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Do sound infrastructure
governance and regulation
affect productivity growth?
New insights from firm level
data

Lilas Demmou,
Guido Franco

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**DO SOUND INFRASTRUCTURE GOVERNANCE AND REGULATION AFFECT PRODUCTIVITY
GROWTH? NEW INSIGHTS FROM FIRM LEVEL DATA**

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By Lilas Demmou and Guido Franco

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ABSTRACT /RESUME**Do sound infrastructure governance and regulation affect productivity growth? New insights from firm level data**

Measuring the quality of governance and regulation in various ways and focusing on energy, transport and telecommunications, this paper shows that both sound governance of infrastructure investment and pro-competitive regulation in network industries are associated with stronger productivity growth in firms operating downstream. Interpreting results causally, the size of the effect is considerable – on average a yearly 0.24 percentage point gain in productivity growth over ten years -- and increasing with firm size. Across the various dimensions of governance, appropriate management, coordination across different government levels and regulation settings that ensure access to infrastructure services appear to be particularly relevant for productivity outcomes. The paper also discusses and finds evidence on two potential channels: sound governance magnifies the downstream productivity effect of infrastructure investment and improves the efficiency of firms operating in network industries.

JEL Classification Codes: D24, H54, K23, L50

Keywords: infrastructure, governance, regulation, investment, total factor productivity

Les effets de la gouvernance et de la réglementation des infrastructures sur la croissance de la productivité. Leçons à tirer d'une analyse empirique sur données d'entreprises

Cet article examine les effets de la gouvernance et de la réglementation des infrastructures sur la productivité des entreprises opérant dans les industries en aval. En mesurant la qualité de la gouvernance et de la réglementation de diverses manières et en nous concentrant sur l'énergie, les transports et les télécommunications, les résultats empiriques qu'une gouvernance efficace des investissements dans les infrastructures et une réglementation favorable à la concurrence dans les industries de réseau sont associées à une croissance plus forte de la productivité des entreprises opérant en aval. En interprétant les résultats de manière causale, l'ampleur de l'effet est considérable – avec un gain annuel moyen de 0,24 point de pourcentage de la croissance de la productivité sur dix ans - et augmente avec la taille de l'entreprise. Parmi les différentes dimensions de la gouvernance, une gestion adéquate, une coordination entre les différents niveaux de gouvernement ainsi qu'une réglementation qui garantit l'accès aux services d'infrastructure semblent être des facteurs affectant particulièrement les performances de productivité des entreprises. Les résultats empiriques corroborent également l'existence de deux canaux de transmission potentiels: une bonne gouvernance amplifie l'effet positif des investissements dans les infrastructures sur la productivité des entreprises opérant dans les industries en aval et l'efficacité des entreprises opérant dans les industries de réseau.

Classification JEL : D24, H54, K23, L50

Mots-clés : infrastructure, gouvernance, réglementation, investissement, productivité totale des facteurs.

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Do sound infrastructure governance and regulation affect productivity growth? New insights from firm level data

By Lilas Demmou and Guido Franco¹

1. Introduction

1. Improving infrastructure is a key priority in the agenda of most OECD countries. A rapidly changing technological and economic environment has affected firms' production functions, emphasizing the role of good infrastructure services. Accessing a broadband network and adopting digital technologies have become critical to compete in a globalized world, but investment gaps in ICT infrastructure remain large (OECD, 2019). The transition towards more efficient and less polluting energy systems consistent with moving towards net zero carbon emissions to halt global warming requires establishing new types of energy-production and energy-use infrastructures, as well as a transformation of existing ones. Growing population in urban areas highlight issues related to transport and communication congestion as well as bottlenecks and insufficient connectivity. Facing these challenges requires complex investment decisions concerning the expansion and renewal of obsolete and saturated infrastructure.

2. An advanced and well-functioning infrastructure system is a catalyst for aggregate productivity growth (Égert et al, 2009).² Not only the value added of infrastructure sectors – such as utilities (electricity, gas and water), transport and telecommunications – represents a significant share of GDP in OECD countries (10% on average in 2015), but their services also account for a substantial part of intermediate inputs costs in many industries (12% on average across all industries in 2015). Therefore, their efficient provision can be expected to increase the productivity of both capital and labor. Yet, several studies have stressed that the returns from infrastructure investment have declined over time.³ A simple explanation

¹ The authors would like to thank Ciaran Mac An Bhaird, who was visiting the OECD at the time the paper was written and contributed to the literature review and to the initial stages of the paper through precious discussions. We are also grateful to Andrew Barker for his contribution to the description of country-specific best governance practices and insightful comments. Acknowledgements also go to Luiz de Mello, Alain de Serres, Giuseppe Nicoletti, Boris Cournède, Andrés Fuentes Hutfilter, Sahra Sakha, Yehuda Porath, (all from the OECD Economics Department), Timothy Bishop, Federica Maiorano (all from the DAF directorate) Ana Maria Ruiz (from the GOV directorate), Rudiger Ahrend, Dorothee Allain-Dupre, Alexander Lembcke (all from the CFE directorate), participants in the Economics Department Brown Bag Seminar, in the OECD-G20 Task-Force meeting on infrastructure, in the ENRI meeting (EIB-Luxembourg), in the AFSE-Tresor-Evaluation des Politiques Publiques Seminar, (Paris) and delegates of the Working Party 1 of the OECD Economic Policy Committee for their very useful comments. Sarah Michelson (also from the Economics Department) provided impeccable editorial assistance.

² Access to and the quality of infrastructure have also wider economic and social impact (e.g., infrastructure services could be an important determinant of inclusion), an issue that goes beyond the scope of this paper.

³ For instance, Fernald (1999) found a positive effect of highway constructions in United-States during the 50s and 60s but no more after the network completed. Similarly, Warner (2014) examine five large public investment projects financed by the World Bank and provides empirical evidence of a positive impact on growth in the short term but not in the long term.

might be that the low hanging fruit from old infrastructure investments has already been picked, but a recent strand of research claims that lower returns of infrastructure investment could be due to failures in infrastructure governance and ineffective regulatory settings. More specifically, large inefficiencies in the infrastructure investment process reduce the extent to which spending effectively translates into a larger and higher quality capital stock (Agenor, 2010; Gupta, 2014; Mourougane et al., 2016). Similarly, inappropriate incentives shaped by regulatory settings in network industries could undermine productivity growth if they divert resources from the most productive firms (Araujo, 2011; Bourles et al., 2013).

3. This paper investigates empirically whether sound public infrastructure governance practices and pro-competitive regulatory and ownership policies can together sustain productivity growth in firms using infrastructure services downstream, namely by reducing those inefficiencies in infrastructure investment that hinder the transmission channels from investment to growth and by strengthening the efficiency of firms providing infrastructure services. It focuses on three upstream sectors -- utilities, transport and telecommunications -- and defines sound governance as the systems, processes, methods and structures supporting the provision of infrastructure in a cost efficient way.

4. While earlier estimates had set global infrastructure investment needs worldwide at about 3.5 percent of world GDP per year by 2030 (OECD, 2006; OECD, 2007), the efforts over the past decade have fallen short of these objectives. Indeed, following the 2008 financial crisis, the structure of government spending has switched in many OECD countries from capital investment to current expenditures, reducing public investment in infrastructure and potential growth (Fournier, 2016; EIB, 2019). Moreover, private capital formation has not yet recovered its pre-crisis levels. This stresses the need to optimally allocate scarce public resources available for investment and provide the right regulatory incentives for private investment in network industries. Further, infrastructure projects (public or private) generally entail large and irreversible investments, hence getting them right is of paramount importance to boost infrastructure contribution to productivity growth.⁴

5. Against this background, the paper contributes in four ways to the understanding of the economic effects of infrastructure governance. First, by focusing on its implications for firm-level productivity growth in a large set of OECD countries, it complements past research that has examined the direct impact on the productivity of capital and aggregate economic growth, but focusing mostly on emerging economies or specific countries. To our knowledge, it is also the first study focusing on the effects of governance on downstream sectors and firms using several indicators to proxy the quality of governance.⁵ Second, taking advantage of the granularity of the data, the study provides preliminary insights on the type of industries and firms most impacted by infrastructure governance as well as on the channels potentially involved. Third, it provides evidence of the downstream productivity effects of pro-competitive regulations, complementing previous studies that focus on the implications of more general services sectors' regulation on manufacturing productivity outcomes.⁶ Finally, it also examines how the quality of regulatory governance interacts with the content of regulation in designing framework conditions that are supportive of productivity growth.

6. The analysis estimates a dynamic model of productivity growth for 23 OECD countries over the period 1995 to 2015. The empirical methodology relies on an extremely rich fixed effects structure and is close in spirit to a difference in difference approach, as identification is achieved by exploiting the different exposure of industries and firms to infrastructure governance and regulation. The main challenge is related

⁴ In this respect, sub-optimal investment due to mismanagement may also lead to increased economic fragility, as the reduced benefits from investment may not offset the debt accumulated to finance it (Ansar et al., 2016).

⁵ The indicators mainly refer to public governance of infrastructure; however, sound public governance of network industries is expected to affect private owned infrastructure either directly (e.g., public-private partnerships) or indirectly by shaping the environment in which private firms operate.

⁶ Barone and Cingano (2011); Bourlès et al. (2013); Cette, Lopez and Mairesse (2016).

to the lack of time varying indicators to measure the quality of infrastructure governance across OECD countries. The baseline measure is the governance index provided by the Hertie School of Governance; however, given that the index is time invariant, we also proxy infrastructure governance with government effectiveness and infrastructure quality (based on World Bank indicators). Cross-country differences in regulatory settings are proxied by the sector specific indicator of regulation in energy, transport and communications from the OECD PMR database (so-called ETCR indicator), while firm-level data on productivity and downstream dependence on infrastructure services are obtained from the Orbis dataset and the OECD Input-Output tables, respectively.

7. Our findings suggest that sound public infrastructure governance and pro-competitive regulatory and ownership policies in network industries are associated with higher productivity growth in downstream sectors. For instance, moving governance quality from relatively low (e.g. Portugal) to relatively high (e.g., Finland) standards implies a yearly 0.24 percentage point increase in productivity growth over ten years for the average firm in an average infrastructure dependent sector. Further, specific governance dimensions, such as coordination across government levels, anti-corruption provisions and contractual arrangements, are the most relevant features shaping downstream productivity outcomes. The effect is likely to be driven by the detrimental impact that governance failures have on the efficiency of upstream sectors and on the contribution of investment to growth.

8. The remainder of the paper is organized as follows. Section 2 presents the conceptual framework underlying the analysis, a brief overview of the related literature and some preliminary evidence based on aggregate data. Section 3 describes the empirical setup and the firm-level data used in the analysis. Section 4 discusses the main findings and their policy implications. Section 5 concludes.

2. Infrastructure governance, regulation and productivity

2.1. *The contribution of infrastructure to growth: channels and challenges*

9. Infrastructure investment can contribute to aggregate productivity growth in two main ways (Figure 1): by directly affecting productivity in infrastructure sectors and by indirectly affecting the productivity of firms using infrastructure services as intermediate inputs into production. While the first channel is conceptually straightforward, as it reflects capital deepening in infrastructure sectors, the second channel combines several effects: lower costs, better quality and wider variety of services offered to downstream firms as well as the efficiency gains derived from network externalities. More specifically, the following downstream effects can be singled out:

- Inputs' cost and quality: efficient infrastructure can reduce the cost of intermediates or lead to an improvement in the quality and scope of those inputs. For instance, Cohen and Morrison Paul (2004) provide evidence that a 10% increase in motorway capital stock leads to a 1.5% reduction in variable costs downstream. Similarly, Dlugosch and Koźluk (2017) show that an increase in energy prices reduces domestic investment in all sectors, as firms may tend to absorb the higher energy costs rather than to invest in efficiency improvements.
- Cascading and technological diffusion effects: high infrastructure quality increases the productivity of both capital and labour and can encourage firms' investment in their own production processes. For instance, the provision of advanced and efficient telecommunication infrastructure can contribute to technological diffusion by increasing firms' digital adoption (De La Fuente, 2010; Estache and Garsous, 2012; Deng, 2013; Andrews et al., 2018).
- Market structure effect: efficient and widespread infrastructure services can enlarge the size of the market, reducing market power associated with few competitors and potentially related inefficiencies (Aghion and Schankerman, 2004; Andersson et al., 2015).

