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ORIGINAL ARTICLE

Filling the gap: Infrastructure investment in Brazil

Carlos Góes[1], Mercedes Garcia-Escribano[2] and Izabela Karpowicz[3]*

[1]Department of Economics, University of California, San Diego, United States
[2]Fiscal Affairs Department, International Monetary Fund, Washington DC., United States
[3]European Department, International Monetary Fund, Washington DC., United States

ABSTRACT

Infrastructure bottlenecks have been identified as a key obstacle to growth affecting productivity and market efficiency, and hindering domestic integration and export performance. This paper assesses the state of Brazil's infrastructure, in light of past investment trends and various quality and quantity indicators. Brazil's infrastructure stock and its quality rank low in relation to that of comparator countries, chosen among main export competitors. We provide evidence that infrastructure affects domestic integration by analyzing price convergence of tradable goods across major cities. The government's concession program will narrow part of the infrastructure gap; however, governance reforms will be crucial to improving investment efficiency.

Keywords: *infrastructure; public investment; domestic market integration*

1. Introduction

Developing an economic strategy to scale up infrastructure investment requires establishing the link between infrastructure provisions and growth, determining the infrastructure gap, and identifying financing and optimal provisioning. Areas where Brazil's competitiveness has lagged include, but are not limited to, education, innovation, governance, and justice. Yet, inadequate infrastructure is increasingly identified as the key bottleneck behind low productivity, stagnating export performance, insufficient domestic market integration, and weak growth potential. Market segmentation caused by divergence in relative prices can have potentially severe social and macroeconomic implications. Income inequality may also increase with market segmentation, as low-income producers in rural areas are adversely impacted by difficulties accessing large consumer markets. Several years of underinvestment in infrastructure have contributed to reducing potential growth. It has been estimated that inefficiencies due to inadequate infrastructure subtract 10−15% from the country's GDP (Credit Suisse, 2013).[1]

To underscore Brazil's need for greater investment in infrastructure, we attempt to throw some light on Brazil's infrastructure gaps. Infrastructure investment is often seen as a strategy to promote internal integration and export competitiveness. Following this logic, we first

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***CORRESPONDING AUTHOR**
Izabela Karpowicz, European Department, International Monetary Fund, Washington, D.C., United States. E-mail: ikarpowicz@imf.org

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1. According to Credit Suisse (2013), most of the R$1 trillion investment gap is infrastructure related. Underinvestment is especially notable in greenfield projects as brownfield projects were granted to the private sector through concessions. Airports, ports, and rail are the most constrained sectors.

look at how infrastructure affects domestic integration by analyzing price convergence across major cities. Second, using quantity and quality indicators, we look closely at infrastructure gaps across sectors against Brazil's current income levels and against infrastructure levels and quality of Brazil's competitors in its export markets. We then document historical infrastructure investment trends in Brazil and describe the authorities' concessions program in light of the most pressing infrastructure needs. Finally, we discuss policies that could help close the infrastructure gap.

2. How well integrated is the Brazilian domestic market?

We assess market segmentation in Brazil by analyzing the convergence of prices across major metropolitan areas. We use the dataset constructed by Góes and Matheson (2015), to look for evidence of domestic market segmentation by exploring the convergence of prices of tradable goods between large metropolitan areas and Sao Paulo, which is used as reference city.[2] The objective is to assess whether infrastructure adequacy could help explain the domestic integration through the study of prices and travel times between cities.

We take monthly price indices for 51 products across 10 metro areas over the past 14 years, and test for panel unit root using the methodology developed by Im et al. (2003). Intuitively, we are testing for the law of one price (LOOP): If goods markets are well integrated, the difference between the log of price levels (p_{it}) for tradable products in different *i* cities should be stationary, that is, mean reverting, with relatively fast reversion to the mean after some shock causes a divergence to appear.

For each product *m,* we run individual Augmented Dickey–Fuller (ADF) regressions of the differences in the price level $(p^*_{(i,m,t)} \equiv p_{(i,m,t)} - \underline{p}_{(m,t)})$ for every city *i*, where $\overline{p}_{m,t}$ is the log of the price level in São Paulo. We include lags and select lag-lengths $K_{m,i}$ using the Akaike Information Criterion to assure that residuals $\eta_{i,m,t}$ approximate white noise, while allowing $K_{m,i}$ to be heterogeneous among individuals. For those processes which are not explosive, we calculate the half-life ($h_{i,m}$) of the autoregressive parameter from the individual ADF regressions.

$$(1)\quad \Delta p^*_{i,m,t} = \tilde{c}_i + \sum_{k=1}^{K_{m,i}} \phi_{i,m,k}" p^*_{i,m,t-k} + (\rho_i - 1) p^*_{i,m,t-1} + \eta_{i,m,t}, i = [1,2,...,10]^T$$

$$(2)\quad h_{i,m} = \frac{\ln(0.5)}{\ln(|\rho_{i,m}|)}, |\rho_{i,m}| < 1 \forall i,m$$

Afterward, we collect individual t-statistics for *i* cross-sections ($t_{i,T}$) and from their average calculate a panel $Z_{t\text{-bar}}$ statistic, which should also be asymptotically normally distributed. $E\left[t_{i,m,T} | \rho_{i,m} = 1\right]$ and $Var[t_{i,m,T} | \rho_{i,m} = 1]$ are obtained by interpolating the values from Im et al. (2003) tables.

$$(3)\quad Z_{t-bar} = \frac{\sqrt{N}\left(N^{-1}\sum_{i=1}^{N} t_{i,m,T} - N^{-1}\sum_{i=1}^{N} E\left[t_{i,m,T} | \rho_i = 1\right]\right)}{\sqrt{N^{-1}\sum_{i=1}^{N} Var[t_{i,m,T} | \rho_{i,m} = 1]}}, \rho_{i,m}\left(\bar{\rho}, \sigma^2_{\rho_{i,m}}\right)$$

Empirical results suggest that most tradables prices converge to the mean. We reject the null of unit root for about ⅔ of the tradable products, for which the LOOP holds. These are most notably

2. The original works studies convergence to the national mean.

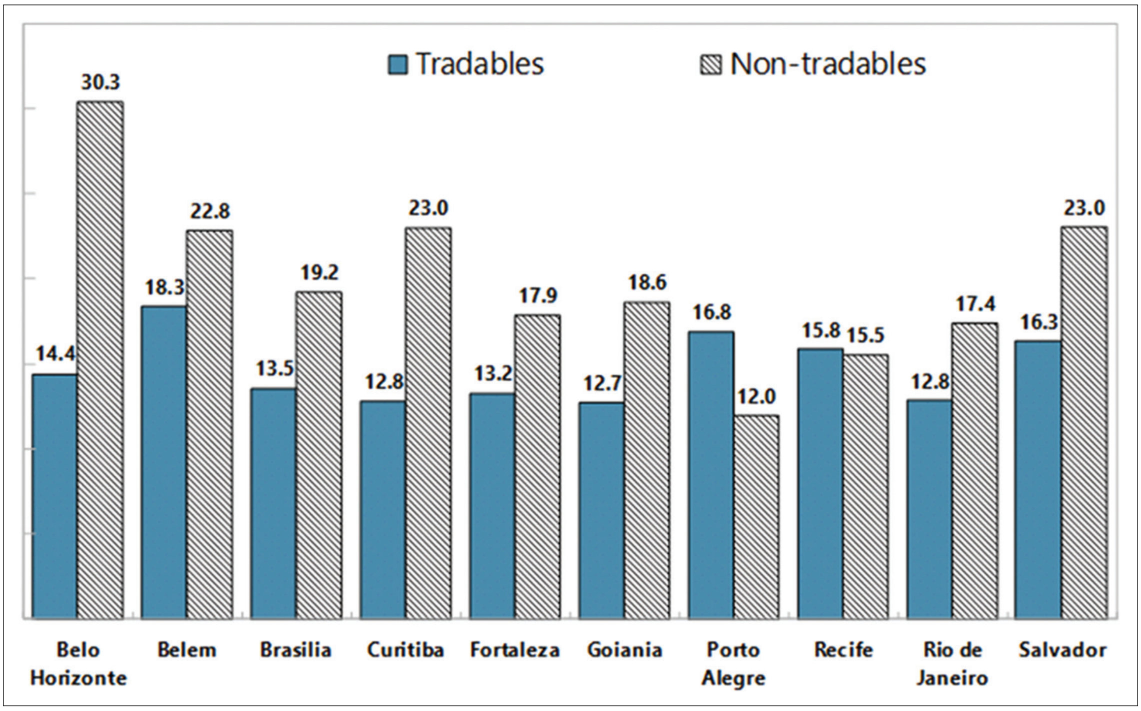

Figure 1. Brazil: Metro-Area CPI Divergence Half-Lives (in months).
Sources: Authors' estimates

food and fuels. The majority of non-tradable products, on the contrary, fail to satisfy the LOOP, which is consistent with economic intuition. Individual ADF equations show that, while only 5% of tradable product prices have explosive processes, about 18% of non-tradable prices do.

