic diseases' mortality, ensuring quality healthcare, strengthening capacity to prevent and manage global health threats, ending HIV/AIDS and Tuberculosis and implementing the Framework Convention on Tobacco Control.

rational established for Europe 2020 strategy and allow for countries that set their national target below the headline 2020 target (10 and 40 percent) to reach it by 2030.

Box 3: National Energy Efficiency Action Plan

Article 4 of Energy Efficiency Directive (EED) requires Member States "to establish a long-term strategy beyond 2020 for mobilizing investment in the renovation of residential and commercial buildings with a view of improving the energy performance of the building stock to meet Europe’s GHG emissions reduction targets (EC 2016). Each Member Sate was requested to develop a National Energy Efficiency Action Plan (NEAP), while plans around Europe are very different and inconsistent, and many were reported to be incompliant with the Directive.

The Czech Republic plan defines five scenarios, with a wide horizon up to 2050: from a “business as usual” case up to an "ideal hypothetical" potential if deep renovation of 3 percent per year of the residential building stock. (Ministerstvo Prumyslu A Obchodu 2014). Scenario number 3 “Slow but, for energy purposes, deep renovation of the building stock” introduces a 1 percent additional renovation for energy related renovation. While these number are not adopted formally by other countries and related to residential building stock, we consider them to be prudential enough to proxy as at least part of the deep renovation that will happen across Europe to comply with energy efficiency measures regarding the construction share of infrastructure of both healthcare and education sector.

6. Conclusion

Prior research indicates that there is an expected wide gap in infrastructure (Fay 2000, OECD 2006; 2007; 2012; 2017, EC 2011, WEF 2012; 2013; 2014, McKinsey 2013, EIB 2013; 2017, Oxford Economics 2017). However, despite the number of previous studies, little light was shed into EU Member States endowment of social infrastructure or the size and characteristics of its gap. This paper, by attempting to address several gaps of earlier literature and focusing on the peculiarities of social infrastructure, adds to the empirical literature on the relationship between infrastructure levels and macroeconomic variables (Fay 2000, Oxford Economics 2017).

Firstly, and foremost, findings suggest that the demand for infrastructure is driven by policy choices.

The bond between public spending and infrastructure suggests the existence of a relationship between resources allocated to the sector and the demand of infrastructure, where actually the offer of infrastructure drive the demand for it. This implies that infrastructure investment strategies by governments should be better designed and linked to the services provided. Given the labor intensive nature of healthcare and education sectors we can suggest that infrastructure development plans should stem from the desired service provision, in line with envisioned outcomes and not vice versa.

Fay (2000) and Oxford Economics (2017) point out that the only significant explanatory variable in the variation of infrastructure expenditure is GDP per capita. The reason could be that all other factors being equal, a growing economy has more resources to invest in social infrastructure and individual demand for social services linked to the infrastructure provision is higher.

Infrastructure investments will remain a pillar for many governments and supranational institutions across the world, not only because infrastructure provides the foundations for virtually all modern-day economic activity, constitute a major economic sector in its own right, and contribute importantly to raising living standards and the quality of life, but also because of a few key characteristics that distinguish infrastructure from other types of capital. First, infrastructure investments are often large, capital-intensive projects and while they are mostly a responsibility of governments and local authorities, all levels are operating in a context of curtailed public budgets. Second, they tend to have significant up-front costs, while the benefits or returns accrue over very long periods of time, often many decades, intensifying the importance of strategic long-term planning. Yet, infrastructure investments have the potential to generate positive externalities, so that the social return to a project can exceed the private returns it can generate for the operator and shouldn't take a peripheral position in policy discussions.

There is a growing and awareness of the need for investments in social infrastructure, across all sectors, to improve the productive efficiency and quality of publics services. In the years following the Lisbon Agenda agreement (2000) we have witnessed levels of infrastructure investments between 3 and 7 percent of stock, these levels of growth will hardly be sustainable in the long term. In an era of fiscal constraints and tiered growth any investment exceeding the real GDP growth, will have to be closely evaluated. In a scenario in which long-term budgetary projections show that the annual average potential GDP growth rate will remain moderate and stable we can't expect this alone to sustain infrastructural needs, and not even maintain current stock levels. Therefore, it will become crucial to justify the need for additional capital spending in front of citizens and institutions.

Hence, in an era of tight fiscal constraints, it is evident that public budgets alone won't be able to satisfy demand, there is need for a wider discussion on resource mobilization as many local-level service providers will have to engaging with providers of external capital to sustain infrastructure.

Moreover, government should be aware that, when it comes to social infrastructure investments, policy choices due matter, *ceteris paribus*, if a country systematically doesn't invest in a sector no macroeconomic demand for infrastructure will emerge, while investment may be "socially" needed.