- Scale and specialisation effects: lower distribution costs allow access to new markets and could foster productivity growth by facilitating the division of labour (Krugman, 2009; Sutherland et al., 2009).
- Agglomeration and network effects: the extension of critical links or the elimination of bottlenecks in broadband networks or transport systems can favour the local diffusion of knowledge, best practices and skills matching, as well as the clustering of economic activity (Eberts and McMillen, 1999; Puga, 2008).

Figure 1. From governance to productivity growth downstream: economic channels

10. However, both the extent and efficiency of infrastructure investment and the realization of the downstream productivity gains associated with it are likely to be heavily influenced by infrastructure governance and regulation (see Figure 1). Together with macroeconomic and framework conditions, infrastructure governance and regulation shape the level and quality of investment in infrastructure and, consequently, the accumulation of efficient infrastructure capital: governance and regulation affect the value for money of public infrastructure investment and drive private firms' incentives to invest and innovate in infrastructure.

11. Commonly used measures to estimate infrastructure capital are rather imperfect, as they relate to public expenditure or total capital expenditure (Égert et al., 2009). When inefficient management practices are widespread, one dollar spent in public investment does not translate into an additional dollar of public capital stock, leading to an overestimation of the latter (Pritchett, 2000; Chakraborty and Dabla-Norris, 2009). It follows that the lack of sound infrastructure governance might undermine the transmission channels from investment to outcomes and explain the inconclusive evidence provided by the literature studying the link between public capital and growth (Caselli, 2005; Romp and de Haan, 2007; Bom and

Lighthart, 2009). In line with this, recent empirical studies confirm that public capital makes a stronger contribution to potential growth when its measure is adjusted for efficiency (Gupta, 2014; Crivelli, 2017).⁷

Figure 2. The same stock of public capital may lead to different infrastructure quality outcomes

Note: The figure shows the correlation between the quality of infrastructure (global competitiveness indicators; 2010-2015 average) and the public stock of capital as a percentage of GDP (IMF; 2010 value). We use the 2010 value for the public stock of capital to ensure that we do not inflate the measure of public capital stock with uncompleted investment projects (the outcome is unchanged when using the 2010-2015 average). The quality of infrastructure used here is a survey-based measure, reflecting the perception of quality. The construction of public capital stock follows the perpetual inventory method, using different depreciation rates for middle (CHL, HUN, MEX, POL, TUR) and high (all others) income countries (WDI income groupings). Estimates should be interpreted with caution, as the underlying series of public investment is based on gross fixed capital formation of the general government, hence ignoring alternative modes by which governments could support overall investment (e.g., investment grants, tax concessions, state owned enterprises). Japan is excluded from the sample as the data series for public capital stock is not fully comparable. The display of the correlation line is subject to (at least) a 15% level of statistical significance.

Source: OECD calculations on IMF and WEF data.

12. There is widespread evidence that infrastructure projects often fail to meet their timeframe, budget, and service delivery objectives (OECD, 2017). The extent of this phenomenon can be large. For instance, recent estimates suggest that between 10% and 30% of investment in publicly-funded construction could be lost due to mismanagement and corruption (COST, 2012).⁸ As illustrated in Figure 2, these inefficiencies could weaken the expected positive correlation between the stock of public capital (normalized by GDP) and the quality of infrastructure in OECD countries. Indeed, while the expected positive relationship holds, the scatter plot suggests the existence of large differences in perceived infrastructure quality across countries displaying a similar public capital stock.⁹ Along similar lines, the IMF estimates an infrastructure

⁷ These studies have been mostly undertaken at the macroeconomic level and refer to a set of low income and emerging countries.

⁸ In line with this, the Inter-American Development Bank estimated that inadequate projects selection, cost overruns and delays induce additional costs up to 1% of GDP in Latin American countries (IDB, 2019). On the anecdotal side, airport without planes or highways going nowhere made the headlines in the last years. Similarly, the World Bank undertook also a benchmarking exercise on public spending using a distance to efficient frontier approach (Herrera and Ouedraogo, 2018).

⁹ The indicator of infrastructure quality is derived from the World Economic Forum's Executive Opinion Survey. In particular, from the answer to the question: How do you assess the general state of infrastructure (e.g., transport, communications, and energy) in your country? [1 = extremely underdeveloped - among the worst in the world; 7 = extensive and efficient - among the best in the world]. The public capital stock measure is an imperfect proxy for the availability of infrastructure, but it allows to compare a large number of countries.

quality efficiency frontier and calculates, for a given level of capital stock, a 40% infrastructure quality shortfall in low-income developing economies, 27% in emerging-market countries and 12% in advanced economies (IMF, 2015).

2.2. *The role of infrastructure governance*

13. The decision process concerning infrastructure investment is extremely complex, because it involves the interaction of multiple public and private actors whose incentives are shaped by the regulatory environment and governance settings. Therefore, precisely defining sound public infrastructure governance is a challenging task. Nonetheless, several infrastructure governance indicators aimed at identifying good practices have been developed by international organizations and academics.¹⁰

14. Using the Hertie School Infrastructure Governance Indicator, which covers several dimensions that could potentially influence productivity growth (Figure 3 and Annex A), there is *prima facie* evidence that sound governance correlates with high quality of infrastructure and higher average productivity in network industries (Figure 4).

Figure 3. Structure of the Hertie School Infrastructure Governance Indicator

Source: Hertie Business School data.

15. Sound governance contributes to a variety of policy objectives, but some dimensions of governance may matter more than others for productivity growth. We provide below some additional preliminary evidence linking specific dimensions of the Hertie indicator displayed in Figure 3 with the performance of infrastructure sectors (productivity and quality). While these broad correlations do not imply causation, for instance due to the omission of potentially confounding factors that could drive both quality or productivity and governance, they are consistent with the mechanisms described in Figure 1.

¹⁰ The analysis relies on the Hertie School Infrastructure Governance Indicator, which covers mainly public infrastructure governance. The other compilations of cross-country data on infrastructure governance, namely the IMF indicator of Public Investment Management Assessment (IMF, 2018) and the set of answers to the OECD survey on infrastructure governance (Government at a Glance, 2017), could not be used in the empirical analysis as the former covers exclusively emerging economies, while the answers to the OECD survey have not been yet aggregated into summary indicators and often cover a limited and non-overlapping (across answers) set of countries.

Figure 4. Sound infrastructure governance is associated with higher efficiency and quality of infrastructure

Note: The figure shows the correlation between the average productivity of infrastructure sectors (left panel) or the quality of infrastructure (right panel) and infrastructure governance. Both variables on the y-axis are averaged over the 2010-2015 period and are adjusted for cross-country differences in GDP per capita.¹¹ The productivity of infrastructure sectors is the average of the MFP level estimates of the energy, transport and telecommunications industries from the STAN database; the sample is restricted to countries with MFP estimates available for the three sectors and for each year in the 2010-2015 period. The quality of infrastructure used here is a survey-based measure, reflecting the perception of quality (Global Competitiveness Indicators). In the right panel, only the planning and management dimensions of the Hertie Business School governance indicator are considered in order to avoid including quality of infrastructure (a component of the outcome dimension of governance) in both the x- and y-axis. The display of the correlation line is subject to (at least) a 15% level of statistical significance.

Source: OECD calculations based on the STAN database, WEF and Hertie Business School data.

2.2.1. Infrastructure Planning

16. Good planning practices appear to be positively related to the quality and, to a lower extent, to the efficiency of infrastructure sectors (Figure 5). A proper assessment of investment gaps and robust cost-benefit analysis are critical to ensure that investment is productive. Careful long-term planning minimizes the risk of shortfalls in returns as well as unexpected opportunity costs and contingent liabilities, with the associated negative fiscal implications Box 1). In many countries, substantial costs overruns are frequent, partly reflecting the mismatch between the timing of economic returns to infrastructure investment and the political cycle, which constitutes a major impediment to consistent long-term planning (Coelho, Ratnoo and Dellepiane, 2014; Jacobs, 2016). Going forward, one of the most severe and pervasive risks would come from an insufficient integration of environmental challenges in strategic long term planning.

¹¹ Note that all correlations shown in this section are robust to alternative adjustments of the y-axis variables; they are qualitatively unchanged when adjusting infrastructure sectors MFP with economy-wide MFP or quality of infrastructure with the amount of capital stock.

Figure 5. Long term infrastructure planning is related to higher efficiency and quality of infrastructure

Note: The figure shows the correlation between the average productivity of infrastructure sectors (left panel) or the quality of infrastructure (right panel) and infrastructure planning (Hertie Business School). Both variables on the y-axis are averaged over the 2010-2015 period and are adjusted for cross-country differences in GDP per capita. The productivity of infrastructure sectors is the average of the MFP level estimates of the energy, transport and telecommunications industries from the STAN database; the sample is restricted to countries with MFP estimates available for the three sectors and for each year in the 2010-2015 period. The quality of infrastructure used here is a survey-based measure, reflecting the perception of quality (Global Competitiveness Indicators). The display of the correlation line is subject to (at least) a 15% level of statistical significance.

Source: OECD calculations based on the STAN database, WEF and Hertie Business School data.

Box 1. Examples of sound practices on developing a strategic vision for infrastructure

A long-term strategic vision for infrastructure should be set out in a politically sanctioned document that affects concrete action in terms of infrastructure services to society over the long term. This long-term vision needs to address the complex and multi-faceted issues of infrastructure, which cut across multiple stakeholders, sectors and interests. It should also be aligned with spatial and land-use planning policies. Around half of all OECD countries currently have an overall long-term strategic infrastructure plan and prepared a priority shortlist.

Appropriate strategic planning is a necessary condition for a successful infrastructure programme. An overall infrastructure plan that is co-ordinated across levels of government and considers stakeholder views is also valuable to increase coordination. Through assisting the government in formulating integrated policy and investment packages, strategic infrastructure planning can help unlock potential benefits across a broad range of infrastructure services. Two countries that undertake regular, independent strategic planning are Australia and the United Kingdom.

Infrastructure Australia is an independent advisory body responsible for updating the Australian Infrastructure Plan every five years and regularly publishing a shortlist of priority investments based on consultation with states, local governments and the private sector. The creation of Infrastructure Australia added greater transparency to the process of project selection and prioritisation through a structured and standardised approach. Considering all infrastructure sectors within a single plan encourages greater alignment across sectors and investments, and improves the scope for generating synergies. Infrastructure Australia has been effective in increasing the focus on cost-benefit analysis as a basis for decision-making and is responsible for independent review of the business case for projects where the proponent is seeking AUD 100 million or more. Infrastructure Australia also advises subnational governments on how to manage infrastructure gaps that hinder economic growth.

In the United Kingdom, the National Infrastructure Commission is responsible for long-term strategic infrastructure planning through the 30-year National Infrastructure Assessment. The first Assessment was released in 2018 following consultation on the methodology and evidence base in 2016. The National Infrastructure Commission concluded that to meet the infrastructure needs of the 21st century, the UK needs to harness the potential of data and digital connectivity, build a low-cost, low-carbon energy system, and revolutionise the road network to increase the use of electric and autonomous vehicles. The UK government has welcomed the National Infrastructure Assessment as an ambitious, credible and long-term vision. The government plans to publish an in-depth response as part of its own National Infrastructure Strategy in 2020.

Source: OECD (2017), *Getting Infrastructure Right*; ITF (2017), *Strategic Infrastructure Planning: International Best Practice*; HM Treasury (2018), *Interim Response to the National Infrastructure Assessment*.

