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POTENTIAL EFFECTS OF SCALING-UP INFRASTRUCTURE IN PERU : A GENERAL EQUILIBRIUM MODEL-BASED ANALYSIS

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Abstract

This study assesses the potential economic impacts of investments dedicated to filling infrastructure gaps in Peru. By using a national database at the firm level, we start by empirically estimating the positive externalities of Peruvian infrastructure on private activities' output. In the second step, these estimates are introduced in a dynamic Computable General Equilibrium model used to conduct counterfactual simulations of various investment plans in infrastructure over a 15-year period. These simulations show to what extent scaling-up infrastructure could be a worthwhile strategy to achieve economic growth in Peru; however, they also show that these benefits depend on the choice of funding schemes related to such public spending.

Keywords: Infrastructure, Productivity, CGE model, Peru
JEL classification: H54, O47, D58

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1. Introduction

Over the last decade, public investments in infrastructure have significantly increased in Peru while the country benefited from the windfall revenues of the commodity prices' boom. However, current levels of Peruvian infrastructure remain insufficient with major deficits areas including economic assets such energy, telecommunications, and transportation facilities or social infrastructure such water and sanitation, health, or education (AFIN, 2015; ECLAC, 2015a; Sánchez et al., 2017). Although maintaining a high level of investments dedicated to filling these gaps might be difficult for the next years with the likely adverse fiscal consequences of the end of the commodity super cycle (Werner and Santos, 2015), many studies advocate that such investments should not be neglected despite these new unfavourable conditions. In the short term, they might represent an alternative engine for growth; in a longer term, they might also contribute to breaking some bottlenecks often cited as impediments to development of this country (Kohli and Basil 2011; IMF, 2014, CEPLAN, 2011, 2015; IMF, 2016; Fay et al., 2017; Sánchez et al, 2017). In this context, the main objective of this study is to value the potential effects that investing in scaling-up infrastructure could generate on Peruvian economic performance.

We follow many studies in the economic literature which consider that public infrastructural assets are critical features for developing countries such as Peru and which highlight various direct or indirect links between infrastructure stocks (or their variations) and growth or other development outcomes (for comprehensive surveys, see e.g. Estache, 2006; Romp and de Haan, 2007; Straub, 2008, 2011). However, while the majority of this literature uses partial equilibrium or macro level empirical approaches, we preferred to use a dynamic Computable General Equilibrium (CGE) model to numerically simulate the potential impacts of various multi-annual public investment plans in infrastructure in Peru. According to our knowledge, such an applied economy-wide Walrassian framework has never been used for these purposes in this country (see e.g. IMF, 2016 for a survey) even if it can be a useful complement to partial equilibrium constructs or pure empirical analyses. By addressing the complexity of a market-driven economy and capturing various feedback effects among prices, supply, demand, and income, CGE modelling can provide a substantial understanding of the multiple micro-macro links through public spending on new infrastructure may affect an economy. In this spirit, in addition to the common short-term multiplier or crowding-on effects usually captured in models, some recent CGE studies drawing on growth theory have for instance introduced the positive externalities that public spending on new infrastructure can generate on private activities' output (see e.g. Rioja, 2001; Adam and Bevan, 2006; Estache et al., 2012; Cockburn et al., 2013; Boccanfuso et al., 2014; Borojo, 2015; Chitiga et al. 2016; Mbanda and Chitiga, 2017). However, these studies have rarely valued these critical parameters accurately and often take them from the extant empirical literature which has considerably grown up since the seminal works of Aschauer (1989) or Munnell (1992). But estimates display large variations across studies due to differences in the definitions of infrastructure; type of output measures used as dependent variables; econometric specifications and sample coverage; or whether endogeneity and stationarity concerns are properly addressed (see e.g. Bom and Ligthart, 2014 or Sanchez et al., 2017 for a global review and Vasquez, 2008, Urrunaga and Aparicio, 2012, or Machado and Toma, 2017 for Peruvian specific analyses). Accordingly, following this research stream, we introduce such externalities in our CGE model for Peru but we make our own estimates of these potential supply effects of infrastructure by using a national firm database provided by the Peruvian National Statistical Institute (INEI).

Section 2 details the main features of the dynamic CGE model and section 3 describes the empirical strategy that we use to quantify the private output elasticities of public infrastructure in Peru. Section 4 details the results of simulations of various scenarios of public investment plans dedicated to scaling-up infrastructure in the country over a 15-year period. Finally, section 5 concludes and provides suggestions for further research.

2. General equilibrium modelling framework

Our CGE model is relatively aggregated and features one household, one government agent, eight private activities, and one non-merchant activity. This model is mainly adapted from the PEP 1-t model of Decaluwé et al. (2013) and relies on fairly standard assumptions of dynamic general equilibrium analysis (equations and variables are provided in the Appendix).