Although most tradable satisfy the LOOP, we note that, following a shock to the relative price of a tradable good, prices converge to the São Paulo benchmark only very slowly. The average time it takes for half of the initial price discrepancy to disappear (the so-called "half-life") is 14 months, with the speed of convergence varying across cities significantly. In Curitiba, for example, the average half-life of tradables price convergence is 12.8 months, while in Belem it is 18.3 months. Around 90% of price convergence occurs over 3 years (Figure 1). For all products that satisfy the LOOP, price convergence is considerably slower for non-tradable products (Figure 2). The average half-life of non-tradable price convergence is 20 months, whereas the half-life of tradable price convergence is 14 months. Price convergence in Brazil is also slower than in comparator countries. International evidence using similar empirical approaches, also applied to monthly CPI data, points to significantly lower half-lives of price convergence in other countries. The average half-life of convergence for China between 1993 and 2003 (Li and Huang, 2006) was 2.4 months, and the half-life for Canada between 1978 and 1994 was 5 months (Fan and Xiangdong, 2006). The results for both countries suggest that more than 90% of relative price shocks dissipate within 18 months, much faster than in the case of Brazil (Figure 3).[3]

Robustness checks have confirmed slow price convergence and evidence of market segmentation in Brazil. Góes and Matheson (2015) extended this analysis adopting a method proposed by Levin, Lin and Chu's (2002) and using the national average, rather than São Paulo, as the reference price in the cointegration analysis. The results are consistent with ours, with somewhat more non-

3. Using the aforementioned half-lives (h), we derive the autoregressive term as $|\rho|=\exp(\ln(0.5)/h)$ and plot their respective response functions.

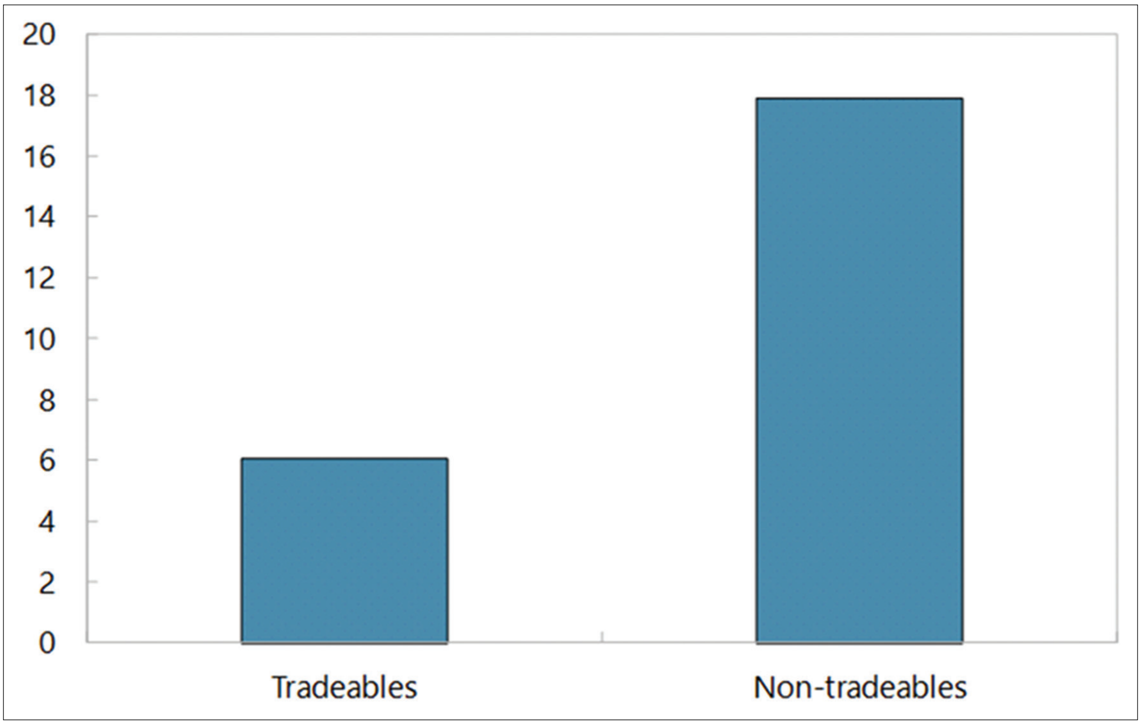

Figure 2. Domestic Integration: Tradeables and non-tradeables (percent of ADF coefficients that are ≥1).
Sources: Authors' estimates.

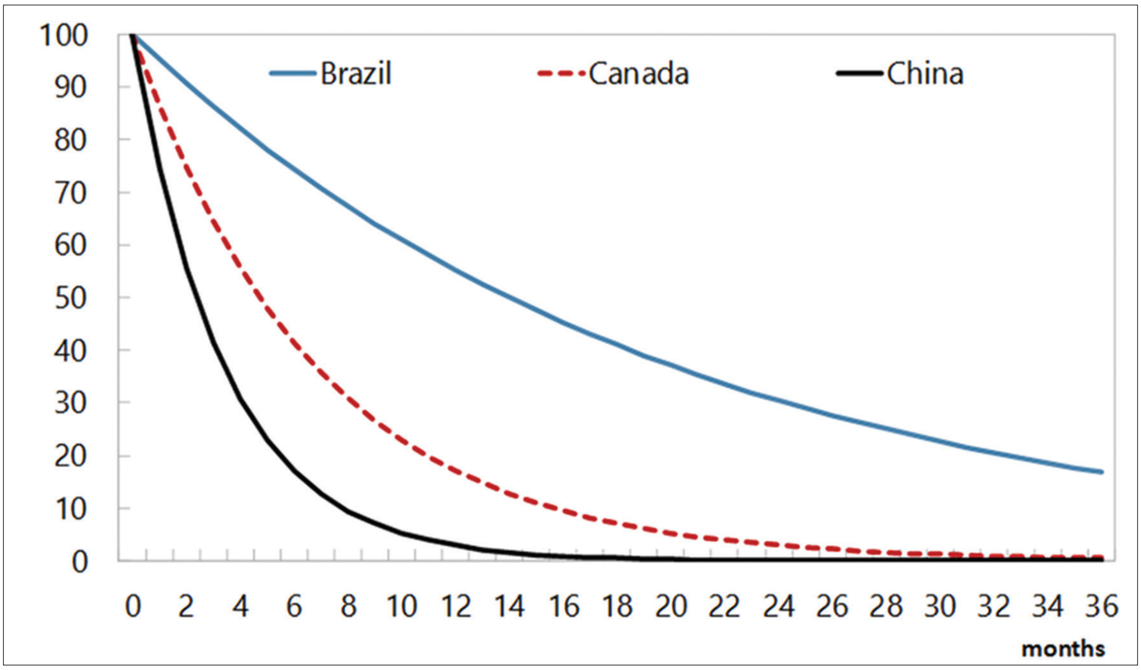

Figure 3. Path of Price Convergence: Response Functions (shock = 100, X-axis in months).
Sources: Authors" calculations. Canada and China calculated from half-lives estimated by Li and Huang (2006) and Fan and Wei (2006).

tradables failing to satisfy LOOP, while the estimated average half-life of tradable products price convergence is slightly higher (16 months).

Next, we examine if poor infrastructure contributes to market segmentation. We find a correlation between slower domestic price convergence and longer commuting times between

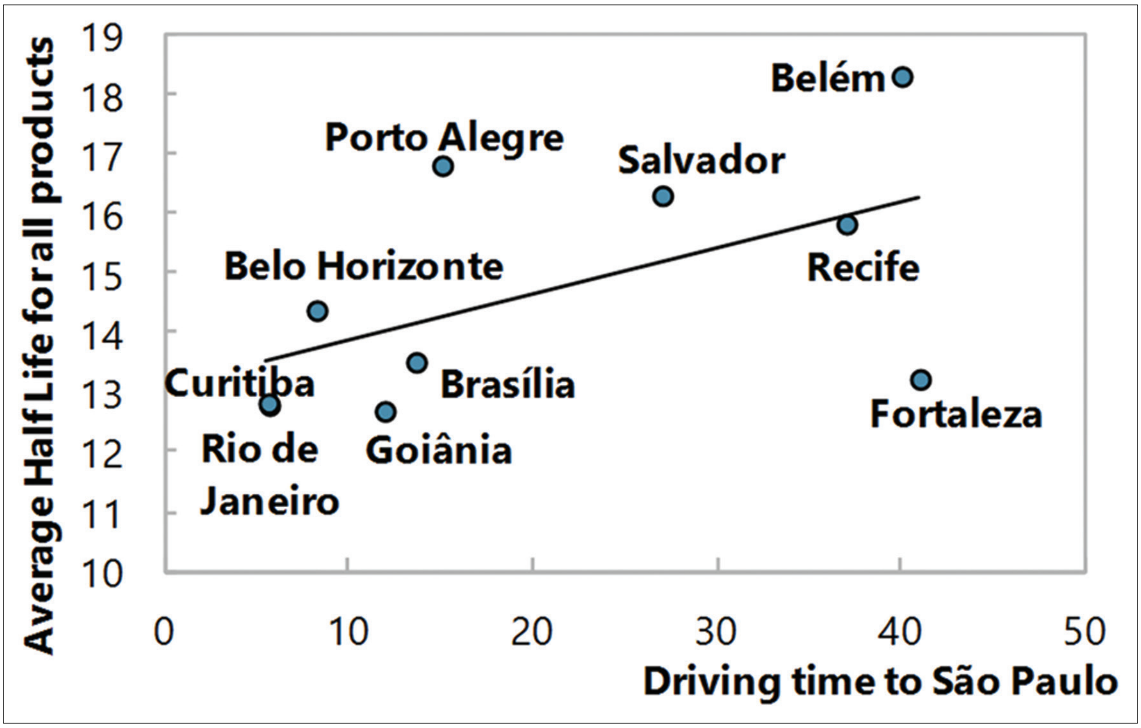

Figure 4. Brazil: Half Lives of Tradables and Driving Time to São Paulo (Y-axis: half-lives in months; X-axis, driving time to São Paulo in hours).
Sources: Authors' calculations and Google Maps.

cities. Half-lives of tradables price convergence are found to increase with the travel time between cities (Figure 4). Market integration could, therefore, benefit from an overall improvement in transport infrastructure, namely roads or railways, that could bring down travel times between cities. However, even controlling for physical distance, convergence occurs very slowly in Brazil (see the vertical intercept of the chart below). This suggests that other barriers to Inter State Trade are also important - for example, the state-level indirect tax (the ICMS), could be one of them.[4]

3.Infrastructure gap: The choice of comparator countries

One way of looking at infrastructure gaps is to assess the adequacy of Brazil's physical capital against that of its exports competitors. Infrastructure gaps are often measured in terms of distance from a benchmark defined by a country's level of development, or the level of infrastructure necessary to reach the next development stage. However, a gap can also be considered to exist when infrastructure quality (and quantity) falls below that of trading competitors. When gaps exist, countries should be able to extract more rents from exports and possibly gain market share by decreasing business costs from inadequate infrastructure.