2.2.2. Infrastructure Management

17. Beyond the self-evident negative impact of corruption on efficiency, which is extensively studied (Tanzi and Davoodi, 1997; Salinas-Jiménez, 2007; OECD 2017c), weaknesses in coordination and the type of contractual arrangement could also severely limit the gains from infrastructure investment.

Coordination

18. Coordination in infrastructure governance appears to be strongly correlated with the efficiency of infrastructure services (Figure 6).¹² In particular, coordination failures across the different government levels involved in investment decisions are likely to result in inefficiencies that curb productivity. The need for strong coordination across levels of government is closely related to their respective fields of competence. Subnational authorities may have a relevant advantage in determining local needs and their higher accountability may contribute to an efficient management of the investment process. The central government arguably has a more comprehensive view, taking into account economy-wide spillovers and returns to scale, as well as the technical capabilities for an accurate cost-benefit analysis often missing at the local level.¹³ Approximately two-thirds of public investment in OECD countries is currently implemented at the subnational level, making coordination all the more important. Recent OECD analysis suggests potential room for progress in this area, as one quarter of the OECD countries surveyed do not yet have infrastructure investment planning that integrates subnational government and central government (OECD, 2017). However, a number of good practices supporting an effective public investment process have been identified (Box 2).

¹² The coordination component of the Hertie index is derived in majority from questions to experts related to the quality of the coordination across government levels, but covers also a small subset of questions on the coordination across infrastructure sectors and between public authorities and private stakeholders. As it is not possible to disentangle each sub-component, the analysis emphasizes coordination across government levels, which is prevalent in the survey.

¹³ The extensive research looking at the role of decentralization for infrastructure investment provides inconclusive results. On the one side, the competition for capital and labour across different sub-entities might result in an over-provision of infrastructure services (Keen and Marchand, 1997; Kappeler and Väilä, 2008; Blöchliger and Egert, 2013; Kappeler et al., 2013); on the other side, under-provision of infrastructure services may occur due to the more binding financing constraints at the local level (De Mello, 2012) or to pecuniary externalities where local governments have an incentive to keep mobile workers in their region (Meurers and Moenius, 2018).

Box 2. Council recommendation on effective public investment across levels of government

The OECD Council recommended in 2014 that Member countries implement a set of 12 principles to strengthen the effectiveness of public investment across all levels of government. The principles are grouped into three pillars: co-ordinate across governments and policy areas; strengthen capacities and promote policy learning across levels of government; and ensure sound framework conditions at all levels of government.

Follow-up work on implementing the OECD principles provides a number of examples of good practices both in federal and unitary systems of government.

Examples from federal countries

- Canadian Regional Development Agencies are working to strengthen the level of co-ordination across levels of government and with other stakeholders by collaborating on targeted, evidence-based actions.
- Federal states in Germany may call upon the services of Partnerships Germany, an independent advisor on conceptual planning and strategic development, large scale project management and procurement options. A federal expertise network in public-private partnerships (*Föderales PPP Netzwerk*) helps facilitate reciprocal vertical and horizontal knowledge transfers between the federal government, federal states and municipalities.
- In Mexico, many states have legislated to undertake regulatory reform and subnational governments are required to adopt key tools such as Regulatory Impact Assessments.

Examples from unitary countries

- Ireland (via the Oversight and Audit Commission) and Norway (via the electronic reporting system KOSTRA) publish performance indicators for local government to facilitate benchmarking and learning from best practice.
- In Chile, the National Investment System offers specialised training courses on formulation and evaluation of public investment projects, with a goal to develop competencies among subnational civil servants.
- A centralised system is used to gather regional data on Italian public investments. Regions have their own evaluation and monitoring units, supported by the national Public Investment Evaluation Unit in the Ministry of Economic Development.

Examples from both federal and unitary countries

- Australia (via the Council of Australian Government), Slovenia (National and Regional Permanent Conferences) and Sweden (National Forum for Regional Growth and Attractiveness 2014-2020) hold regular high-level meetings between national and subnational governments to improve coordination and develop national strategies.
- A number of countries have adopted measures to encourage horizontal co-ordination between lower levels of government. For example, France, Switzerland and Slovenia provide central government funding for entities that facilitate cooperation across local governments.

Source: OECD (2014), *Recommendation of the Council on Effective Public Investment Across Levels of Government*; OECD (2019), *Effective Public Investment Across Levels of Government: Implementing the OECD Principles*.

Figure 6. Coordination across government levels is associated with higher efficiency and quality of infrastructure

Note: The figure shows the correlation between the average productivity of infrastructure sectors (left panel) or the quality of infrastructure (right panel) and infrastructure governance coordination across levels of government (Hertie Business School). Both variables on the y-axis are averaged over the 2010-2015 period and are adjusted for cross-country differences in GDP per capita. The productivity of infrastructure sectors is the average of the MFP level estimates of the energy, transport and telecommunications industries from the STAN database; the sample is restricted to countries with MFP estimates available for the three sectors and for each year in the 2010-2015 period. The quality of infrastructure used here is a survey-based measure, reflecting the perception of quality (Global Competitiveness Indicators). The display of the correlation line is subject to (at least) a 15% level of statistical significance.

Source: OECD calculations based on the STAN database, WEF and Hertie Business School data.

Contract design

19. Contractual arrangements for infrastructure delivery, for instance the choice between public procurement and public private partnership contracts, are also key to an efficient investment process (Burger and Hawkesworth, 2011; OECD, 2017), as they induce differences in firms' technical efficiency (Mollisi, 2018). Yet, Figure 7 shows that less than half of OECD countries implement systematically a quantitative comparison between these arrangements. An extensive literature investigates the advantages of each modality and in particular the pros and cons of public private partnerships (PPPs), which are increasingly common for infrastructure projects (Araújo and Sutherland, 2010). PPPs internalize the externalities related to the different phases in the life-cycle of the asset by bundling the construction and the management phase (Blanc-Brude, Goldsmith and Vällilä, 2009) and by incentivizing private investors to monitor and maintain infrastructure facilities. Moral hazard and asymmetry of information with respect to maintenance costs and the infrastructure operational quality could potentially lead to lower efficiency under more standard procurement arrangements (Hart et al., 1997; Iossa and Martimort, 2016). But PPPs are not a panacea: the optimal delivery mode depends on the nature of the assets involved, the services provided, and the objective in terms of affordability (Engel et al., 2014).¹⁴ To be efficient, PPPs require market risk to be shared appropriately between the government and the private partner(s), so that contract design plays a critical role.¹⁵ Public procurement may also be better suited to achieve some specific political objectives. For instance, green public procurement, i.e. the public purchasing of products and services which are less environmentally damaging when taking into account their whole life cycle, is

¹⁴ Current OECD-ITF work on the procurement design assessment system could further contribute to identify evidence-based best practices in terms of PPP design (ITF, 2018).

¹⁵ For instance, PPPs in the ICT sector are hard to implement, as continuous and fast technological change impedes an easy prediction of future outputs. Also, PPPs may hide high contingent liabilities and could hence be associated with significant fiscal risks (IMF, 2015).

increasingly widespread and allows countries to support directly their environmental goals in sectors such as transport, where the public purchase accounts for a large share of the market (OECD, 2015).

Figure 7. Less than half of OECD countries implement quantitative comparison between delivery modes

Note: Data for Canada, Greece, Iceland, Israel, Japan, Latvia, Poland, Portugal, the Slovak Republic and United States are not available.
Source: OECD, Government at a Glance (2017).

2.3. The role of regulation: competition and country regulatory governance

20. Pro-competitive regulatory and ownership policies might also entail relevant downstream productivity effects. A reduction in barriers to entry and vertical unbundling in infrastructure sectors attenuate incumbent firms' monopoly power and their subsequent ability to set prices, which could harm firms' investment in network industries and ultimately productivity growth of downstream firms' heavily relying on infrastructure services (Alesina et al., 2005; Egert, 2009; Araujo, 2011).¹⁶ Barriers to entry may also undermine technological diffusion (Andrews et al., 2018), and in particular with respect to the diffusion of renewable energy technologies in upstream and downstream industries. Similarly, privatization might increase incentives for cost-savings, new technology adoption and fiercer competition, as owners directly benefit from higher profits; moreover, privately held firms are also arguably less influenced by the political cycle and the tight fiscal constraints that often induce governments to sacrifice long term investment (Araujo, 2011; Cambini and Rondi, 2017). Figure 8 (left panel) suggests that countries where regulatory settings foster competition in network industries tend to be characterized by slightly higher infrastructure quality. Yet, the effects of these policies remain contested: privatisation can generate efficiency losses if done without an adequate regulatory setting and the negative effects of public ownership may be mitigated by specific governance arrangements inducing state owned enterprises to operate on a commercial basis;

¹⁶ For instance, the separation of generation and transmission in the energy sector caused a reduction in the price of electricity (Steiner, 2000; Martin et al., 2005). Analyses on specific network industries confirms the potential benefits of pro-competitive measures: Gonenc and Nicoletti (2000) for air transport, Bottasso and Conti (2010) for the whole transport sector and Soares and Magalhaes (2012) for the gas sector.

legally opening markets may not be sufficient to create truly competitive conditions; and unbundling may be associated with lower efficiency and/or quality if it limits economies of scale and leads to coordination failures between upstream and downstream segments of the industry.¹⁷

Figure 8. Lower regulatory barriers to competition are associated with higher infrastructure quality and sound regulatory impact assessment practices

Note: The figure shows the correlation between the overall regulatory burden in network industries (PMR-ETCR, 2013) and the quality of infrastructure (global competitiveness indicators, 2010-2015 average, adjusted for cross-country differences in GDP per capita) in the left panel, while the correlation between the overall regulatory burden in network industries and the adoption of regulatory impact assessment practices (iREG) in the right panel. The quality of infrastructure used here is a survey-based measure, reflecting the perception of quality. The display of the correlation line is subject to (at least) a 15% level of statistical significance.

Source: OECD calculations based on the WEF database, the PMR-ETCR and the iREG datasets.

21. A critical element to ensure an efficiency-enhancing content of regulation is the quality of regulatory governance practices generally. The engagement of authorities with stakeholders guarantees that regulation responds to the needs of the players in the market, while ex-post evaluation of regulations, by assessing whether they are relevant and fit for purpose (e.g., regulation may become outdated due to technological changes), could be a tool for a coherent regulatory planning (OECD, 2017b). Similarly, the implementation of regulatory impact assessment practices (RIA; e.g., costs and benefits analysis) facilitates the identification of who is likely to benefit from a regulation and who will bear the costs and, thus, the design of reform patterns that are supportive of business activity (OECD, 2017b). Moreover, RIA is a powerful tool to design regulatory settings which are also environmentally friendly (Jacob et al, 2011); accordingly, a number of OECD countries made significant efforts to expand the focus of RIA to integrate environmental protection and the transition towards a low carbon society objective (OECD, 2018). Consistent with the view that sound and transparent processes surrounding the development and implementation of regulatory policy strengthens the quality of laws and regulations, Figure 8 (right panel) displays a positive association between regulatory impact assessment and pro-competitive regulations.

¹⁷ According to the OECD, full unbundling in the rail sector would be associated with an increase in production costs between 20% and 40% due to non-exploitation of economies of scale (OECD, 2006b). A drawback of full unbundling is that not all segments of the relevant markets necessarily need to be unbundled, as what matters is rather to separate the network component from other segments.