APPENDIX 1 - Summary table of findings: Infrastructure gap

Title	Authors	Institution	Year	Sector	Category	Model	Methodology	Findings	Time- Horizon	Nominal Gap
Investing in Infrastructure What is Needed from 2000 to 2010?	Fay and Yepes	World Bank	2003	Economic Infrastructure	Top down	Fay 2000 model	OLS with fixed effects	High performance of the model (over 90% across infrastructure) In the case of water we manage to explain 60% of cross country and over time variation in coverage.	2005-2010	B$ 848 (need)
Infrastructure for 2030 VOL 1	OECD	OECD	2006	Telecoms, Electricity, Surface transport and Water	Bottom Up	Trend driven demand	Expert Knowledge on driving trends	Sum of all micro sector trends I (role of rise in income and reduction of cost of infrastructure service and emerging technologies economic growth, notably growth in per capita income, is acknowledged as the major determinant of the growth in the demand for infrastructure. (only variable used for projections)	2013-2030	T$ 3,7 (need) annual
Infrastructure for 2030 VOL 2	OECD	OECD	2007	Electricity, Water and Transport	Bottom Up	Trend driven demand	Expert Knowledge on driving trends	Sum of all micro sector trends (role of rise in income and reduction of cost of infrastructure service and emerging technologies	2000-2030	n.a
Strategic Transport Infrastructure Needs to 2030	OECD	OECD	2012	Airports, Ports, Rail corridors and Oil & Gas transport	Bottom Up	Trend driven demand	Expert Knowledge on driving trends	Sum of all micro sector trends (role of rise in income and reduction of cost of infrastructure service and emerging technologies	2010-2030	B$ 11,28 (need)
Strategic Infrastructure – Steps to Prioritize and Deliver Infrastructure Effectively and Efficiently	WEF	WEF	2012	Economic and Social Infrastructure	Hybrid				2010-2030	T$ 1 annual
Infrastructure productivity: How to save $1 trillion a year	McKinsey Global Institute	McKinsey Global Institute	2013	Economic Infrastructure	Hybrid				2010-2030	T$ 57 need
Strategic Infrastructure: Steps to Operate and Maintain Infrastructure Efficiently and Effectively	WEF	WEF	2014	Economic and Social Infrastructure	Hybrid				2010-2030	T$ 1 annual
Global Infrastructure Outlook: Infrastructure investment needs 50 countries, 7 sectors to 2040	Oxford Economics	G20	2017	Economic Infrastructure	Top down		standard static panel data models with fixed effects	The key innovation of our study is to combine the approaches used by these authors to model infrastructure needs, with the stochastic frontier modelling techniques. Performance of the model (over 70% across infrastructures except ports 40%)	2015-2040	T$ 94 (need)
Investing in Climate, Investing in Growth. Ch. 3 Infrastructure for climate and growth	OECD	OECD	2017	Electricity, Water and Transport	Bottom Up	Trend driven demand	Expert Knowledge on driving trends		2016-2030	T$ 94 (need)
Bridging the infrastructure gap: Engaging in the private sector in critical national development	Oliver Wayman	Oliver Wayman	2017	Economic Infrastructure	Hybrid				2010-2030	T$ 1 annual

APPENDIX 2 - Summary table of findings: Infrastructure and growth

Title	Authors	Institution/Publisher	Year	Geography	Sector	Category	Findings	Additional Findings
A Database of World Infrastructure Stocks, 1950–95	Canning		1998	Global	Economic Infrastructure	Infrastructure stock	It is clear that the stock of infrastructure across countries varies significantly with their population size, income level, and geography, and this relationship appears stable over time.	It seems likely that the stock of infrastructure in a country varies with population and GDP per capita. It is clear that the stock of infrastructure across countries varies significantly with their population size, income level, and geography, and this relationship appears stable over time.
Contribution to productivity or pork barrel? The two faces of infrastructure investment	Cadot et al.	Journal of Public Economics	2006	France	Economic Infrastructure	public investment decision	feedback effects on production-function estimates are weak, and the marginal product of infrastructure capital does not vary tremendously across regions, so that departures from the first-best allocation of infrastructure across regions are fairly inconsequential.	the proportion of the variability in regional infrastructure investments explained by the policy equation is high. given that the equation includes only DIFF (difference in absolute value between the electoral scores of the left-wing and right-wing coalitions) , PARTY (Dummy=1 when local/national political congruence)
Government Investment and Fiscal Stimulus in the Short and Long Runs	Leeper et al.	World Bank	2010	US	Public Expenditure	public investment decision	When government spending is productive, as is government investment when G > 0, two additional effects follow. First, a higher stock of public capital generates expectations that more goods will be produced in the future, generating a positive wealth effect. Also as public capital gradually builds up, it increases the marginal product of private inputs and eventually induces agents to work and accumulate capital in response to higher expected returns.	
How large is the infrastructure multiplier in the euro area	Broyer et al.	Natix Flash Economics	2013	France, Spain, Germany and Italy		infrastructure stock	Authors find that an increase in public infrastructure investment is associated with an increase in output, private investment and employment in the quarters following the expenditure shock. Finding that infrastructure multipliers are very large: 1 euro invested in transport infrastructure in the EMU-4 raises GDP level by 14.	infrastructure investments has an additional impact on the broader economy when the economy is depressed (Significant results only for France)
Infrastructure in the EU: Developments and Impact on Growth	EC	European Commission	2014	EU	Economic Infrastructure	infrastructure stock	The findings from the econometric analysis indicate that in the long term both transport and electricity infrastructures are positively correlated with GDP. The literature is inconclusive on the direction of the causality and, thus this finding would require further investigation.	Short-run shocks in electricity and transport infrastructure appear to have less substantial impact on the current GDP level. This suggests that positive effects from investments in transport or electricity infrastructure require time to materialize However, the findings indicate that the infrastructure provisions and GDP always converge to their positive long term relationship and that any shocks do not have a permanent impact.