The optimal infrastructure mix will also depend on the type of products exported. Brazil is a diversified economy and a closed one, where exports of goods represent only around 11% of GDP. However, Brazil is a leading exporter of some commodities, and the number-one exporter of soybeans, cane sugar, meats, and coffee/tea. Over two-thirds of the world's cane sugar is produced in Brazil. Yet, other commodity exports, such as iron ore, of which Brazil is the second largest exporter, generate higher revenues from exports (Figure 5).

4. The analysis of the ICMS is beyond the scope of this paper.

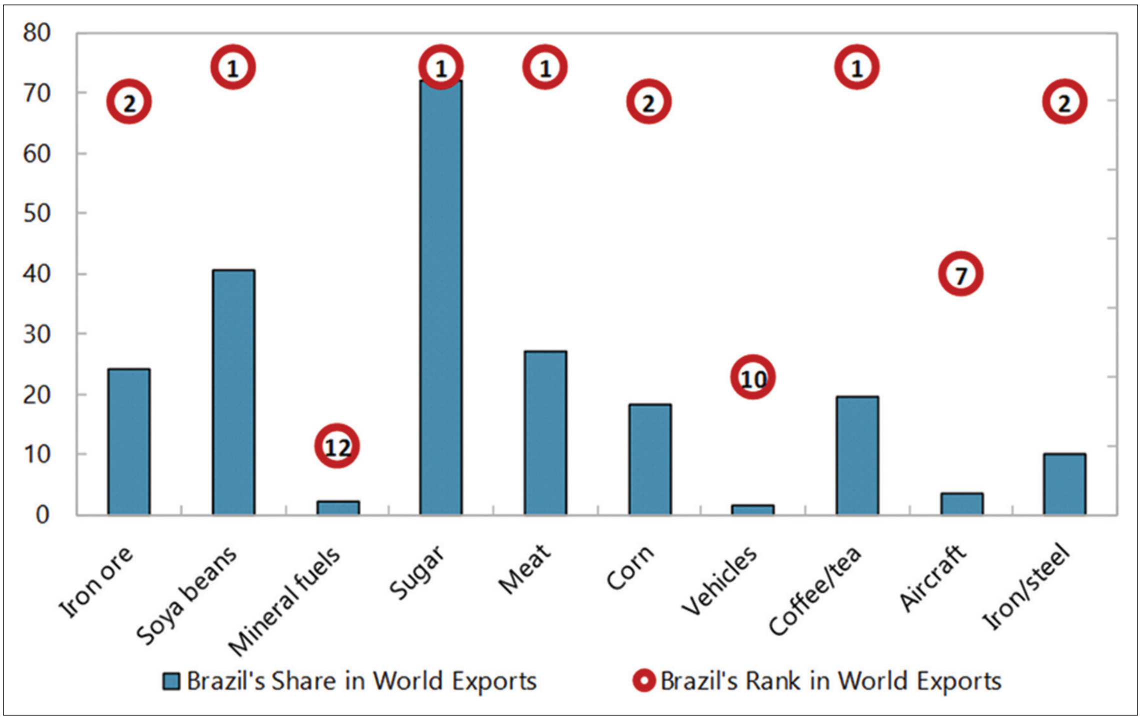

Figure 5. Brazil: Top 10 Commodity Exports (In share of and rank world exports of each commodity, respectively).
Sources: UN Comtrade and authors' estimates.

Who are Brazil's main competitors? Brazil's 10 largest commodity exports by value are used to determine its competitors. Brazil's prospective competitors in each of these products are the 10−15 countries with the largest shares of world exports; Brazil's main export competitors are those countries that compete in at least three of Brazil's top 10 export products. According to this definition, Brazil's closest competitor is the U.S., competing in six of Brazil's export categories, closely followed by Canada and India, competing in five export categories. Other competitors include Argentina, Australia, China, Kazakhstan, Mexico, Russia, and South Africa.

3.1. The state of infrastructure

Infrastructure gaps are usually quantified by estimating the existing capital stock and comparing it to a benchmark, typically based on the country's development level. This method can take into account evolving infrastructure needs along different stages of development and can provide an estimate of underinvestment in a sector. Other quantitative indicators generally measure outputs such as electricity generation, available km of roads, railroads, or waterways, or airline passenger traffic. These indicators are valuable, but they may be difficult to compare across countries. In practice, the information content of quantitative indicators is partial for a variety of reasons. For instance, the indicator quantifying paved roads fails to take account of the state of road support services (gas stations and emergency equipment), how well roads connect main business centers, and how many lanes each road has. Maintenance is also an important unknown. Since obsolete infrastructure cannot adequately support production, qualitative indicators should be used to complement the analysis, ideally along with more detailed, and sector-specific surveys. Such an approach may shed light on infrastructure quality and its suitability to meet the evolving needs of its users.

Brazil scores low on a large variety of qualitative indicators of infrastructure adequacy. Based on overall infrastructure quality, Brazil ranked 120 out of 144 countries surveyed by the World Economic Forum, in 2014, with particularly poor results for roads and air transport quality. In other areas, Brazil ranked in the bottom third of countries surveyed. Brazil's rankings have been low over the past decade and have generally worsened over the past 5 years (Figure A1 in the Appendix).[5]

Brazil has inferior overall infrastructure quality relative to almost all its export competitors. (Figure A2 in the Appendix) Brazil's scores for adequacy of physical capital across all areas of transport infrastructure - roads, ports, railroads, and air transport infrastructure - are substantially lower than those of its main export competitors. Only in the area of electricity and telecommunication does Brazil have a better ranking than some competitors, areas in which it has invested comparably more in recent years and more efficiently - through greater participation of the private sector. Still, according to the, 2010, World Bank Enterprise Survey, 46% of firms in Brazil indicated that electricity was a major constraint to activity (against 38% in LAC) while 28% of firms considered transportation to be a major constraint (against 23% in LAC).

Quantitative indicators of infrastructure also paint a grim picture. <15% of Brazil's roads are paved (including municipal roads), and congestion is a concern; the estimated number of vehicles per km of road was 25, in 2008, and this number has likely increased in the wake of the recent boom in auto loans as vehicle sales have more than doubled over the past 10 years.[6] As a share of paved roads, congestion levels are among the highest against comparators. Moreover, multi-lane roads are still relatively rare in Brazil, although they have doubled over the past half-decade (Figures 6 and 7).

Infrastructure gaps in transport appear more dramatic when quality and quantity indicators are coupled with Brazil's transportation mix. Brazil's competitors rely more on rail for moving goods, which is better suited to high-volume, low-value-added commodities (Figure 8). In Brazil, 60% of agricultural commodities are transported by highways, while most of the iron ore exported travels by rail (Credit Suisse, 2013). Coupled with the poor state of roads, this transportation mix appears to be a very important constraint on exports and competitiveness.

Ports and airports are also constrained. Only one of Brazil's ports - the port of Santos (São Paulo) - was in the top 100 list of best ports in the world, in 2013, occupying the 41st position, thanks to a 6.2% rise in throughput in 2012 (Containerization International, 2014). Anecdotal evidence of bottlenecks in Brazilian ports is easy to find; for example, Credit Suisse (2013) notes "10-mile line of trucks waiting at gates to unload the crop and 200 ships waiting to load the cargo." While part of the growing infrastructure gap may be due to inadequate maintenance and intensification of use, the largest share of the gap is most likely due to a prolonged period of underinvestment relative to other countries.

Energy indicators are more favorable (Figure 9).[7] Per capita, electricity generation and consumption have more than doubled since the 1980s and coverage is near universal. However, electric power transmission and distribution losses have increased and now exceed 15% of electricity output. Moreover, the recent draught episode has underscored vulnerabilities from the high dependence on hydropower for electricity generation.

5. The WEF Survey captures the opinions of 14,000 business leaders around the World on a broad range of topics, including the quality of infrastructure. As such, qualitative infrastructure indicators are based on the aggregation of subjective perceptions. (For the methodology see: World Economic Forum - Methodology)
6. It is estimated that some 20 million of new vehicles were sold in Brazil since 2008.
7. Doing Business ranks Brazil in the top 20 based on affordability and the number of procedures and days it takes to obtain electricity.