3. Data and empirical approach to assess the impact of infrastructure governance

3.1. Empirical strategy

3.1.1. Estimating the differential productivity effect of governance and regulation on downstream industries

22. Our empirical strategy relies on two independent but complementary steps, which allow to fully exploit all dimensions of the available data. In the first step, we estimate a dynamic model directly relating firms' productivity growth in downstream industries to country-sector indicators measuring their exposure to infrastructure governance or regulation (*IndImpact*):

$$MFPgrowth_{icst} = \beta_0 + \beta_1 IndImpact_{cs(t-1)} + \beta_2 LagMFP_{ics,t-1} + \beta_3 \bar{X}_{icst} + \delta_{ct} + \delta_{st} + (\delta_{cs}) + \epsilon_{icst} \quad (1)$$

The subscripts i, c, s, t stand for firm, country, sector and time, respectively; the dependent variable is firm level productivity growth, calculated as the yearly difference in log productivity levels, while *IndImpact* is the weighted indicator measuring the relative exposure of each sector to infrastructure governance or regulation, with weights given by sectoral dependence on the services of upstream infrastructure sectors (Box 3). Note that *IndImpact* has a time dimension only for network industry regulation (*RegImpact*), while it is time-invariant for infrastructure governance (*GovImpact*) due to lack of historical data.

23. To ensure a consistent identification of the governance effect, the model includes a rich set of control variables and fixed effects. The latter however differs for infrastructure governance and network industry regulation, reflecting the different time coverage of the two sets of indicators. Common controls include: i) lagged productivity levels (*LagMFP*) to capture convergence effects (e.g., firms with lower productivity levels tend to grow more compared to their peers); and ii) a vector of firm level characteristics (X) to control for variables which might be correlated with productivity growth: firms' size (number of employees), age, financial leverage ratio, profitability (returns on assets) and cash to assets ratio; (iii) a fixed effects structure that varies as follows:

- the infrastructure governance model includes country-year and sector-year fixed effects to account for time varying omitted variables either at the country or at the sector level, including for instance cyclical effects or sector-specific technological change;
- the network industry regulation model additionally includes country-sector fixed effects to control, for instance, for idiosyncratic differences in sectoral investment and capital stocks across countries.

24. In line with our conjecture that the productivity of firms operating in highly infrastructure-dependent sectors should grow more (less) in countries with good infrastructure governance (tight regulation), the coefficient of interest β_1 is expected to be positive (negative). The fixed effects structure implies that this coefficient is identified from cross-sectional differences in the behaviour of firms over time across country-sector pairs in the case of infrastructure governance; and purely from differences in the behaviour of firms over time (within each country-sector cell) in the case of network industry regulation.

25. The model for infrastructure governance can provide interesting insights on the effect of governance for the average firm, but it might still be subject to omitted variable bias despite the wide range of firm level controls and fixed effects. As the lack of time variation in the governance indicator prevents the inclusion of country-sector fixed effects, it is still possible that other country-sector specific characteristics, correlated to but different from *GovImpact*, affect the estimation outcome. To reduce this risk, we adopt two alternative time-varying proxies for infrastructure governance -- government effectiveness and the quality of infrastructure indicators (from the World Bank) -- and include country-

sector fixed effects.¹⁸ Further, the inclusion of a set of aggregate controls (financial development, GDP growth, R&D expenditures, public capital stock and labour market regulations) interacted with sectoral infrastructure dependence ensures that the differential impact across sectors is not driven by other country level macroeconomic shocks or policies.

26. The second step of our empirical approach expands the baseline model to examine whether the downstream effect of infrastructure governance or regulation depends on firms' size. Indeed, in a given sector, large firms are likely to benefit more from the efficient provision of infrastructure services compared to their smaller competitors: they have wider geographical spread, which will make the quality and volume of transport and communication infrastructure more important to them; they are more exposed to international competition, so that inputs' prices (e.g., energy and transportation costs) are even more binding in shaping their competitiveness; they are better positioned to take advantage of the economies of scale related to lower distribution costs and the availability of new markets. Analytically, we estimate the following model:

$$MFPgrowth_{icst} = \beta_0 + \beta_1 (Size_{ics,t-1} * IndImpact_{cs(t-1)})_{ics,t-1} + \beta_2 LagMFP_{ics,t-1} + \beta_3 \bar{X}_{icst} + \delta_i + \delta_{cst} + \epsilon_{icst} \quad (2)$$

This model ensures a tighter identification especially of the governance impact, as it allows to include both firm fixed effects, which absorb the unobserved firm-specific heterogeneity, and a triple interacted country-sector-year fixed effects, which control for the effects of all time varying shocks at the country-sector level.¹⁹ To clarify, the model is fully saturated and the identification occurs by exploiting exclusively within-firm size variation in a given country-sector-year, allowing to strongly reduce the risk of omitted variable bias.

Box 3. Measuring dependence on infrastructure services and the impact of governance and regulation

Firms in downstream sectors are likely to be impacted by the quality of infrastructure governance and the features of network regulation depending on the extent to which they rely on upstream infrastructure services in their production process, i.e. their exposure to policies and regulations.

Assuming that firms operating in the same sector share a similar production function and using OECD Input-Output tables, we calculate a measure of infrastructure dependence (Dep) at the sector level, by taking the average ratio (over the 2005-2015 period) of each sector intermediate consumption of infrastructure services to value added. Next, the interaction between sectoral dependence and country-specific governance indices or country, sector and time specific network regulation indices allows to obtain a proxy of the exposure of firms in each downstream sector to infrastructure governance or regulation:

$$IndImpact_{cs(t)} = \sum_{j=1}^3 IND_{c(tj)} * Dep_{csj} \quad \text{with } j \neq s \quad (3)$$

here the subscripts c , s , t stand for country, sector and time, respectively, while j refers to the infrastructure industries covered in our paper (energy, transport and telecommunications); Dep_{csj} refers to our measure of infrastructure dependence of downstream industry s in country c from upstream

¹⁸ The positive correlation between quality of infrastructure and infrastructure governance documented in Figure 4 suggests indeed that the quality of infrastructure could be an appropriate proxy for governance.

¹⁹ Recall that the vector $\bar{X}$ includes the main effect for the interaction term, i.e. the regressor Size on its own.

infrastructure industry j ; $IND_{c(tj)}$ refers either to the country level index measuring the quality of public infrastructure governance (Gov_c) or to the degree of regulation in each infrastructure industry j , in country c and time t (Reg_{ctj}). As we are exclusively interested in inter-industry effects, we exclude intra-industry intermediate consumption by dropping infrastructure sectors from the analysis ($j \neq s$).

Note that the baseline equation relies on a time-invariant but country-specific infrastructure dependence measure, while cross-country cross-industry analyses often rely on a benchmark country (usually the U.S.) to reduce endogeneity concerns and overcome data limitations. However, the benchmark approach can create a substantial estimation bias, depending on the level of technological similarity across countries (Ciccone and Papaioannou, 2016). Further, endogeneity concerns are extremely limited in our firm level analysis (e.g., it is plausible to imagine that a single firm productivity does not affect sector level dependence on infrastructure).

A detailed analysis of infrastructure dependence across countries and sectors supports the use of time-invariant but country-specific Dep measures (Annex B), since:

- each country-sector infrastructure dependence varies over time in absolute terms, but the ranking of sectors within countries does not appear to be volatile, so that averaging dependence over time seems a safe assumption; and
- for a given sector, infrastructure dependence appears to differ quite significantly across countries, arguably due to differences in technology, geography and/or relative prices, so that, in the absence of substantive endogeneity concerns, the adoption of a country specific measure seems appropriate.

Yet, to be sure of the robustness of our findings, results are shown to be consistent when choosing the U.S. as a benchmark country.

3.1.2. Estimating the effect on productivity outcomes of firms in upstream industries

27. The link between infrastructure governance (regulation) and productivity growth downstream may stem from the direct efficiency effect of sound governance (pro-competitive regulation) on firms operating in network industries. Equation 4 deals with the identification of this channel and explores the productivity impact of governance or pro-competitive regulation conditional on size, assuming that larger firms in infrastructure industries are affected relatively more by these policies compared to their smaller competitors. As a matter of fact, large firms are often more inclined to participate in large infrastructure projects, where governance or regulation play a critical role -- for instance, coordination needs across different government levels, as well as between public authorities and private entities, are even more binding in large projects, given the higher number of players involved; likewise, sizeable cost overruns or disruptions due to contractors' bankruptcy could turn out particularly burdensome in large projects, making efficient monitoring essential.²⁰ Moreover, large firms tend to have a wider portfolio of projects, so that their interactions with public authorities is relatively more frequent and the impact of policies such as strict anti-corruption practices are expected to be broader.

$$MFPgrowth_{icst} = \beta_0 + \beta_1 (Size_{ics,t-1} * Governance_c \text{ or } Regulation_{cs,t-1})_{ics,t-1} + \beta_2 LagMFP_{ics,t-1} + \beta_3 \bar{X}_{icst} + \delta_i + \delta_{cst} + \epsilon_{icst} \quad (4)$$

²⁰ For instance, there is evidence that SMEs' participation in public procurement is inversely related to contracts' size (Stromback, 2015).

28. The inclusion of firm and country-sector-year fixed effects saturates the model, so that the impact of governance or regulation is estimated exploiting uniquely within firm variation.²¹

3.2. **Data**

3.2.1. *Firm level data on productivity*

29. Firm-level data are obtained from the 2018 vintage of the OECD-Orbis dataset. The data used in the empirical analysis cover all non-financial firms (e.g., two-digits codes are within the 10-82 range according to Nace Rev.2 classification, excluding the 64-66 financial sectors and the 68 real estate sector) with available information to calculate the value added based multi-factor productivity. The data excludes very small firms - those having less than 5 employees throughout the whole sample period - to avoid concerns related to the quality of the data and their consistency over time. Given that some regression specifications exploit exclusively within firm variation, the dataset is further restricted to firms reporting for at least three consecutive years. Ultimately, depending on the estimated specification, the productivity data cover 4 to 8 million firms in 23 countries and 48 sectors over the 2005 to 2015 (governance analysis) or the 1995 to 2013 period (regulation analysis).²²

30. To ensure firms' comparability across countries and sectors, the data are treated according to the cleaning procedures routinely applied at the OECD, which are based on the methodology described in Gal (2013) and Kalemli-Ozcan et al. (2015).²³ Accordingly, firm-level productivity is estimated through the GMM Wooldridge (2009) procedure, with the deflated value of fixed assets used as a proxy for the capital input, the number of employees as a proxy for the labour input and intermediate inputs (e.g., material costs) as an instrument for unobserved firm-specific productivity shocks.²⁴ The advantage of using the Wooldridge (2009) methodology is twofold. On the one side, it overcomes the OLS simultaneity bias, that is, inputs' choices are not independent from unobserved productivity shocks. On the other side, it internalizes the critique on the estimation of the labour coefficient that compromises other semi-parametric approaches (Akerberg, Caves and Frazer, 2015). Further details on the calculation of productivity using Orbis data can be found in Gal (2013).

3.2.2. *Country-level data on governance and regulation*

31. The baseline indicator to measure infrastructure governance is the Hertie Business School Governance Indicator, described in Annex A. The indicator is country-specific but time invariant. Published in 2016, it combines information gathered over the 2014-2016 period. Therefore, the analysis assumes that cross country differences in governance quality have remained constant over the period of estimation (2005-2015). To overcome this limitation, we estimated alternative specifications relying on time varying

²¹ As regulation varies by country, sector and year, the upstream productivity effect of regulation has been also examined unconditional on size. Moreover, note that, to estimate the upstream effect, governance or regulation are by definition no more weighted with sectoral exposure to upstream infrastructure industries.

²² Countries included in the analysis are: Australia, Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Luxembourg, Netherlands, Poland, Portugal, Slovenia, Spain, Sweden, Turkey, United Kingdom and United States. Notice that Luxembourg and Spain are not in the baseline governance sample, as the Hertie Governance Index is not available for these countries.

²³ In order to avoid double-counting, we always privilege unconsolidated accounts over consolidated ones. The only exception is allowed for those firms reporting solely consolidated accounts, which are retained if no unconsolidated accounts are reported during the whole sample period. Note that all findings are robust to the exclusion of all consolidated accounts.