Regarding the within-period specifications of the model, on the supply side, each producer maximises its profit by combining skilled and unskilled labour with fixed capital (Eq. 1–6). On the income side, each agent receives factor revenues on the basis of its initial endowments and transfer income from other agents (Eq. 7–19). On the demand side, intermediate consumption is driven by fixed technical coefficients in production processes (Eq. 24); households' consumption follows a linear expenditure system function derived from utility maximisation behaviours (Eq. 26); government's consumption is supposed to be exogenous; and demands for investment purposes are derived from nominal investments and distributed among commodities in fixed shares (Eq. 20-23). On the product's market, each good can be sold locally or abroad given a Constant Elasticity Transformation specification (Eq. 27–30). The domestic goods are assumed to be imperfectly substitutable with imported products, given an Armington specification (Eq. 31–33). Prices of domestic goods are determined endogenously to equilibrate supply and demand (Eq. 39–40). On the labour market, the skilled and unskilled overall labour forces are fixed, and workers can flow freely across all activities with wage rates determined endogenously (Eq. 41–42). Finally, nominal investments are savings driven on the capital market, and the nominal exchange rate is chosen as the numeraire for the economy (Eq. 44–45).

Regarding the between-period specifications of the model, we consider a dynamic recursive framework which means that agents' behaviours are based on adaptive expectations rather than on forward-looking expectations. A main specification pertains to the accumulation of capital in each activity (Eq. 55), which reflects an exogenous depreciation rate and the volume of new capital installed as determined in the preceding period. In the public sector, the latter is supposed to be given. In private activities, it is derived from an investment demand function and allocated in a putty-clay fashion across sectors in accordance with returns to investment (Eq. 34–38).

How we introduced infrastructure topics in the model deserves more attention. Following recent CGE studies (e.g. Estache et al., 2012 or Boccanfuso et al., 2014), we linked in a Hicks's neutral manner the total factor productivity of Peruvian private activities to the stocks of public infrastructure in the country (Eq. 1 and 56). For a given period t, the value added of each private activity is derived from a standard Cobb-Douglas technology combining labour and capital but also depends on a parameter which reflects the supply effect of infrastructure on the activity's performances. This parameter is time-variant and can increase with exogenous public investments dedicated to scaling-up infrastructure.

On these bases, the model is used to generate time paths for the evolution of Peruvian economic variables by numerical simulation of successive general equilibriums under different scenarios of multi-annual investment plans in infrastructure. For a given period *t*, a general equilibrium of the model is defined by the vector of prices and wages for which demand equals supply in all markets simultaneously. All things being equal, such investments are expected to produce three combined effects. First, by increasing the demand for the activities which produce the capital goods required for scaling-up infrastructure, they could generate a multiplier effect on the economy and, therefore, upward pressure on demand and prices on product markets. Second, given the savings-investment constraint which drives the capital market's equilibrium in the model, and which thus determines how much savings are taken up by public investment, they could generate a crowding-out effect for other investments for non-infrastructural purposes. Third, by changing the nature of production processes in private activities in a Hicks's neutral manner, they finally could also generate a supply effect leading to productivity increases, capital rental rate variations (and therefore to re-allocation of private investments across activities), and producer price reductions.

To define an initial general equilibrium of the economy and to calibrate the CGE model parameters, we used Peru's 2014 Social Accounting Matrix, the most recent data available for the country (Ministry of Production, 2016). When such calibrations were not possible, we obtained the parameters from extant literature, including CGE models that have been established for Peru. However, the calibration of the production functions of private activities deserves more attention. Because of their critical role in the model, we econometrically estimate their parameters.

3. Estimates of private output contributions of public infrastructure in Peru

In the economic literature, most of the analyses use a function primal approach to estimate the effects of exogenous variations of infrastructure on activities' productivity and consider the stock of infrastructure as an additional input in production functions at the aggregated or sector levels. Other studies use a dual approach by estimating a cost function which threats public infrastructure as an unpaid factor of production. A few other studies use non-parametrical models considering non-linearities in the functional relationship of the production technology (see e.g. Bom and Ligthart, 2014). Consistent with our macroeconomic CGE modelling, we use a primal approach at a disaggregated sector level. Data for economic activities are found in the national firm database created by the INEI from 2004–2015 on the bases of its annual economic survey (*Encuesta Economica Annual*, EEA). From the statements of each firm recorded in this survey (almost 60,000 firms), we determine their belonging sector, value added, labour force, and capital stock. For the latter, we use two alternative approaches, specific to small and medium to big firms. For small firms, the capital stock is proxied by the total fixed assets as reported on their general balance sheet. For a medium to big firm, which tends to include financial investments not involved in the productive process as fixed assets, it is proxied by the value of the stock of equipment.