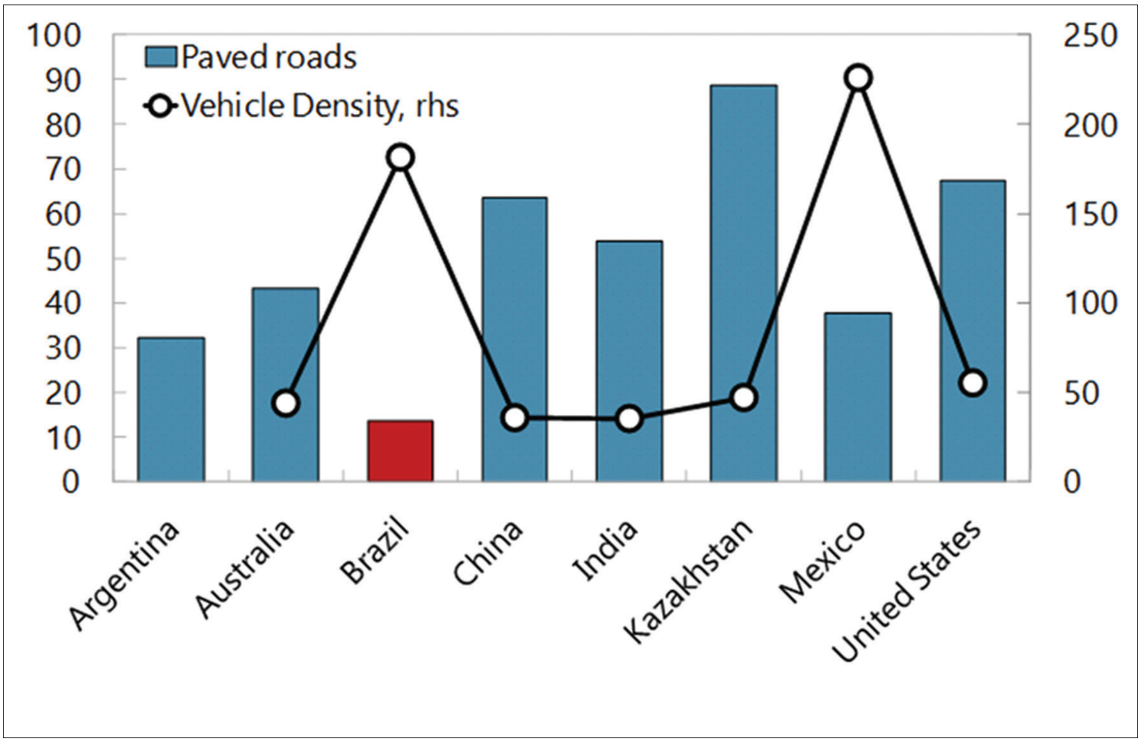

Figure 6. Paved roads and Vehicle Density (In percent of total roads and vehicles per km of paved road, respectively).
Source: World Development Indicators, The World Bank.

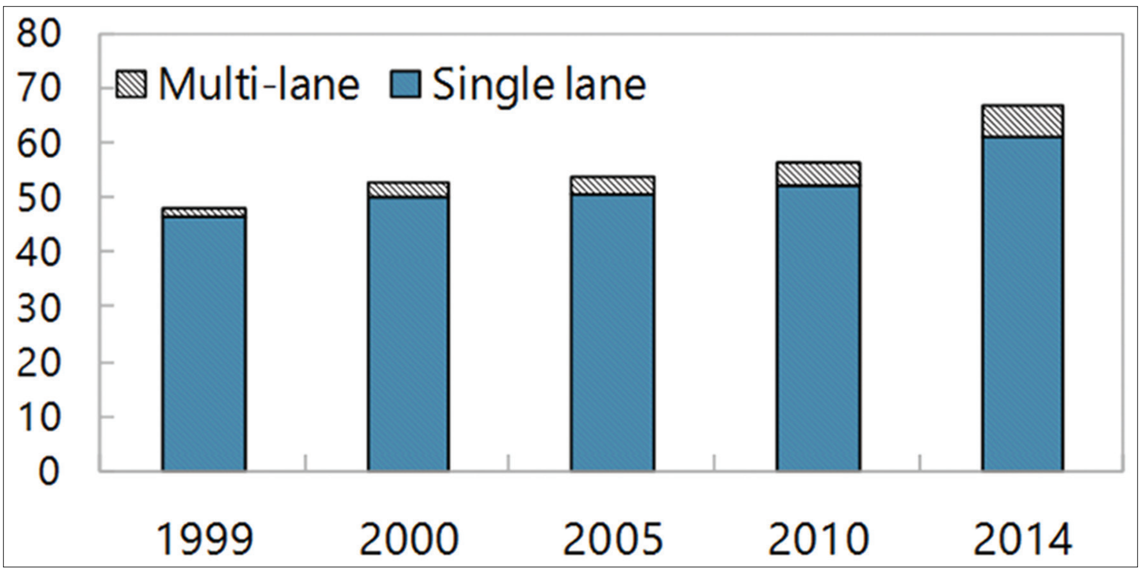

Figure 7. Federal paved roads (In thousands of kilometers).
Source: Departamento Nacional de Infrastructura de Transportes (DNIT) and Fund staff calculations

Brazil's infrastructure quality is also below the expected value for its income level, measured as per the capita GDP adjusted for purchasing power (Figure A3 in the Appendix). Among Brazil's export competitors, the distance from the average was larger only for Argentina. However, the overall result masks differences across sectors. Brazil's electricity supply and telecommunication infrastructure score close to the expected value for its income. In contrast, the quality of roads, railroads, ports, and airports was significantly below the predicted value, with the largest gaps in the road and port infrastructure.

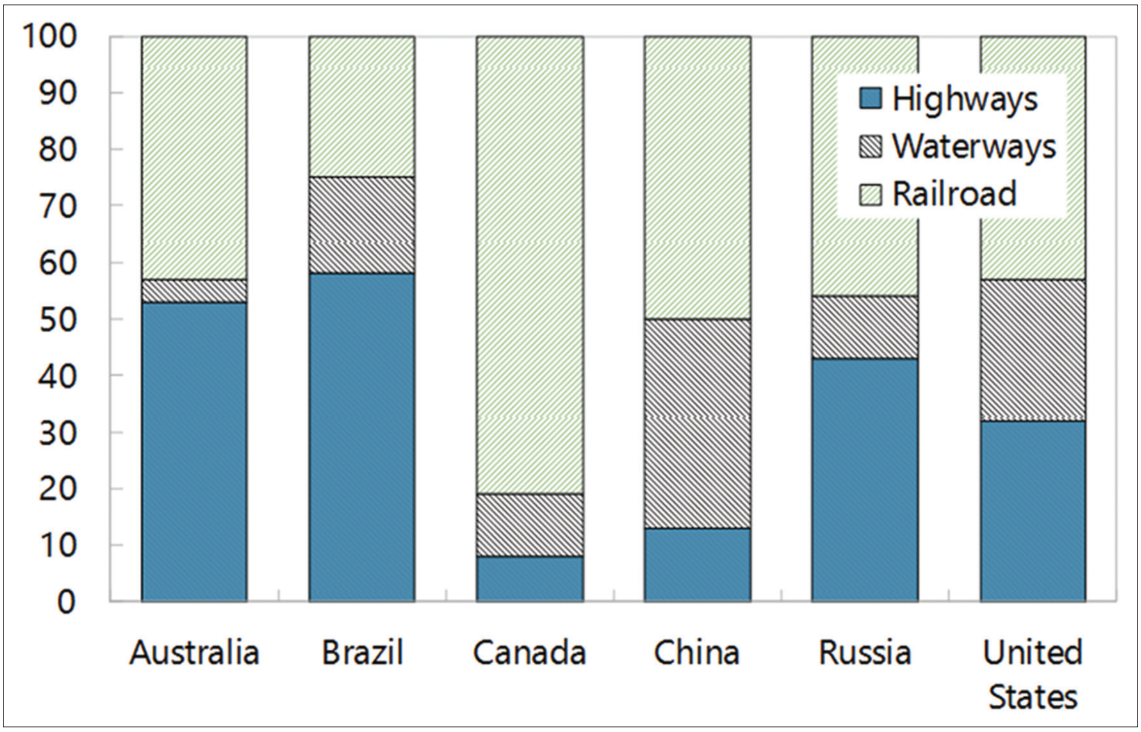

Figure 8. Share of Goods Transport (in percent).
Source: Credit Suisse with World Bank Data, 2013.

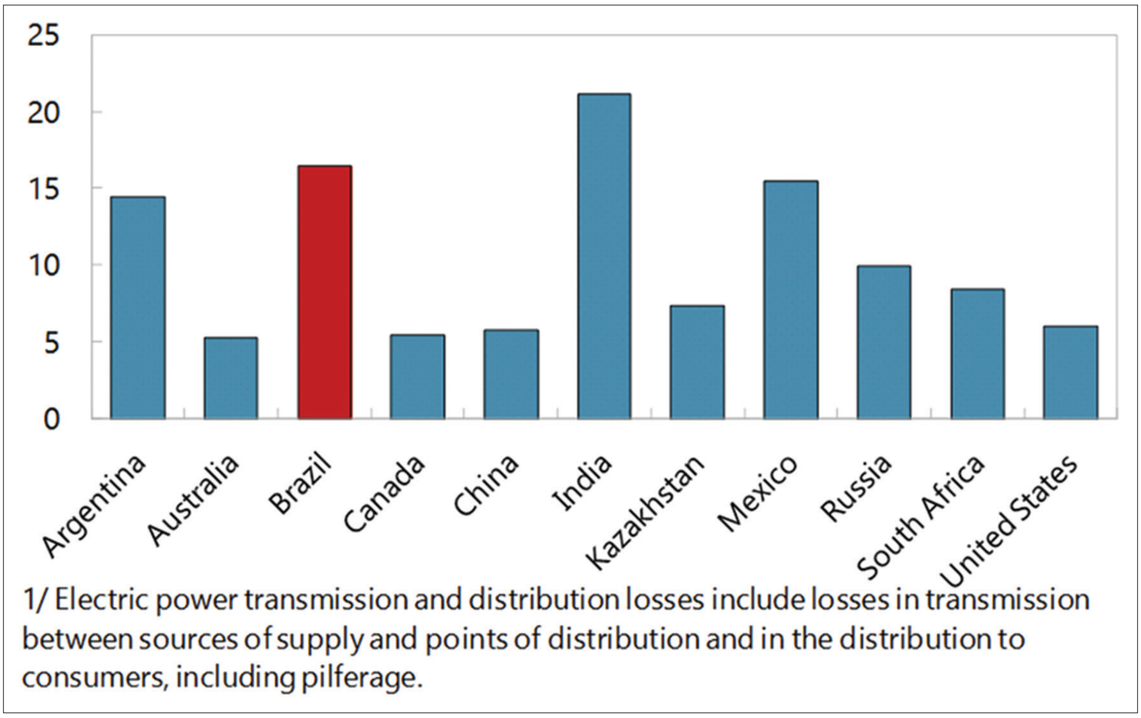

Figure 9. Electric power transmission and distribution losses (In percent of output) 1/1/Electric power transmission and distribution losses include losses in transmission between sources of supply and points of distribution and in the distribution to consumers, including pilferage.
Source: World Development Indicators, The World Bank.