²⁴ Firms are assumed to produce according to a Cobb-Douglas production function, with sector-specific time constant factor shares.

proxies and, in particular, the government effectiveness (WGI dataset, 2018 update)²⁵ and the quality of infrastructure indicators provided by the World Bank. Further, regulatory governance is measured with the Indicators of Regulatory Policy and Governance (iREG), published by the OECD.²⁶

32. Pro-competition regulatory settings in infrastructure sectors are measured using the ETCR indicators provided by the OECD as part of the Product Market Regulation database.²⁷ Based on detailed information on laws, rules and industry settings, they vary over countries, industries and time. More specifically, they provide information on entry barriers, public ownership and vertical integration in the energy (electricity and gas), transport (air, post, rail, roads) and telecommunications (fixed and mobile) sectors.

4. Results

4.1. *Sound infrastructure governance and pro-competitive regulation spur productivity growth in downstream industries*

33. The main dimensions of the governance index, with the only exception of planning, show a statistically significant and positive coefficient, suggesting that sound governance is related to higher productivity growth downstream (Table 1). Results are qualitatively similar when using alternative time-varying proxies for infrastructure governance, allowing to estimate a more demanding model that exploits exclusively time variation in firm performances within each country-sector and rules out reverse causality concerns related to the time mismatch of governance indicators. The productivity growth of downstream firms is positively affected by an increase in government effectiveness and/or by an improvement in the quality of infrastructure (Table 2). Further, the inclusion of aggregate controls, each interacted with infrastructure dependence (Table 2, columns 3 and 4), and/or firm fixed effects, as well as the adoption of the U.S. benchmark for the infrastructure dependency exposure variable do not alter the significance of these findings (Table C.2).

34. Interpreting results causally, the magnitude of the effect is not negligible (Figure 9, upper panel): moving governance quality from Portuguese to Finnish standards at the average level of infrastructure dependency is related to a 0.83 percentage point increase in productivity growth for the average firm, when using the overall governance index.²⁸ The impact gradually declines over time, implying overall an average yearly 0.24 percentage points increase in productivity growth during a 10 years period (Figure 10). The effect tends to be lower for infrastructure planning and larger for infrastructure management and outcome; when disentangling further the impact of each subcomponent of the governance indicator, dimensions such as coordination along the investment process, anti-corruption provisions, PPP design and access to infrastructure services show up as particularly relevant in shaping downstream productivity growth (Figure 9; Panel B). Interestingly, the subcomponent of the planning index that directly refers to long-term infrastructure strategies is also statistically significant.²⁹

²⁵ See Kaufmann et al. (2010) for a detailed description of the methodology used to construct WGI dataset.

²⁶ The iREG indicator is at a country level and covers all regulation (e.g., it is not sector specific); yet, the infrastructure sectors regulation is expected to incorporate the required practices. Details can be found at <https://www.oecd.org/gov/regulatory-policy/indicators-regulatory-policy-and-governance.htm> and in Annex A.

²⁷ Details can be found at <http://www.oecd.org/economy/reform/indicators-of-product-market-regulation/> and in Annex A. See also Conway and Nicoletti (2006).

²⁸ The shock is equivalent to a one-standard deviation increase in *GovImpact*.

²⁹ The detailed output of the regressions behind the bottom panel of Figure 9 is reported in Table C.4.

Table 1. Sound infrastructure governance increases productivity growth downstream

	(1)	(2)	(3)	(4)
<i>Governance Indicators</i>	Overall	Planning	Management	Outcome
GovImpact	0.002*	0.001	0.002**	0.002*
	(1.8)	(1.1)	(2.2)	(1.9)
Lagged MFP Level	-0.328***	-0.328***	-0.329***	-0.328***
	(-38.6)	(-38.6)	(-38.6)	(-38.6)
Observations	4,666,227	4,666,227	4,666,227	4,666,227
R-squared	0.264	0.264	0.264	0.264
Firm Level Controls	YES	YES	YES	YES
Country-Time FE	YES	YES	YES	YES
Sector-Time FE	YES	YES	YES	YES

Note: T-statistics in parentheses; standard errors clustered at the firm and country-sector level. Firm controls included: size (number of employees), age, financial leverage ratio, profitability (returns on assets) and cash to assets ratio. The estimation sample covers the 2005-2015 period.

Source: OECD calculations based on the Orbis dataset, the OECD Input-Output tables and Hertie Business School data.

Table 2. Infrastructure quality and government effectiveness spur productivity growth downstream

	(1)	(2)	(3)	(4)
<i>Governance Indicators</i>	Quality of Infra	GovEffectiveness	Quality of Infra	GovEffectiveness
GovImpact (Time Varying Proxy)	0.061**	0.160***	0.064*	0.105**
	(2.6)	(3.8)	(1.9)	(2.4)
Lagged MFP Level	-0.360***	-0.348***	-0.360***	-0.348***
	(-110.5)	(-134.7)	(-110.4)	(-134.5)
Observations	5,496,288	8,105,916	5,492,986	8,102,253
R-squared	0.283	0.276	0.283	0.276
Firm Level Controls	YES	YES	YES	YES
Aggregate Controls	NO	NO	YES	YES
Country-Sector FE	YES	YES	YES	YES
Country-Time FE	YES	YES	YES	YES
Sector-Time FE	YES	YES	YES	YES

Note: T-statistics in parentheses; standard errors clustered at the firm and country-sector-year level. Firm controls included: size (number of employees), age, financial leverage ratio, profitability (returns on assets) and cash to assets ratio. Aggregate controls (interacted with infrastructure dependence) included: financial development, GDP growth, R&D expenditures, public capital stock and labour market regulations. Due to data availability, the estimation sample covers the 2007-2015 period in models (1) and (3) and the 1995-2015 period in models (2) and (4).

Source: OECD calculations based on the Orbis database, the OECD Input-Output tables and World Bank data.

Figure 9. Productivity gains associated with the various dimensions of infrastructure governance

Note: The figure shows the downstream productivity growth percentage points increase for the average firm in an average infrastructure dependent sector following a 1-standard deviation increase in infrastructure governance. The top panel reports calculations for the overall index and its three main dimensions (based on Table 1), while the bottom panel for each governance sub-component (based on Table C.4). Bars are filled in white when results are not statistically significant; each colour refers to a specific governance dimension and its subcomponents (see Figure 3).

Source: OECD calculations based on the Orbis dataset, the OECD input-output tables and Hertie Business School data.

35. The country-specific gains from adopting good practices are potentially substantial. Figure 11 simulates, for each country, the increase in the productivity growth of the average firm in an average infrastructure dependent sector the first year following a reform moving the current level of infrastructure governance to best practices according to the overall index (e.g., in our regression sample, the Netherlands score). Italy, Hungary and Slovenia would benefit the most, up to a two percentage points increase in productivity growth.³⁰ Further, a simple extension of the model also confirms the theoretical prediction that a potential channel driving these results is the beneficial impact that governance may have on the productivity of infrastructure investment (Box 4).

³⁰ To clarify, this simulation and the following ones refer to the first year impact of the policy change. By construction, the cumulative effect in the long term follows a trend similar to the one presented in Figure 10.

Figure 10. Long-term productivity gains

Long-term cumulative gains from improving the overall governance index by one standard deviation

Note: Based on the first model in Table 1, the figure shows the cumulative productivity gains (percentage points) for the average firm in an average infrastructure dependent sector following a 1-standard deviation increase in infrastructure governance (proxied by the overall index). Source: OECD calculations based on the Orbis dataset, the OECD input-output tables and Hertie Business School data.

Figure 11. Dividends from moving to sound practices are sizeable

Productivity gains of raising infrastructure governance standards to those of the Netherlands for the average firm in sectors with different levels of infrastructure dependence

Note: Based on the first specification in Table 1, the figure shows the downstream productivity growth percentage points increase from moving to infrastructure governance best practices (the Netherlands in the estimation sample) for the average firm in an average (manufacture of food products, beverages and tobacco products) / high (manufacture of paper and printing of media) / low (professional services) infrastructure dependent sector. We use the median value for each sector across countries to obtain a country-invariant infrastructure dependence measure; infrastructure governance is proxied by the overall index from the Hertie Business School. Source: OECD calculations based on the Orbis dataset, the OECD input-output tables and Hertie Business School data.

Box 4. The investment channel

To test whether the link between infrastructure governance and downstream productivity growth goes through the investment channel, the following model is estimated:

$$\begin{aligned}
 MFPgrowth_{icst} = & \beta_0 + \beta_1 (InfraInv_{c,t-1} * Dep_{cs})_{cs,t-1} \\
 & + \beta_2 (InfraInv_{c,t-1} * GovImpact_{cs})_{cs,t-1} \\
 & + \beta_3 LagMFP_{ics,t-1} + \beta_4 \bar{X}_{icst} + \delta_{cs} + \delta_{ct} + \delta_{st} \\
 & + \epsilon_{icst}
 \end{aligned} \tag{5}$$

where *InfraInv* consists of the share of gross fixed capital formation in infrastructure sectors value added calculated based on OECD-STAN database. As in the previous models, the large set of control variables and higher order fixed effects strongly reduce the risk of omitted variables bias.

The findings, which are robust to the inclusion of firm fixed effects, confirm that investment in infrastructure has a positive productivity effect downstream for relatively high levels of infrastructure governance, while the impact may even turn negative for countries with very low governance scores (Figure 12 and Table C.5). While this last result might be surprising at a first sight and surely needs further investigation to assess its robustness, it is consistent with “crowding out” effects being larger when infrastructure governance is poor, due to a diversion of resources to less productive uses (Agenor and Moreno-Dodson, 2006).

Figure 12. Sound governance magnifies the effect of infrastructure investment on downstream productivity

Note: The figure shows the downstream productivity growth percentage points increase for the average firm in an average dependent sector at different level of governance following a 1-standard deviation increase in infrastructure investment. Calculations are based on the first column of Table C.5; infrastructure investment is calculated as the ratio between gross fixed capital formation and value added in infrastructure sectors (STAN data, energy, transport and telecommunication industries). The green and red circles indicate statistically significant positive and negative effects respectively, while points outside the circles are not statistically significant.

Source: OECD calculations based on the Orbis dataset, the OECD input-output tables and the STAN database.

36. The empirical analysis also provides support to the hypothesis that regulation affecting competition in upstream infrastructure sectors hinders productivity growth downstream (Table 3). Interpreting results causally, an easing of anticompetitive regulations in energy, transport and telecommunications from around a level observed in Turkey and Mexico to the one observed in countries such as the Netherlands, Austria and the United States would induce a 0.95 percentage points increase in the productivity growth

of the average firm in an average infrastructure-dependent sector, a magnitude comparable to that found in previous studies looking more broadly at the industry-level productivity effects of services sectors deregulation (Bourlès et al., 2013).³¹

37. At the same time, the detrimental downstream impact of regulatory policies that might inhibit competition in network industries is found to be partially offset by the adoption of high-quality regulatory governance practices (Table 3, models 4 and 5), and in particular by the implementation of regulatory impact assessment (RIA) and stakeholder engagement (SE).³² These findings suggest that the two policies may be considered as complementary and that sound regulatory governance practices could assist authorities in designing productivity enhancing regulatory frameworks, for instance by reducing the scope for regulatory capture.

Table 3. Competition-distorting regulation in network industries hinders productivity growth downstream

	(1)	(2)	(3)	(4)	(5)
<i>Regulation & RegGov Indicators</i>	Overall	Entry	Public Own	Overall & RIA	Overall & SE
RegImpact	-0.029**	-0.018**	-0.021*	-0.142***	-0.109***
	(-2.2)	(-2.4)	(-1.7)	(-3.9)	(-5.9)
RegImpact # Regulatory Gov				0.073***	0.070***
				(3.6)	(6.9)
Lagged MFP Level	-0.347***	-0.347***	-0.348***	-0.347***	-0.347***
	(-144.0)	(-144.0)	(-145.6)	(-144.0)	(-144.0)
Observations	8,741,962	8,741,962	8,788,587	8,741,962	8,741,962
R-squared	0.278	0.278	0.279	0.278	0.278
Firm Level Controls	YES	YES	YES	YES	YES
Aggregate Controls	NO	NO	NO	NO	NO
Country-Sector FE	YES	YES	YES	YES	YES
Country-Time FE	YES	YES	YES	YES	YES
Sector-Time FE	YES	YES	YES	YES	YES

Note: T-statistics in parentheses; standard errors clustered at the firm and country-sector-year level. Firm controls included: size (number of employees), age, financial leverage ratio, profitability (returns on assets) and cash to assets ratio. RIA and SE stand for Regulatory Impact Assessment and Stakeholder Engagement respectively. Due to data availability, the estimation sample covers the 1995-2013 period.