Is Infrastructure Capital Productive? A dynamic heterogeneous approach.	Calderon et al.	World Bank - Banco de Espagna	2011	Global	Economic Infrastructure	infrastructure stock	estimates, based on heterogeneous panel time-series techniques, place the output elasticity of infrastructure in a range between 0.07 and 0.10.	
Is Public Expenditure Productive	Aschauer	Journal of Monetary Economics	1989	US	Infrastructure (non military)	public investment decision	significant weight should be given to public investment decisions when assessing the role the government may play in economic growth and productivity improvement. Public-sector hospitals, 6% of the total stock, carries an elasticity of 0.06 but is insignificantly different from zero at the 10% level. the stock of educational buildings- 16% of the total stock- has an estimated elasticity which is negative and insignificant. (possible lagged effect)	the result that the estimated coefficient on educational buildings is minor in conjunction with the fact that the share of educational structures in total structures is large offers some additional evidence against the argument of a reverse causation from per capita income to the demand for public capital.
Testing the endogenous growth model: public expenditure, taxation, and growth over the long run	Bleaney et al.	Canadian Journal of Economics	2001	OECD	Public Expenditure	public investment decision	Productive expenditures have a significant positive coefficient; the point estimate suggests that an increase by one percentage point of GDP raises the growth rate by 0.30 percentage points. Excluding social security the authors treat most other expenditure e.g., transport and communication, education, health as productive expenditure	When education and health were separated out, we could find no evidence that they have any smaller impact on growth than other productive expenditures. The coefficient on health expenditures is found to be virtually identical to that for other productive expenditures at 0.33, while the coefficient of education expenditures is about 50 per cent greater at 0.48, although the difference is not significant.
REGIONAL INEQUALITIES AND COHESION POLICIES IN THE EUROPEAN UNION	Basile et al.	ISAE Instituto di Studi e Analisi Economica	2001	EU	Economic Infrastructure	infrastructure stock	The result confirms that the infrastructure endowment significantly foster regional development. The share of agricultural employment on total employment was also included in the empirical equation, in order to control for the effect of the regional economic structure.	
Infrastructure and Growth: Empirical Evidence	Égert et al.	OECD	2009	OECD	Economic Infrastructure	Infrastructure stock	the contributions of infrastructure to long-run output levels and growth are not homogenous across countries and that the expansion of infrastructure could be both more or less productive with respect to other capital expenditure. Furthermore, the result that more does not always mean better (in terms of GDP per capita) seems to be robust across different specifications including control variables such as human capital, trade openness and tax revenues	We identified a robust positive and highly nonlinear link between infrastructure and economic growth using low-frequency multi-annual average using Bayesian averaging of classical estimates. The cross-section growth regressions suggests greater provision of broad measures of infrastructure is associated with higher subsequent growth rates and that the link is non-linear, with a potentially higher impact of additional infrastructure in countries with initially lower levels of provision.
IS IT TIME FOR AN INFRASTRUCTURE PUSH? THE MACROECONOMIC EFFECTS OF PUBLIC INVESTMENT (CH. 3 of World Economic Outlook)	IMF	IMF	2014	Global	Public Expenditure	public investment decision	The results of this simulation suggest that a 1 percent of GDP permanent increase in public investment increases output by about 2 percent in the same year in advanced economies.	

The effect of public investment in Europe: a model-based assessment	de Jong et al,	ECB	2017	EU	Public Expenditure	public investment decision	The empirical analysis carried out in the paper, estimating country-specific VAR models , provides evidence of a generally positive output impact of an increase in the public capital stock. Structural model-based simulations of an increase in public investment in a large euro area economy illustrate first, an increase in public investment will have the strongest short-term demand effects. .In the longer-term positive effects on the economy's potential output and the impact on public finances crucially depend on the effectiveness of investment and the productivity of public capital.	

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