3.2. Infrastructure investment trends

The infrastructure gap described above reflects a prolonged period of low infrastructure investment. Infrastructure investment in Brazil has dropped significantly from an average of 5.2% of GDP in the early 1980s to an average of 2¼% of GDP over the past two decades and slightly increased to around 2½% of GDP, in 2013 (Figure 10). While good and standardized infrastructure investment data, in particular for cross-country comparison is not available, different data sources confirm that for a couple of decades Brazil's infrastructure investment has fallen short of the levels observed in other Latin America and emerging market countries such as Chile, China, and India (Calderón and Servén, 2010; Frischtak, 2013). There are also important differences in the investment levels by sector. In particular, the electricity and telecommunications sectors continue to represent the bulk of infrastructure investment in Brazil, reflecting the participation of the private sector under the concessions scheme. By contrast, Chile has invested more in roads and distribution/supply of water and sanitation (Figure 11).

The decline in infrastructure investment in Brazil is mostly explained by a reduction in public infrastructure investment (Figure 12). The 1988 constitution reduced the pool of federal funds available for capital expenditures as it replaced sector-specific federal taxes earmarked to energy, transport, and telecommunications with non-specific state-level ones; raised transfers to sub-national governments; and earmarked revenues to certain current public expenditures. The fiscal adjustment effort carried out from 1999 limited the available fiscal space for public investment, due to the budgetary rigidities and mandatory current primary spending. Consequently, public expenditures allocated for infrastructure investment have remained subdued since then, despite initiatives aimed at prioritizing infrastructure investment such as the *Programa de Aceleração do Crescimento* (PAC), which was launched in 2007 by the Federal government with the goal of accelerating economic

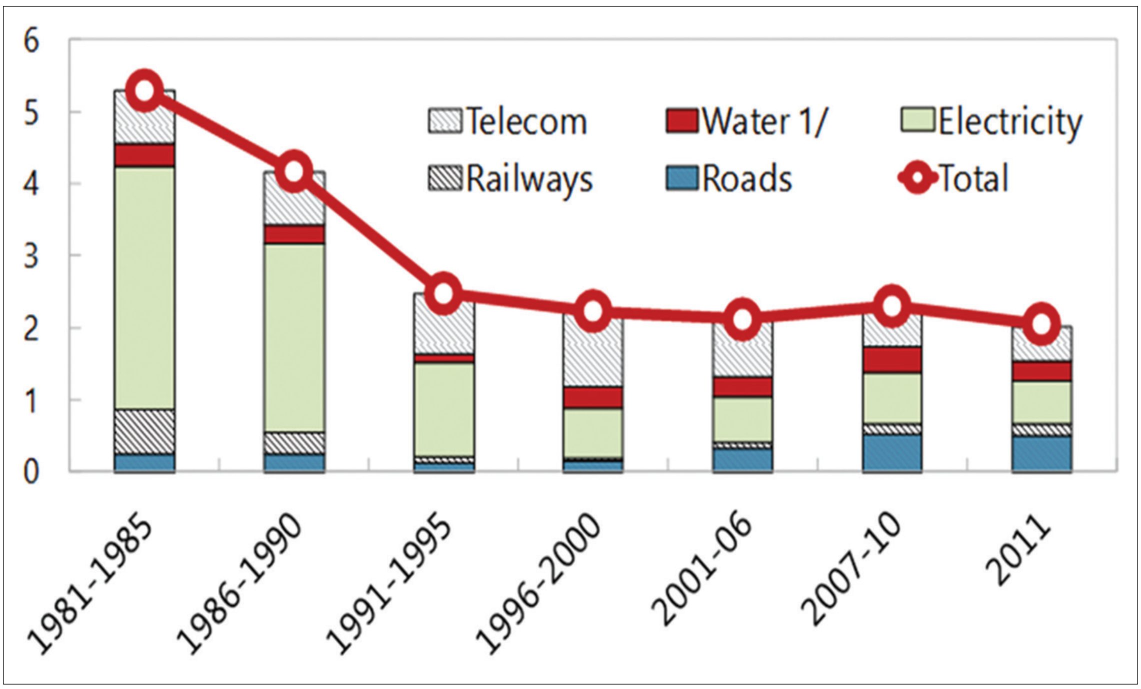

Figure 10. Brazil: Infrastructure Investment (In percent of GDP).
Sources: The chart shows data until 2006 from Calderón and Servén, 2010; and for the period 2007-2011 from Frischtak, 2013. Differences across databases are negligible. 1/ Includes also infrastructure investment in ports and airports.

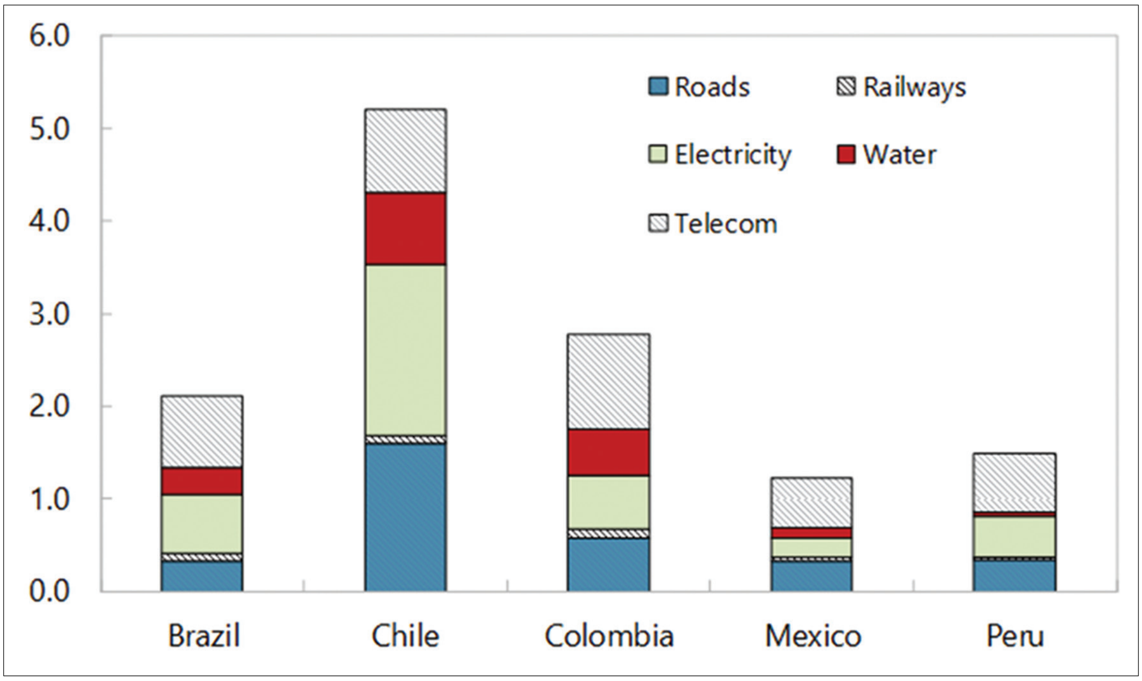

Figure 11. LA5: Infrastructure Investment, average 2001-2006 (In percent of GDP).
Sources: Calderón and Servén, 2010.