Source: OECD calculations based on the Orbis dataset, the OECD input-output tables, PMR-ETCR and iREG data.

4.2. Larger firms downstream benefit relatively more from sound governance and pro-competitive regulation

38. These results are confirmed when estimating the productivity effect of governance conditional on size (equation 2). The differential effect across firms of different sizes is statistically significant and relevant in terms of magnitude (Table 4, first model): a one-standard deviation increase in *GovImpact* boosts productivity growth by 0.69 percentage points for small firms and by 2 percentage points for large companies (Figure 13). Note that this model is arguably the most reliable given its extremely demanding

³¹ The shock is equivalent to a one-standard deviation decrease in *RegImpact*. The estimation is robust to the same range of robustness checks performed with respect to governance. See Table C.3.

³² For the sake of exposition, the statistically non-significant findings on ex-post evaluation are not reported in Table 3.

fixed-effects structure, allowing to control for firms characteristics as well as for any type of shock at the detailed country-sector level.³³

39. The combined impact of pro-competitive regulation and good regulatory practices in upstream network sectors also differs across firms of different size. The estimates deliver statistically significant outcomes and a reasonable interval for the magnitude of the differential effect, which ranges from 0.6 for small firms up to 1.7 percentage points for larger firms (Table 4, second model; Figure 13). Moreover, the effect stays significant when simultaneously including infrastructure governance and regulation in the regression, suggesting that both dimensions matter for productivity growth.

Table 4. Infrastructure governance and pro-competitive regulation have a stronger impact on large firms downstream

	(1)	(2)	(3)
<i>Governance and Regulation Indicators</i>	Overall	Overall	Overall
GovImpact # Size	0.001***		0.003***
	(2.9)		(13.0)
RegImpact # Size		-0.012***	-0.071***
		(-11.5)	(-14.3)
Size	0.102***	0.094***	0.099***
	(54.9)	(125.5)	(54.5)
Lagged MFP Level	-0.863***	-0.785***	-0.891***
	(-780.9)	(-911.2)	(-688.1)
Observations	4,620,187	8,661,701	3,590,866
R-squared	0.631	0.584	0.650
Firm Level Controls	YES	YES	YES
Firm FE	YES	YES	YES
Country-Sector-Time FE	YES	YES	YES

Note: T-statistics in parentheses; standard errors clustered at the firm level. Firm controls included: age, financial leverage ratio, profitability (returns on assets) and cash to assets ratio. Due to data availability, the estimation sample covers the 2005-2015 period in model (1), the 1995-2013 period in model (2) and the 2005-2013 period in model (3).

Source: OECD calculations based on the Orbis dataset, the OECD input-output tables, the PMR-ETCR database and Hertie Business School data.

³³ Note that one should interpret with caution the size of the coefficients and t-statistics of lagged MFP in these models, due to the so-called Hurwitz-Nickell bias: Hurwitz (1950) and Nickell (1981) show that the introduction of fixed effects in a dynamic model, especially if the panel has a large number of units and a rather small number of time periods, tends to bias upwards the coefficient of the lagged dependent variable. However, as shown in Beck and Katz (2011), the bias can be considered negligible when T is large.

Figure 13. Impact of infrastructure governance and pro-competitive regulation on the productivity of downstream firms, contingent on firms' size

Note: Based on the first two models in Table 4, the figure shows the downstream productivity growth percentage points increase for firms' of different sizes in an average infrastructure dependent sector following a 1-standard deviation increase (decrease) in infrastructure governance (regulation). Size is proxied by the number of employees and, to simplify the calculations, we choose firms with 5, 15, 35 and 100 as representative for small, medium-small, medium-large and large firms, respectively.

Source: OECD calculations based on the Orbis dataset, the OECD input-output tables, the PMR-ETCR database and Hertie Business School data.

40. A number of robustness tests are performed to challenge the validity of these findings. We first check against the use of alternative proxies for firms' size (material costs, total assets or fixed assets in place of the standard number of employees) (Table C.6). Next, the use of U.S. sector dependence on infrastructure as a benchmark to build the *GovImpact* (or *RegImpact*) indicator eliminates any contribution from cross-country differences in sectoral dependence from the estimation, as well as any residual concern with respect to endogeneity between productivity and dependence (Table C.7). Results remain broadly unchanged throughout. Finally, to rule out the possibility that the findings are the outcome of a purely statistical relation, we conduct a placebo test in which the values of *GovImpact* (*RegImpact*) are replaced with random draws from a normal distribution parametrized on the mean and variance of the true *GovImpact* (*RegImpact*) and the outcome is reassuringly not significant (Table C.8).

4.3. Sound governance and pro-competitive regulation increase the efficiency of upstream sectors

41. Moving to the direct effect of infrastructure governance on upstream sectors (equation 4), the result highlights potential efficiency gains from improved governance, and in particular from appropriate infrastructure planning and management in upstream sectors (Table 5 and Figure 14). Similarly, regulation that excessively restricts competition may act as a drag on the productivity growth of firms operating in network industries and especially so with respect to large companies. The overall effect is predominantly driven by barriers to entry, vertical integration and market structure, while public ownership is not significant (Table 6 and Figure 15);³⁴ further, it is robust to the simultaneous inclusion of both identified regulatory factors and governance, hinting that the two types of policies are not substitutes also upstream.

³⁴ Table C.9 and Figure C.1 provide the outcome of a parallel analysis not relying on the differential impact contingent on firms' size. Results are qualitatively unchanged.

Table 5. Sound infrastructure governance increases firm-level productivity growth in network industries

	(1)	(2)	(3)	(4)
<i>Governance Indicators</i>	Overall	Planning	Management	Outcome
Governance # Size	0.0002**	0.0003***	0.0002**	0.0000
	(2.1)	(3.2)	(2.1)	(0.3)
Lagged MFP Level	-0.8331***	-0.8333***	-0.8330***	-0.8327***
	(-215.2)	(-215.5)	(-215.2)	(-215.2)
Observations	386,111	386,111	386,111	386,111
R-squared	0.6325	0.6326	0.6325	0.6325
Firm Level Controls	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES
Country-Sector-Time FE	YES	YES	YES	YES

Note: T-statistics in parentheses; standard errors clustered at the firm level. Firm controls included: size (number of employees), age, financial leverage ratio, profitability (returns on assets) and cash to assets ratio. The estimation sample covers the 2005-2015 period.

Source: OECD calculations based on the Orbis dataset and Hertie Business School data.

Figure 14. Impact of infrastructure governance on the productivity of firms in network industries, contingent on firms' size

Note: Based on the analysis in Table 5, the figure shows the productivity growth percentage points increase for firms' of different sizes following a 1-standard deviation increase in infrastructure governance.

Source: OECD calculations based on the Orbis dataset and Hertie Business School data.

Table 6. Competition-distorting regulation hinders firm-level productivity growth in network industries

	(1)	(2)	(3)	(4)	(5)	(6)
<i>Regulation Indicators</i>	Overall	Entry	Public Ownership	Mkt Structure	Vertical Integration	Overall
Regulation # Size	-0.006***	-0.004***	-0.003	-0.006**	-0.011**	-0.005**
	(-7.2)	(-3.9)	(-1.5)	(-2.3)	(-2.5)	(-3.4)
Governance # Size						0.001***
						(5.0)
Lagged MFP Level	-0.778***	-0.778***	-0.783***	-0.788***	-0.756***	-0.822***
	(-200.2)	(-200.3)	(-89.9)	(-85.1)	(-55.4)	(-166.7)
Observations	415,632	415,632	55,204	48,665	25,938	275,839
R-squared	0.603	0.603	0.621	0.622	0.612	0.627
Firm Level Controls	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES
Country-Sector-Time FE	YES	YES	YES	YES	YES	YES

Note: T-statistics in parentheses; standard errors clustered at the firm level. Firm controls included: size (number of employees), age, financial leverage ratio, profitability (returns on assets) and cash to assets ratio. The estimation sample covers the 1995-2013 period. In specification (6), infrastructure governance is proxied by the overall index provided by the Hertie Business School.

Source: OECD calculations based on the Orbis dataset, Hertie Business School data and the PMR-ETCR database.

Figure 15. Impact of competition-distorting regulation on the productivity of firms in network industries, contingent on firms' size

Note: Based on the analysis in Table 6, the figure shows the productivity growth percentage points increase for firms' of different sizes following a 1-standard deviation decrease in network industries regulation. Public ownership is not significant and thus not included in the figure, while the effect of market structure is not reported as it almost perfectly overlaps with the overall regulation pattern.

Source: OECD calculations based on the Orbis dataset and the PMR-ETCR database.

5. Concluding remarks

42. The paper provides novel evidence on the productivity effect of infrastructure governance focusing on both public governance of infrastructure investment and certain regulatory settings in network industries. Results suggest that implications of regulatory setting affecting competition and general regulatory practices, along with poor public governance -- in the form of improper prioritisation, poor procurement, corruption, lack of cooperation and coordination across different government levels -- are sizeable. Governance failures are found to reduce productivity growth in downstream sectors, possibly because they hinder the returns from infrastructure investment and obstruct the efficient provision of infrastructure services.

43. These findings deliver interesting insights for policy makers. First, the paper shows that not only the level of investment in infrastructure but also its efficient allocation and management matter for productivity growth. This is an important and timely result given the lively debate on investment gaps in infrastructure worldwide, notably related to the ICT revolution and the transition towards a green economy. Second, specific governance dimensions matter more than others for productivity growth (e.g., coordination across government levels, anti-corruption provisions, long-term planning, selection process, contractual arrangements and barriers to entry in network industries), suggesting that they should be prioritized when designing infrastructure governance and regulation frameworks.³⁵

44. The estimation strategy and the wide set of robustness checks ensure the consistency of our findings. Yet, these results should be viewed as preliminary; indeed, the paper goes as far as possible to exploit available data on governance, but it still suffers from a lack of time-varying comparable data for OECD countries on the planning and management dimensions of infrastructure governance. In order to further confirm the role of governance in shaping downstream productivity growth, future research would benefit greatly from the development of such indicators. For instance, the extension of the OECD survey undertaken in the context of Governance at a Glance publication to a larger number of OECD countries, as well as its repetition at different points in time, could provide a valuable input.

³⁵ Table A.1 summarizes recent reforms adopted by OECD countries with respect to infrastructure governance and regulation.

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Annex A. Infrastructure governance and regulation indicators

Infrastructure governance

1. The **Hertie School Governance Indicator (2016)** is based both on responses to the *Hertie School-OECD Global Expert Survey on Public Infrastructure* (compiled from replies by infrastructure experts from 29 OECD and 7 non-OECD countries) and on indicators provided by third party institutions (World Bank, Gallup, INSEAD, Cornell University and WIPO). The indicator is estimated from a Bayesian Factor Analysis model; results are rescaled on a 0-100 basis and countries ranked in order of governance, with best performing countries achieving higher scores (Figure A.1 and Figure A.2). It focuses on three dimensions of infrastructure governance:

- **Infrastructure Planning.** It requires expansive analytical capacity on the part of governments and concerns the organization of knowledge and type of advice that informs governmental policy-making. It involves project and policy analytics related to making decisions about planning and funding infrastructure projects. Sub-components: *Funding, Involving Multiple Actors, Planning*.
- **Infrastructure Management.** It captures governments' coordination and regulatory capacities. While regulation is about control and oversight over project and decision-making processes, coordination capacity is the ability to coordinate between multiple actors and organizations with diverse interests and goals. Sub-components: *Coordination, Procurement, Construction and Monitoring, Public Private Partnerships, Use of Best Practices, Preventing Corruption*.
- **Infrastructure Outcomes.** It captures governments' delivery capacity in terms of the ways in which they execute policies and provide quality services. Sub-components: *Infrastructure Access, Project Delivery, Infrastructure Quality*.

Regulation and competition settings in network industries

2. The **ETCR indicators (OECD)** measure restrictions to competition in a number of different (horizontal or vertical) segments of the energy, transport and telecommunication industries (see Figure A.3 for a cross-country comparison). Estimated yearly over the 1975-2013 period, they are for the most part based on explicit regulatory settings and market conditions (i.e., they are not the outcome of a "subjective" assessment gathered from opinion surveys). The indicators are computed using a bottom-up approach in which regulatory data are quantified using a scoring algorithm and then aggregated into summary indicators by sector of activity in each of the following areas:

- **Barriers to entry.** Based on third party access, it captures the extent to which consumers are able to choose across suppliers and to which new firms can enter the market.
- **Public ownership.** It assesses the degree of public ownership in each infrastructure sector, ranging from fully public to fully private.
- **Vertical integration.** It quantifies the extent to which competitive activities are separated from segments of the sector that remain natural monopolies.

- **Market structure.** It measures whether regulatory settings are able to attenuate incumbents' market power, promoting competition. More specifically, it records the market shares of the largest company in the different segments of the industry and the maximum number of operators that compete in the same geographical area.

General regulatory governance practices

3. The **Indicators of Regulatory Policy and Governance (iREG) (OECD, 2017)**, provide the first comprehensive evidence on the progress made by OECD countries in improving the way they regulate based on the practices described in the *2012 OECD Recommendation of the Council on Regulatory Policy and Governance*. Relying on the answers to the *2014 OECD Regulatory Indicators Survey*, the indicator covers primary laws and subordinate regulations initiated by the executive on three main dimensions:

- **Stakeholder Engagement.** It quantifies the extent to which countries use various forms of stakeholder engagement, ranging from public online consultation to formal consultation with social partners as well as informal consultation mechanisms.
- **Regulatory Impact Assessment.** It assesses the degree to which countries examine the costs and benefits of regulation and non-regulatory alternatives of achieving policy goals, identifying the approach that is likely to deliver the greatest net benefit to society.
- **Ex-post Evaluation.** It measures whether countries perform an ex-post evaluation of regulations, assessing their direct, indirect and unintended consequences as well as detecting areas for potential improvements.

4. Each dimension is related to an indicator composed of four equally weighted categories: methodology, oversight and quality control, systematic adoption and transparency. The maximum score for each category is 1 -- the more of the suggested practices a country has adopted, the higher the score -- and the total score for each composite indicator ranges from 0 to 4 (see Figure A.4 for a cross-country comparison).

Figure A.1. Infrastructure governance by country

Note: The figure shows each country level of infrastructure governance according to the summary index provided by the Hertie Business School. The indicator is estimated from a Bayesian Factor Analysis model; the red rhombus shows the average estimate, while the black square and the black circle the upper and the lower bound respectively.

Source: OECD calculations on Hertie Business School data.

Figure A.2. Infrastructure planning, management and outcome by country

Note: The figure shows cross-country differences in infrastructure planning, management and outcome according to the indicators developed by the Hertie Business School. Each indicator is estimated from a Bayesian Factor Analysis model; the red rhombus shows the average estimate, while the black square and the black circle the upper and the lower bound respectively.

Source: OECD calculations on Hertie Business School data.

Figure A.3. Network industries regulation, by country and over time

Note: The figure shows cross-country differences and within country changes over time (1998 vs 2013) in network industries overall regulation (top panel), barriers to entry (middle panel) and public ownership (bottom panel).

Source: OECD calculations on the PMR-ETCR database.

Figure A.4. Regulatory governance indicators, by country

Note: The figure shows cross-country differences in regulatory governance indicators. For each indicator and country, the blue bar refers to primary laws, while the red rhombus to secondary regulations. The indicator for primary laws in the stakeholder engagement and regulatory impact assessment dimensions is not available for the U.S., as the executive do not initiate primary laws at all.

Source: OECD calculations on the Regulatory Policy and Governance database.

Table A.1. Recent reforms in infrastructure governance and regulation

Country	Year of Implementation	Reform Details
Australia	2017	Release of new guidelines for transport assessment and planning.
Australia	2017	Establishment of the Infrastructure and Project Financing Agency to expand debt and equity financing to foster infrastructure spending.
Belgium	2016	Agreement for a national plan for strategic investment.
Canada	2017	Establishment of the Canada Infrastructure Bank.
Denmark	in progress	Modernisation of competition law (in particular cartel control), pro-competitive reforms in the electricity sector.
France	2018	Re-organization of the railway sector to open-up the passenger-transport sector to competition.
Germany	2016	Development of e-procurement (e.g., acceptance of electronic bids, online documents).
Germany	2017	Special working group to improve PPP transparency, especially w.r.t. their financial risks.
Israel	2016	Allow private firms access to new segments of the postal market.
Israel	2016	Tender of maintenance services in the railway sector to increase competition; simplification of administrative burdens in the gas distribution network sector.
Italy	2017	The anti-corruption agency (ANAC) issued the regulations of the New Public Procurement code.
Italy	in progress	The 2019 budget plans to establish a central public investment unit to enhance capacity at central and local levels in infrastructure management and project selection.
Korea	2017	New measures to boost PPPs.
Mexico	in progress	Implement a mechanism to prioritize infrastructure project development to meet the National Infrastructure Program objectives. Strengthen project preparation and structuring to consolidate a pipeline of bankable projects for private investment.
Spain	2018	Promotion of competition and more rigorous planning of the railway infrastructure
Spain	2018	Establishment of the National Evaluation Office to evaluate financial sustainability for concession contracts.
United Kingdom	2016	Establishment of the National Infrastructure Commission to provide independent recommendations on national infrastructure priorities; consolidation of several administrative units into a single Infrastructure Delivery Authorities responsible for all major projects.
United Kingdom	2016	Ex-post evaluation of all new PPP projects to compare forecasts and actual returns.

Note: The table reports the reforms in infrastructure governance and regulation that have been (are about to be) implemented in OECD countries since 2016.

Source: OECD elaboration on the OECD Reform Tracker database.

Annex B. Analysis of infrastructure dependence

Figure B.1. Infrastructure dependence varies across sectors

Downstream dependence on infrastructure services, median across OECD countries

Note: The figure shows downstream dependence from infrastructure services. Infrastructure dependence is calculated as the ratio between inputs' provision from infrastructure industries (energy, transport and telecommunications) and sectoral value added. First, infrastructure dependence is averaged over time (2005-2015) for each country sector pair; second, we take the median value across OECD countries.

Source: OECD calculations on the OECD Input-Output tables.

Figure B.2. Sectoral dependence on infrastructure varies across countries

Sectors rank in infrastructure dependence, benchmarks comparison

Note: The figure shows downstream sectors rank in terms of dependence from infrastructure services. Infrastructure dependence is calculated as the ratio between inputs' provision from infrastructure industries (energy, transport and telecommunications) and sectoral value added. For each country-sector pair, infrastructure dependence is averaged over time (2005-2015); next, for each benchmark country, sectors are ranked according to their level of dependence.

Source: OECD calculations on the OECD Input-Output tables.

Table B.1. Sectoral dependence ranking is stable over time

Rank correlation over time in infrastructure dependence, by country

Country	Total Infra	Energy	Telco	Transport
AUS	0.90	0.94	0.90	0.92
AUT	0.97	0.98	0.91	0.97
BEL	0.95	0.97	0.83	0.95
DEU	0.97	0.98	0.90	0.96
DNK	0.94	0.96	0.83	0.91
ESP	0.98	0.98	0.88	0.97
EST	0.95	0.94	0.87	0.92
FIN	0.94	0.97	0.86	0.94
FRA	0.96	0.96	0.95	0.98
GBR	0.97	0.98	0.93	0.98
GRC	0.88	0.90	0.80	0.79
HUN	0.96	0.97	0.86	0.94
IRL	0.88	0.91	0.78	0.81
ITA	0.98	0.98	0.85	0.97
JPN	0.98	0.99	0.96	0.97
LUX	0.91	0.93	0.87	0.86
NLD	0.98	0.99	0.98	0.99
NOR	0.95	0.97	0.84	0.92
POL	0.97	0.97	0.85	0.95
PRT	0.94	0.96	0.92	0.95
SVN	0.92	0.92	0.82	0.95
SWE	0.95	0.97	0.90	0.94
TUR	0.97	0.98	0.96	0.96
USA	0.97	0.99	0.96	0.99
CAN	0.97	0.98	0.88	0.97
CHE	0.89	0.89	0.87	0.95
CZE	0.96	0.97	0.95	0.95
KOR	0.98	0.99	0.96	0.98
LTU	0.83	0.81	0.79	0.79
LVA	0.78	0.82	0.67	0.80
MEX	0.98	0.98	0.99	0.99
SVK	0.89	0.83	0.77	0.89

Note: The table shows the downstream sectoral rank (in terms of infrastructure dependence) correlation over time. Infrastructure dependence is calculated as the ratio between inputs' provision from infrastructure industries (energy, transport and telecommunications) and sectoral value added. For each country-year, sectors are ranked in ascending order; next, we calculate the average correlation of the yearly rank series for each country. Countries in the bottom part of the table are not included in the regression analysis due to data availability.

Source: OECD calculations on the OECD Input-Output tables.

Annex C. Detailed tables and robustness checks

Table C.1. Descriptive Statistics

Variable	Mean	St. Dev.	P10	P50	P90
MFP	10.480	0.880	9.439	10.482	11.542
MFP Growth	0.005	0.461	-0.364	0.007	0.374
Number of Employees	70	2149	4	10	79
Age	19	15	5	15	37
Total Assets	1.74E+07	3.06E+08	164173.3	1168324	1.87E+07
Return on Assets	0.051	0.160	-0.069	0.036	0.211
Cash to Assets Ratio	0.144	0.176	0.002	0.071	0.404
Financial Leverage Ratio	0.167	0.231	0.000	0.076	0.466
Total Infrastructure Dependence	0.183	0.155	0.065	0.138	0.343
Energy Dependence	0.081	0.111	0.014	0.046	0.172
Transport Dependence	0.087	0.063	0.030	0.072	0.159
Telco Dependence	0.015	0.014	0.007	0.011	0.028
GovImpact	10.797	10.377	3.205	7.726	21.789
RegImpact	0.606	0.637	0.165	0.420	1.213
Regulation, Overall	2.690	0.932	1.602	2.603	4.038
Regulation, Transport	2.783	0.914	1.563	2.722	4.027
Regulation, Energy	3.060	1.265	1.645	2.913	4.938
Regulation, Telco	1.575	1.194	0.511	1.204	3.387
Quality of Infrastructure	5.427	0.918	3.986	5.695	6.443
Government Effectiveness	1.413	0.540	0.585	1.571	2.026
Governance, Overall Index	59.4	22.3	29	65	86
Governance, Planning	57.0	28.4	17	60	94
Governance, Management	58.6	25.4	26	53	95
Governance, Outcome	62.7	23.1	30	70	84

Note: The table reports the descriptive statistics for the main variables employed in the analysis. The statistics refer to the sample underlying the baseline estimation of the governance analysis (2005-2015), with the only exception of regulation related variables, whose statistics are computed over the 1995-2013 sample.

Source: OECD calculations based on the Orbis dataset, the OECD input-output tables, the PMR-ETCR database and on Hertie Business School data.