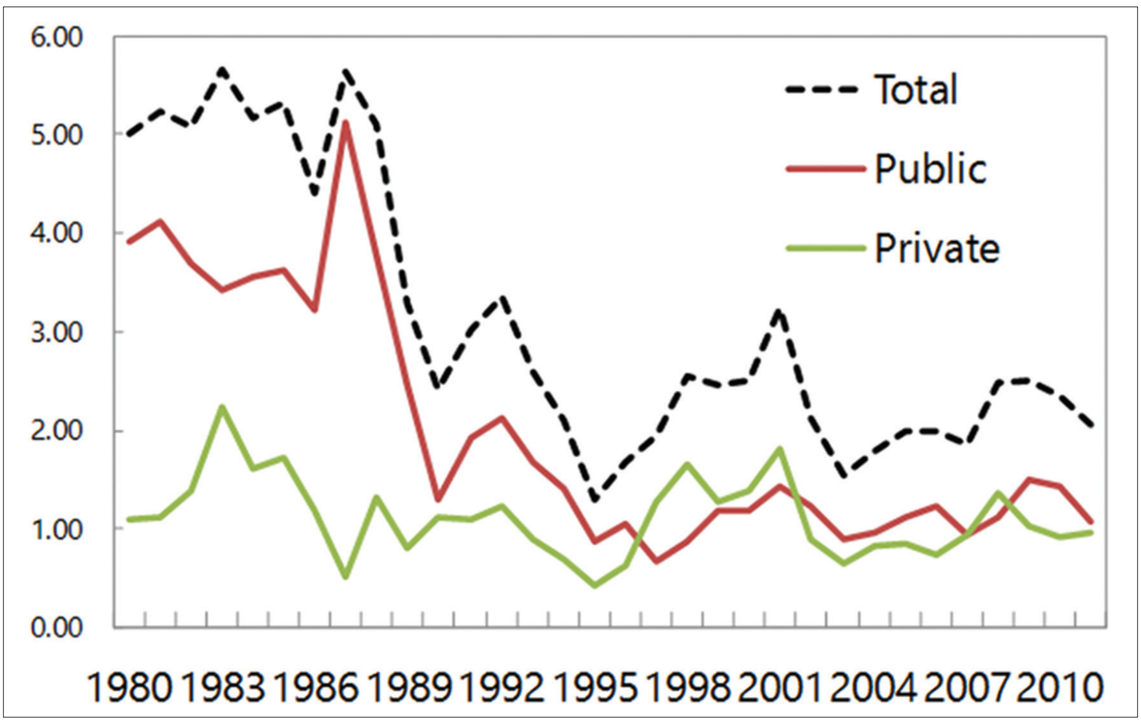

Figure 12. Brazil: Public and Private Infrastructure Investment (In percent of GDP)
Source: The chart shows data until 2006 from Calderón and Servén, 2010; and for the period 2007-2011 from Frischtak, 2013.

growth.[8] In 2013, about 75% of total investment for the general government was executed at the subnational level (Figure 13).

8. The PAC—excluding allocations to defense, education and the *Minha Casa Minha Vida* programs—amounted 0.5% of GDP in 2013, up from 0.3% of GDP in 2007.

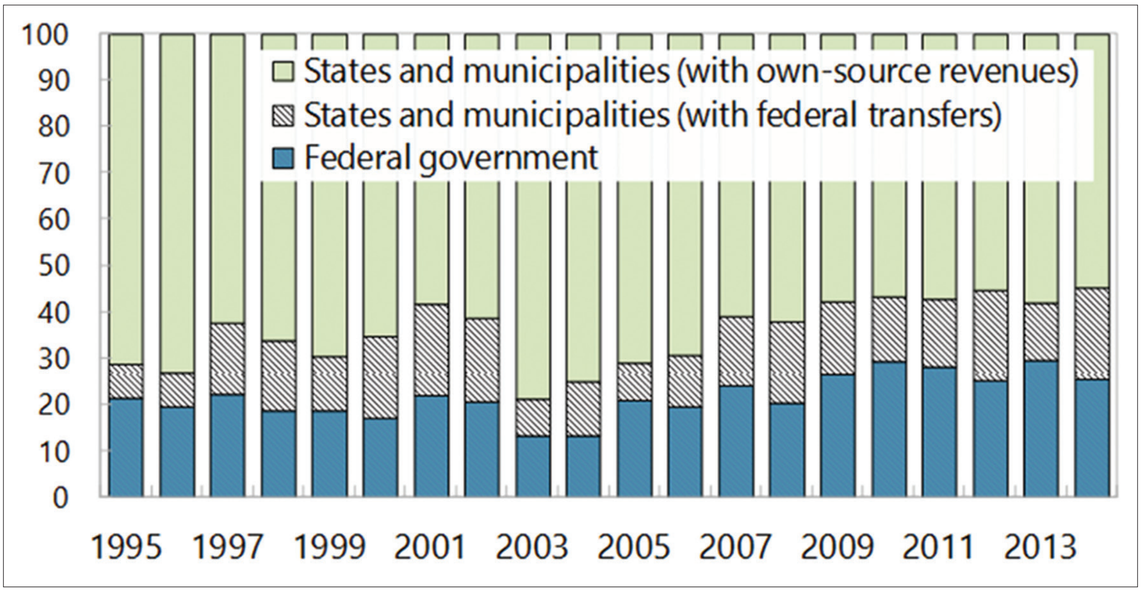

Figure 13. Brazil: Public Investment by Level of Government (In percent of total) 1/2.
Source: Ministry of Finance. 1/Excludes public enterprises. 2/Investment refers to the gross capital formation, and therefore, covers not only infrastructure investment.

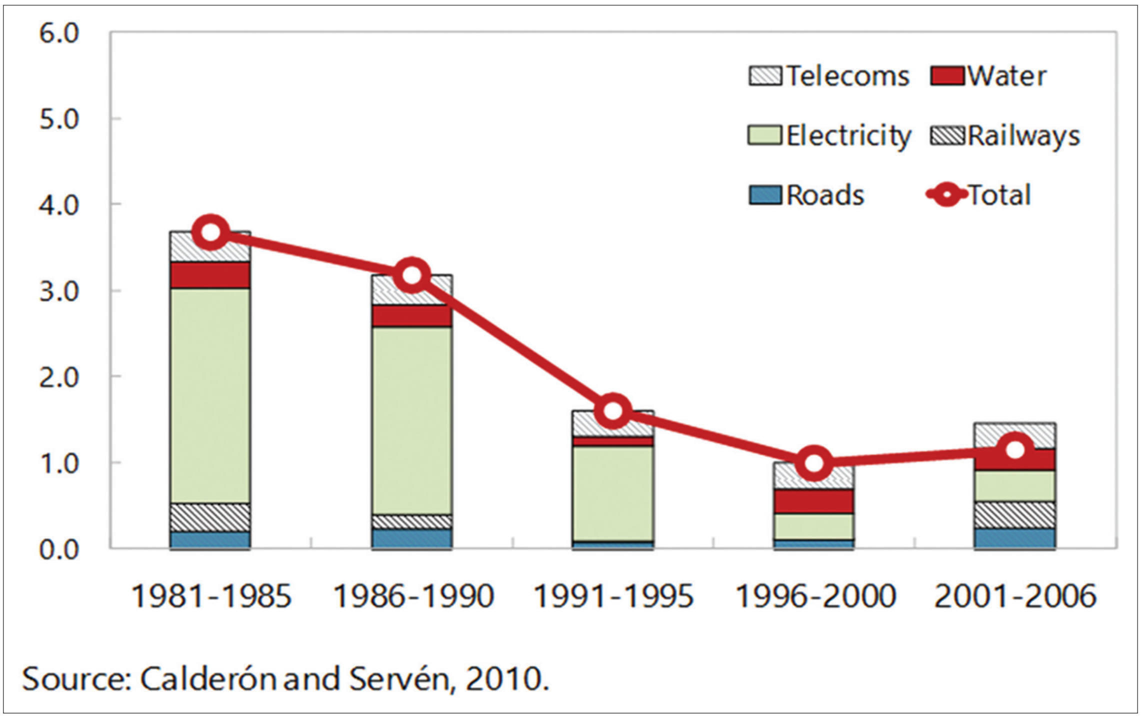

Figure 14. Brazil: Infrastructure Investment by Public Sector (In percent of GDP).
Source: Calderón and Servén, 2010.

Meanwhile, private sector investment has not filled the space vacated by the public sector (Figure 14). During the 1990s, privatization and concessions opened up key infrastructure sectors such as telecommunications, energy, and transport to private investment, but private investments have not been sufficient to compensate for the decline in public investment (Figure 15).[9] Private participation in

9. In contrast, in Chile, the private sector more than compensated for the fall in public expenditures since 1989, with a net positive impact on total investments (World Bank, 2007).

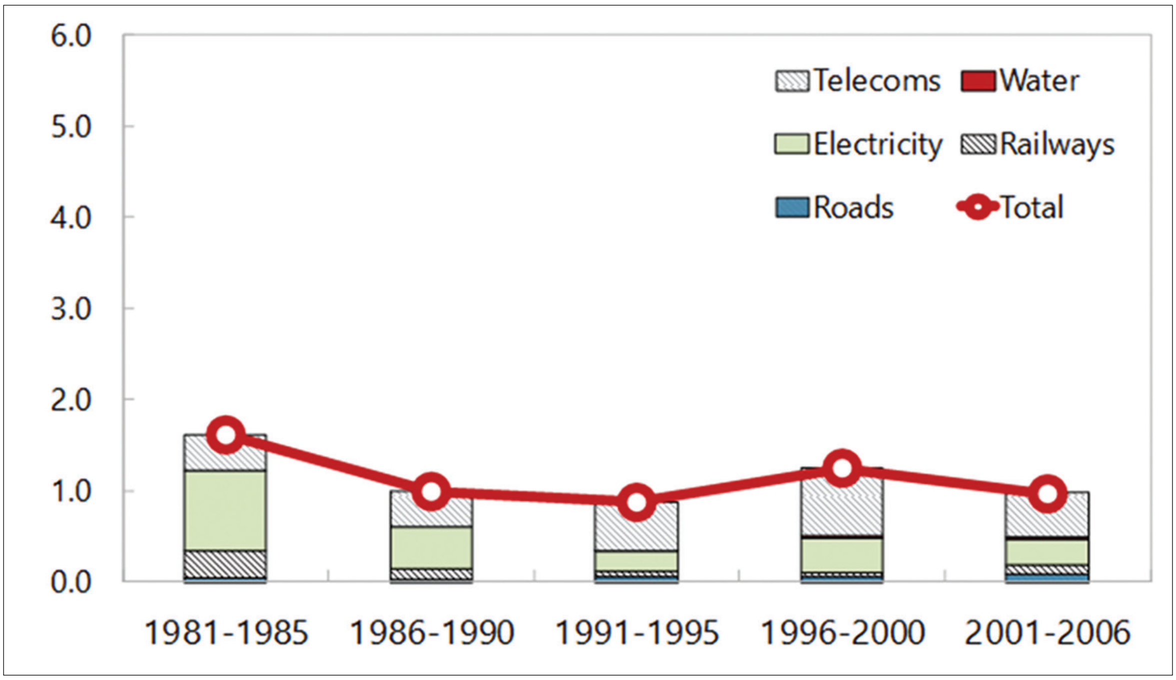

Figure 15. Brazil: Infrastructure Investment by Private Sector (In percent of GDP)
Source: Calderón and Servén, 2010.

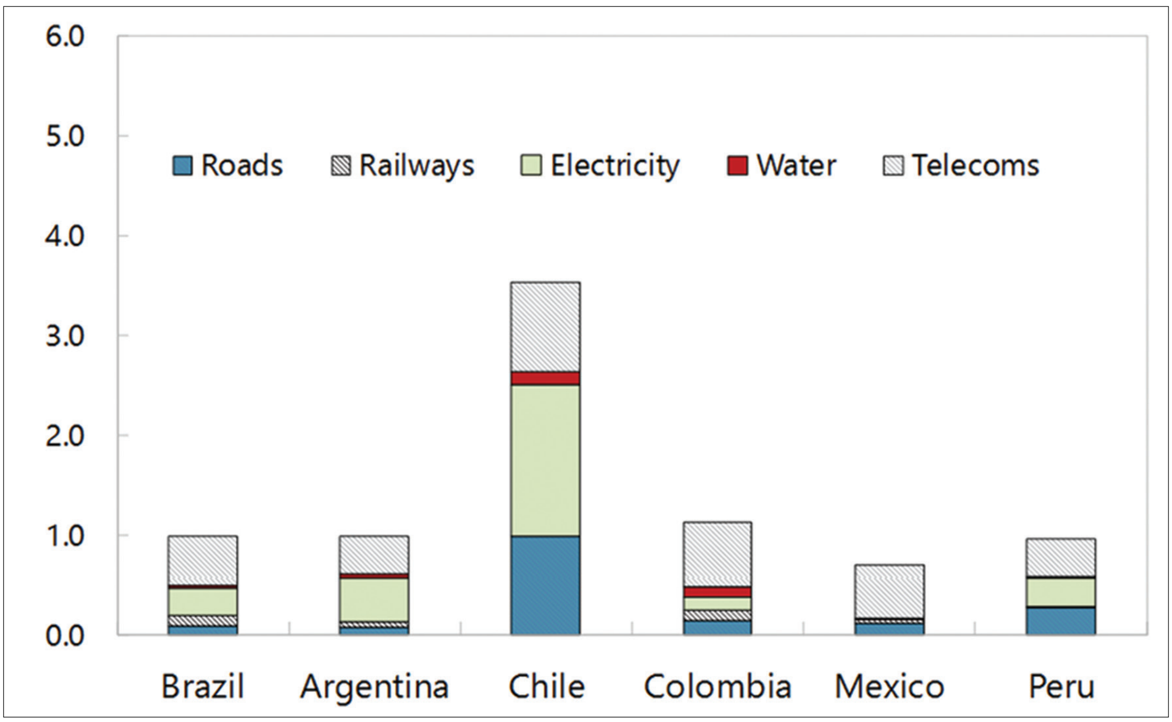

Figure 16. LA5: Infrastructure Investment by Private Sector, 2001-06 (Average, in percent of GDP)
Source: Calderón and Servén, 2010.

infrastructure in Brazil has been low in comparison with other Latin American countries, corroborating that the investment environment, including investment opportunities, and regulatory and institutional frameworks play a major role in determining overall infrastructure investment levels and therefore tackling the infrastructure gaps (Figure 16).

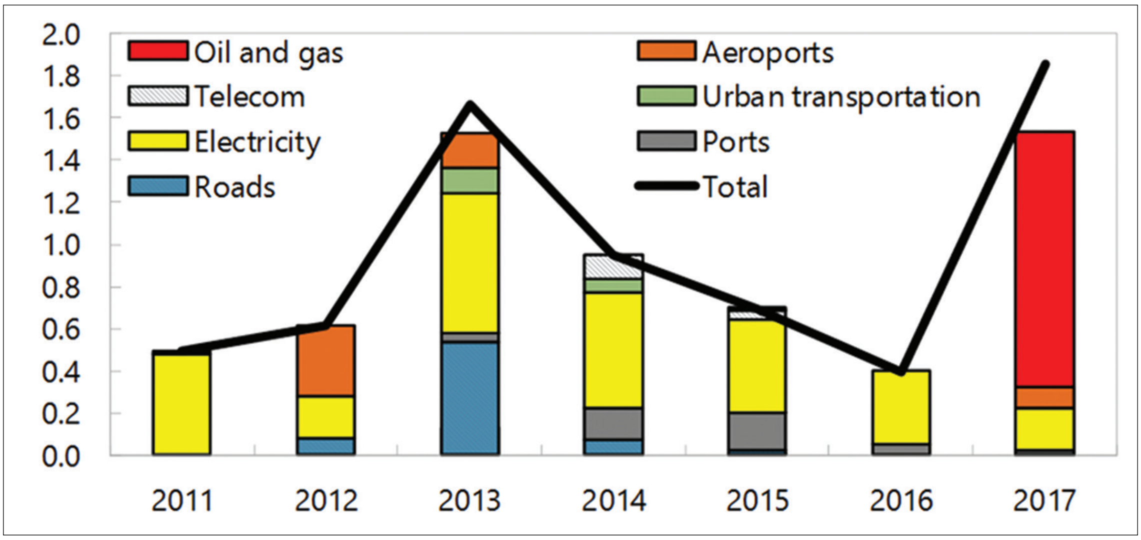

Figure 17. Brazil: Annual investments through concessions (awarded) (in percent of GDP).
Source: Secretaria de Acompanhamento Economico do Ministerio da Fazenda.

4. The role of the concession program

Brazil has been pursuing opportunities for concessions with the aim of filling infrastructure gaps. The concessions can bring in private sector expertise and efficiency and also help bypass some of the challenges faced by public investment - such as contracting obstacles - and therefore speed up the process of investment. The first phase of concessions in Brazil took place during the late 1990s. Through privatization, the private sector became the main operator in telecommunications, electricity, and railways. During this period, concessions were also granted for about 5,000 km of federal roads. It is worth noting that private sector investment through concessions in the telecommunications and electricity sectors helped eliminate the infrastructure gaps and improved Brazil's ranking in these areas, as mentioned earlier in the text.

During the period 2011−14, concession projects were auctioned mainly in the areas of transport and energy, with an associated total investment estimated at R$181 billion, split between airports, ports, roads, urban transportation, as well as power generation and transmission (Figure 17). The infrastructure concession program faced a decline in interest in the following 2 years, due to the uncertainty surrounding the probe into corruption concerning Petrobras, as several of the largest construction companies have been involved in the investigation and saw their access to funding diminished. The government has since then made stride in attracting investors by developing a new debenture model featuring income tax incentives, payment of interest throughout the existence of the project, and premium quality guarantee on the debt principal. Brazil has lifted the estimated returns on infrastructure concessions to between 9 and 13% to make projects more appealing to investors. Domestic-content rules were also relaxed in the oil and gas sector spurring renewed interest in the energy sector.

5. Conclusion

From the analysis of quantitative and qualitative indicators and our own econometric exercise, we find evidence of infrastructural inadequacies in Brazil. The infrastructure gap has grown over time due to the low public and stagnating private investment across all sectors over the past decade or so. Such an infrastructure gap has become a major obstacle to growth as it limits domestic integration and hinders external competitiveness. Yet, infrastructure gaps may underestimate true needs. Past infrastructure demand in Brazil may not be a good predictor of the population (and businesses) needs because the pervasive bottlenecks in provision may have caused some self-imposed rationing or discouraged utilization. Moreover, infrastructure investment must have a forward-looking orientation, because it must support achievement of successive higher levels of development and not resort to meeting exclusively current needs. Making gains in spatial and social integration by expanding the transport network and improving access to basic infrastructure services in an equitable way will remain paramount for Brazil's development for many years to come.

The government's concession program has the potential to step up and speed up infrastructure investment; but by itself, it may not be enough to boost potential growth significantly. Other reforms to eliminate "soft" bottlenecks, including reforms to enhance governance standards, will have to accompany efforts to fill the infrastructure gap to make the business environment more attractive to foreign and domestic investments in an environment where regional competition to attract investments is set to intensify.