Table C.2. Infrastructure quality and government effectiveness spur productivity growth downstream: robustness check with firm fixed effects and U.S. dependence

	(1)	(2)	(3)	(4)
<i>Governance Indicators</i>	Quality of Infra	GovEffectiveness	Quality of Infra	GovEffectiveness
GovImpact (Time Varying Proxy)	0.151***	0.209***	0.094*	0.199**
	(4.5)	(3.8)	(1.9)	(2.3)
Lagged MFP Level	-0.882***	-0.800***	-0.360***	-0.348***
	(-191.0)	(-225.9)	(-110.5)	(-134.7)
Observations	5,425,177	8,045,350	5,494,423	8,103,758
R-squared	0.632	0.586	0.283	0.276
Firm Level Controls	YES	YES	YES	YES
Firm FE	YES	YES	NO	NO
Country-Sector FE	NO	NO	YES	YES
Country-Time FE	YES	YES	YES	YES
Sector-Time FE	YES	YES	YES	YES

Note: T-statistics in parentheses; standard errors clustered at the firm and country-sector-year level. Firm controls included: size (number of employees), age, financial leverage ratio, profitability (returns on assets) and cash to assets ratio. Due to data availability, the estimation sample covers the 2007-2015 period in models (1) and (3) and the 1995-2015 period in models (2) and (4). Models (1) and (2) include firm fixed effects in place of country-sector dummies, while specifications (3) and (4) exploit U.S. infrastructure dependence to calculate the GovImpact indicator. Source: OECD calculations based on the Orbis dataset, the OECD input-output tables and World Bank data.

Table C.3. Competition-distorting regulation in network industries hinders productivity growth downstream: robustness check with aggregate controls, firm fixed effects and U.S. dependence

	(1)	(2)	(3)	(4)
<i>Regulation Indicators</i>	Overall	Overall	Overall	Overall
RegImpact	-0.216***	-0.043***	-0.157***	-0.216***
	(-3.7)	(-2.6)	(-3.6)	(-3.7)
Lagged MFP Level	-0.347***	-0.773***	-0.347***	-0.347***
	(-143.7)	(-231.6)	(-144.0)	(-143.7)
Observations	8,731,610	8,663,150	8,741,962	8,731,610
R-squared	0.278	0.575	0.278	0.278
Firm Level Controls	YES	YES	YES	YES
Aggregate Controls	YES	NO	NO	YES
Firm FE	NO	YES	NO	NO
Country-Sector FE	YES	NO	YES	YES
Country-Time FE	YES	YES	YES	YES
Sector-Time FE	YES	YES	YES	YES

Note: T-statistics in parentheses; standard errors clustered at the firm and country-sector-year level. Firm controls included: size (number of employees), age, financial leverage ratio, profitability (returns on assets) and cash to assets ratio. Aggregate controls (interacted with infrastructure dependence) included: financial development, GDP growth, R&D expenditures, public capital stock and labour market regulations. Due to data availability, the estimation sample covers the 1995-2013 period. Model (1) adds aggregate controls to the baseline specification, while model (2) includes firm fixed effects in place of country-sector dummies; specifications (3) and (4) exploit U.S. infrastructure dependence to calculate the RegImpact indicator.

Source: OECD calculations based on the Orbis dataset, the OECD input-output tables and the PMR-ETCR database.

Table C.4. The productivity effect of each dimension of infrastructure governance

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
<i>Governance Indic.</i>	Funding	# Actors	Planning	Coordination	Procurement	Monitor	PPP	BestPractice	Corruption	Access	Delivery	Quality
GovImpact	0.001	0.001	0.002**	0.004***	0.002*	0.002***	0.002***	0.001	0.003**	0.003***	0.000	0.001
	(1.0)	(0.9)	(2.4)	(4.0)	(1.9)	(2.6)	(2.9)	(0.9)	(2.3)	(3.0)	(0.3)	(1.4)
Lagged MFP Level	-0.328***	-0.328***	-0.329***	-0.329***	-0.328***	-0.329***	-0.329***	-0.328***	-0.330***	-0.329***	-0.328***	-0.328***
	(-38.6)	(-38.6)	(-38.5)	(-38.4)	(-38.6)	(-38.5)	(-38.5)	(-38.6)	(-38.6)	(-38.5)	(-38.6)	(-38.6)
Observations	4,666,227	4,666,227	4,666,227	4,666,227	4,666,227	4,666,227	4,666,227	4,666,227	4,640,434	4,666,227	4,666,227	4,666,227
R-squared	0.264	0.264	0.264	0.265	0.264	0.264	0.264	0.264	0.265	0.265	0.264	0.264
Firm Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Country-Time FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Sector-Time FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES

Note: T-statistics in parentheses; standard errors clustered at the firm and country-sector level. Firm controls included: size (number of employees), age, financial leverage ratio, profitability (returns on assets) and cash to assets ratio. The estimation sample covers the 2005-2015 period.

Source: OECD calculations based on the Orbis dataset, the OECD input-output tables and Hertie Business School data.

Table C.5. Sound governance magnifies the effect of investment on productivity

	(1)	(2)
<i>Governance Indicator</i>	Overall	Overall
Investment # Dependence	-2.003***	-4.282***
	(-3.3)	(-5.6)
Investment # Dependence # Governance	0.038***	0.075***
	(3.4)	(5.6)
Lagged MFP Level	-0.350***	-0.853***
	(-101.2)	(-224.0)
Observations	4,500,189	4,460,136
R-squared	0.275	0.621
Firm Level Controls	YES	YES
Firm FE	NO	YES
Country-Sector FE	YES	NO
Country-Time FE	YES	YES
Sector-Time FE	YES	YES

Note: T-statistics in parentheses; standard errors clustered at the firm and country-sector-year level. Firm controls included: size (number of employees), age, financial leverage ratio, profitability (returns on assets) and cash to assets ratio. The estimation sample covers the 2005-2015 period due to data availability. Model (2) differs from model (1) as it employs firm fixed effects in place of country-sector fixed effects. Infrastructure investment is calculated as the ratio between gross fixed capital formation and value added in infrastructure sectors (STAN data, energy, transport and telecommunication industries), while infrastructure governance is proxied by the Hertie Business School overall governance index.

Source: OECD calculations based on the Orbis dataset, the OECD Input-Output tables, the STAN database and Hertie Business School data.

Table C.6. Infrastructure governance and regulation have a stronger impact on large firms downstream: alternative size proxies

	(1)	(2)	(3)
<i>Size Variable</i>	Materials	Total Assets	Fixed Assets
GovImpact # Size	0.002***	0.001***	0.0003***
	(10.5)	(9.2)	(6.2)
Size	0.064***	0.086***	0.006***
	(50.6)	(60.7)	(9.4)
Lagged MFP Level	-0.863***	-0.785***	-0.891***
	(-780.9)	(-911.2)	(-688.1)
Observations	4,608,917	4,618,192	4,616,719
R-squared	0.634	0.634	0.631
Firm Level Controls	YES	YES	YES
Firm FE	YES	YES	YES
Country-Sector-Time FE	YES	YES	YES

Note: T-statistics in parentheses; standard errors clustered at the firm level. Firm controls included: size (number of employees), age, financial leverage ratio, profitability (returns on assets) and cash to assets ratio. Due to data availability, the estimation sample covers the 2005-2015 period. In model (1), size is proxied by material costs, while in model (2) and (3) by total assets and total fixed assets respectively.

Source: OECD calculations based on the Orbis dataset, the OECD input-output tables and Hertie Business School data.

Table C.7. Infrastructure governance and regulation have a stronger impact on large firms downstream: robustness check with U.S. dependence

	(1)	(2)
<i>Governance and Regulation Indicators</i>	Overall	Overall
GovImpact # Size	0.001**	
	(2.2)	
RegImpact # Size		-0.021***
		(-10.0)
Size	0.103***	0.094***
	(59.6)	(121.7)
Lagged MFP Level	-0.863***	-0.785***
	(-781.1)	(-911.2)
Observations	4,618,290	8,661,701
R-squared	0.631	0.584
Firm Level Controls	YES	YES
Firm FE	YES	YES
Country-Sector-Time FE	YES	YES

Note: T-statistics in parentheses; standard errors clustered at the firm level. Firm controls included: age, financial leverage ratio, profitability (returns on assets) and cash to assets ratio. Due to data availability, the estimation sample covers the 2005-2015 period in model (1) and the 1995-2013 period in model (2). In both specifications, U.S. infrastructure dependence is used to construct the GovImpact and RegImpact indicators.

Source: OECD calculations based on the Orbis dataset, the OECD input-output tables, the PMR-ETCR database and Hertie Business School data.

Table C.8. Placebo Test

	(1)	(2)	(3)	(4)
<i>Placebo Impact Indicator</i>	GovImpact	RegImpact	GovImpact	RegImpact
Placebo Impact Indicator	0.001	0.005*		
	(1.0)	(1.6)		
Placebo Impact Indicator # Size			0.000	-0.000
			(0.6)	(-1.2)
Size	0.071***	0.066***	0.106***	0.090***
	(21.4)	(64.1)	(53.0)	(139.2)
Lagged MFP Level	-0.329***	-0.347***	-0.863***	-0.785***
	(-38.5)	(-144.0)	(-783.6)	(-911.2)
Observations	4,664,183	8,741,962	4,618,290	8,661,701
R-squared	0.265	0.278	0.631	0.584
Firm Level Controls	YES	YES	YES	YES
Country-Sector FE	NO	YES	NO	NO
Country-Time FE	YES	YES	NO	NO
Sector-Time FE	YES	YES	NO	NO
Firm FE	NO	NO	YES	YES
Country-Sector-Time FE	NO	NO	YES	YES

Note: T-statistics in parentheses; standard errors clustered at the firm level and country-sector level in model (1), at the firm level and country-sector-year level in model (2) and at the firm level in model (3)-(4). The values of *GovImpact* (*RegImpact*) are replaced with random draws from a normal distribution parametrized on the mean and variance of the true *GovImpact* (*RegImpact*). Firm controls included: age, financial leverage ratio, profitability (returns on assets) and cash to assets ratio. Due to data availability, the estimation sample covers the 2005-2015 period in model (1) and the 1995-2013 period in model (2).

Source: OECD calculations based on the Orbis dataset, the OECD input-output tables, the PMR-ETCR database and Hertie Business School data.

Table C.9. Competition-distorting regulation hinders productivity growth in network industries, broad picture

	(1)	(2)	(3)	(4)	(5)
<i>Regulation Indicators</i>	Overall	Entry	Public Own	Mkt Structure	Vert Integr.
Regulation	-0.009*	-0.003	0.002	-0.013*	-0.029**
	(-1.7)	(-0.5)	(0.3)	(-1.7)	(-2.4)
Lagged MFP Level	-0.321***	-0.321***	-0.251***	-0.245***	-0.210***
	(-31.5)	(-31.5)	(-31.0)	(-29.0)	(-20.7)
Observations	419,946	419,946	55,998	49,363	26,282
R-squared	0.279	0.279	0.231	0.226	0.226
Firm Level Controls	YES	YES	YES	YES	YES
Country-Sector FE	YES	YES	YES	YES	YES
Country-Time FE	YES	YES	YES	YES	YES
Sector-Time FE	YES	YES	YES	YES	YES

Note T-statistics in parentheses; standard errors clustered at the firm and the country-sector-year level. Firm controls included: size (number of employees), age, financial leverage ratio, profitability (returns on assets) and cash to assets ratio. The estimation sample covers the 1995-2013 period and is based on the following equation:

$$MFPgrowth_{icst} = \beta_0 + \beta_1 Regulation_{cs,t-1} + \beta_2 LagMFP_{ics,t-1} + \beta_3 \bar{X}_{icst} + \delta_{cs} + \delta_{ct} + \delta_{st} + \epsilon_{icst}$$

Source: OECD calculations based on the Orbis dataset and the PMR-ETCR database.

Figure C.1. Decrease in network industries regulation: the direct effect on productivity growth

Note: Based on the analysis in Table C.9, the figure shows the productivity growth percentage points increase for the average firm following infrastructure regulation shocks of different sizes (e.g., decrease in regulatory barriers).

Source: OECD calculations based on the Orbis dataset and the PMR-ETCR database.