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APPENDIX

Appendix. Infrastructure Indicators

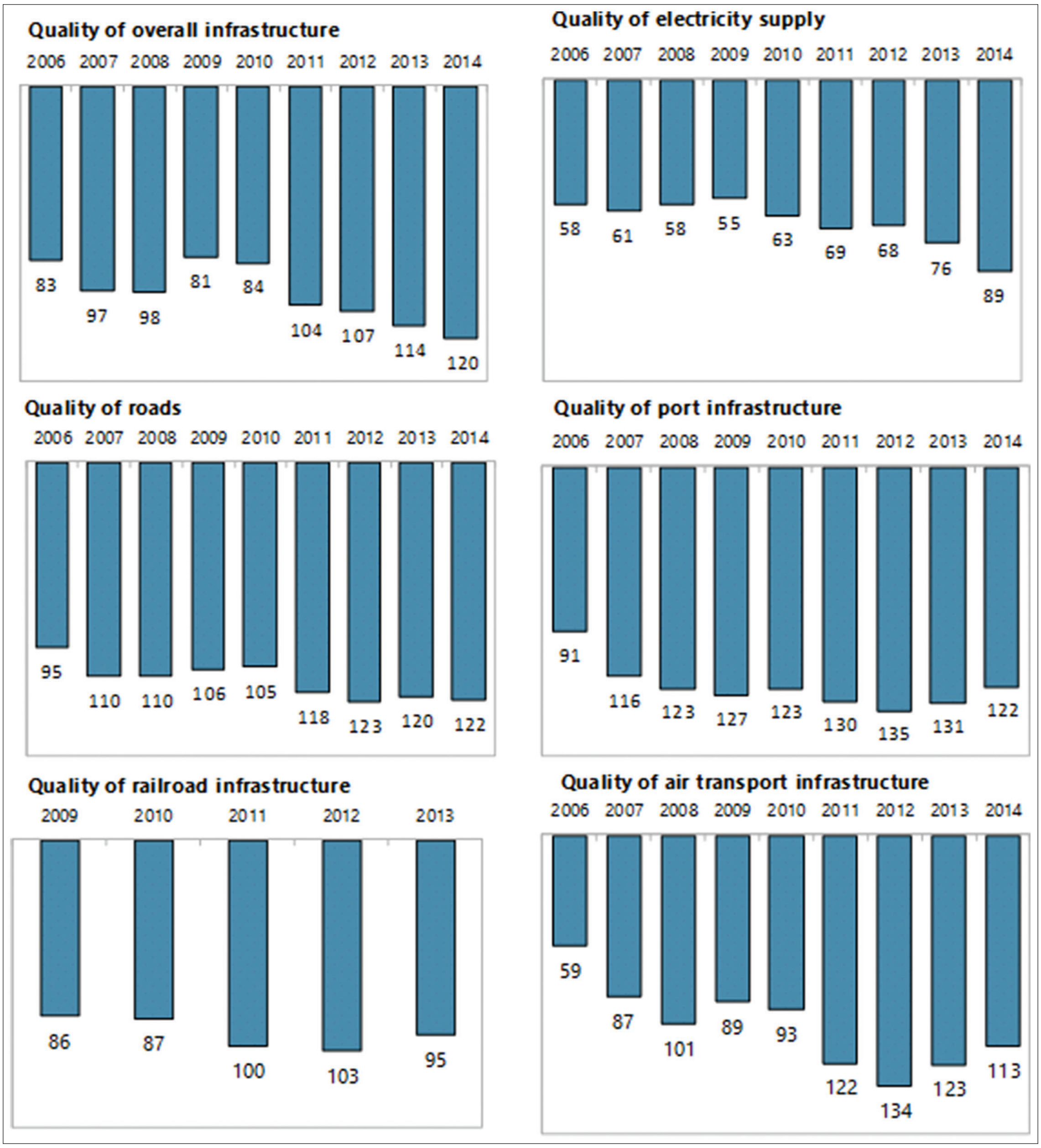

Figure A1. Brazil: Infrastructure Quality (Rank out of 144).
Sources: World Economic Forum.

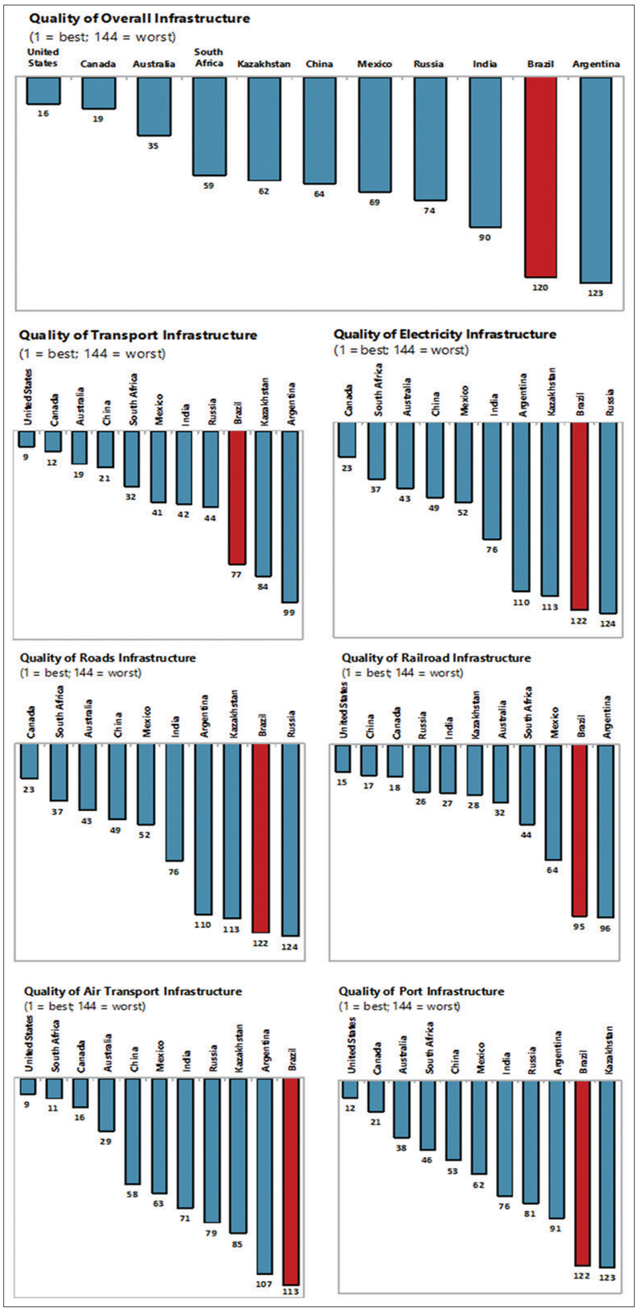

Figure A2. Infrastructure Quality in Brazil and Export Competitors, 2015.
Sources: World Economic Forum.

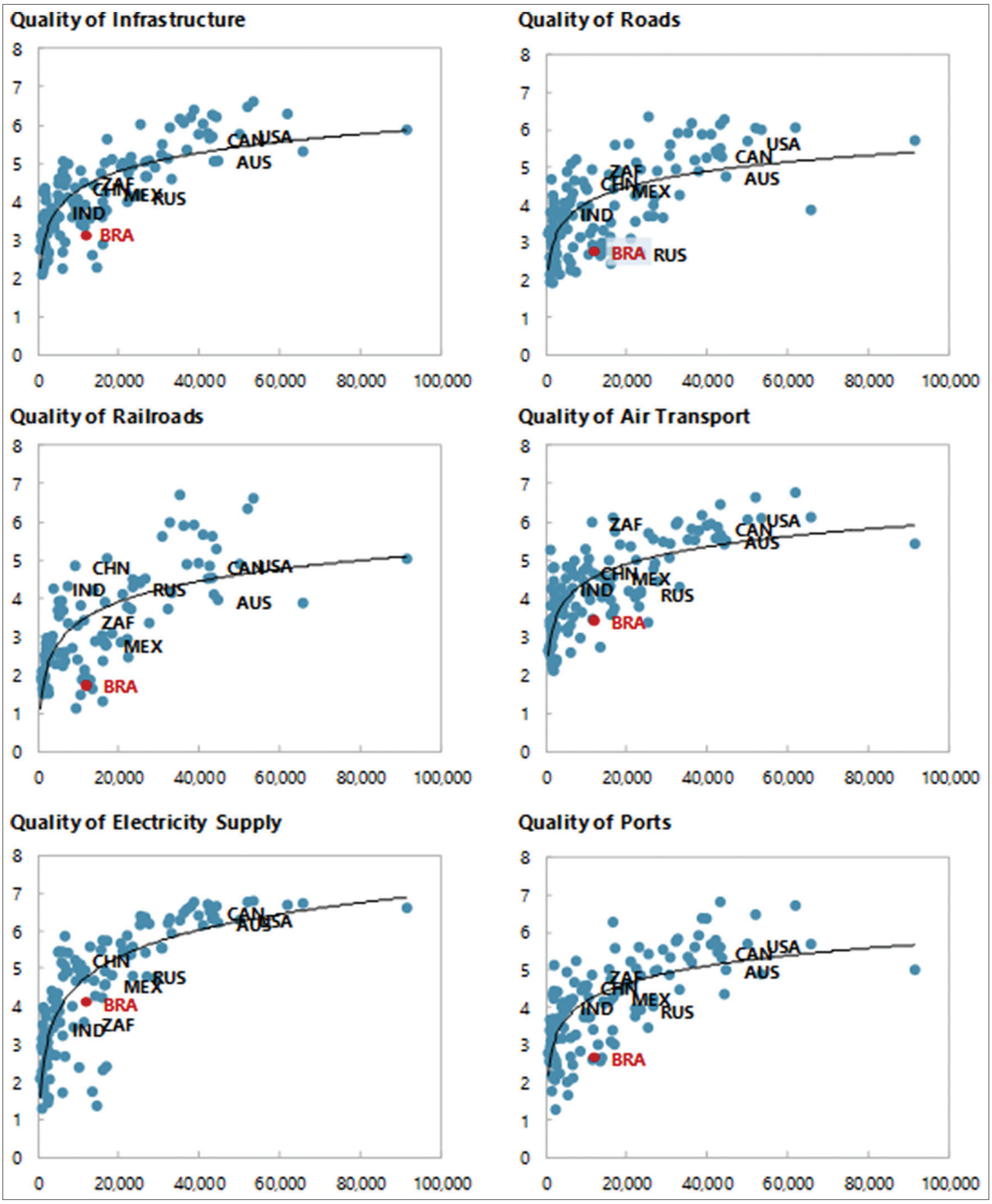

Figure A3. Infrastructure Quality and Income (Y-axis: quality of infrastructure, 2014, 10 = best; X-axis: GDP per capita, PPP dollars, 2012.

Sources: World Bank WDI; and WEF; and Fund staff estimates