On these bases, for each firm i, pertaining to each activity j, we assume a sector-specific production technology with a value added at time t following a Cobb-Douglas specification:

$$(i)\ \ va_{i,t} = \theta_{i,t} A_{i,t} l_{i,t}^{\alpha_j} k_{i,t}^{1-\alpha_j}$$

In equation (i), $va_{i,t}$, $l_{i,t}$, and $k_{i,t}$ are, respectively, the value added, labour, and capital of each firm i, and all are measured in monetary units except for the labour stock (measured as the number workers). Although value added and production factors are endogenously determined, the latter are supposed to be exogenously determined according to the wages and rental rates on labour and capital markets. In our production function specification, $A_{i,t}$ represents the firm specific production scale parameter within activity j. To better model firms' production scale, we consider the potential productivity gains that result from urban agglomeration as motivated by Melo et al. (2009) and Eberts and McMillen (1999), among others. Thus, for a given firm of sector j, we assume $A_{i,t}$ to be a function of the urbanisation rate (calculated by the INEI as a function of the population density of a given region) at the firm's headquarters.

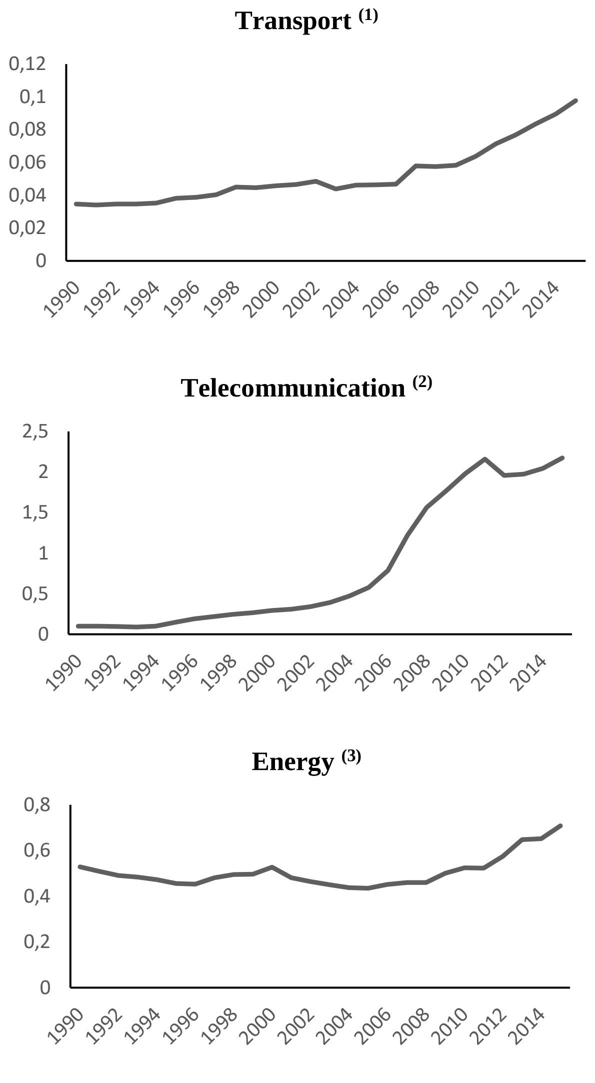
$$(ii)\ \ A_{i,t} = e^{a_j urb_{i,t}}$$

Finally, $\theta_{i,t}$ reflects the firm specific supply effect of infrastructure on the activity's performances. Similar to the macro CGE model, it is supposed to be a function of the variation of the stocks of the various public infrastructure available to the *i-th* firm within activity j:

$$(iii)\ \ \theta_{i,t} = \prod\nolimits_{Infr} \left[\frac{Kinfr_{i,t}^{infr}}{Kinfr_{i,t-1}^{infr}}\right]^{\varepsilon_j^{infr}}$$

To define the stocks of infrastructure ($Kinfr_{i,t}^{infr}$), we built indicators by focusing on three types of assets which have been identified as major deficits areas in Peru (see e.g. AFIN, 2015 or Sánchez et al., 2017) and are generally perceived as "core" infrastructure that facilitate and support economic activity (see e.g. Torrisi, 2009): *Transport*, which connects producers and consumers to markets; *Energy*, which provides essential inputs for production; and *Telecommunication* systems, which facilitate the exchange and dissemination of information and knowledge. As proxy measures for each category of infrastructure, following Canning (2007), Calderón and Servén (2010), Vasquez (2012), or Calderón et al. (2014), we use physical measures rather than monetary measures (e.g. public investment flows), therefore retaining the following: for *Transport*, the road density as measured by the total length of the paved road network (in km) relative to the country's total agricultural land (in sq. km); for *Telecommunication,* the telephone density as measured by the total number of phone lines (fixed and mobile) per 1000 workers; for *Energy*, the electricity availability (in megawatts per 1000 workers). On these bases, Figure 1 shows the evolution of these indicators over the 1990–2015 period in Peru. As expected, we observe that infrastructure development was somewhat neglected in the 1990s in the context of the structural adjustment programmes but has experienced a recovery since the 2000s linked to renewed economic growth.

FIGURE 1 - Evolution of Peruvian infrastructure indicators from 1990–2015



Notes: (1) Paved road network in km relative to agricultural land in sq. km; (2) Number of fixed and mobile lines per 1000 workers; (3) MW per 1000 workers

Sources: For 1990–2000, data are obtained from Vasquez (2012). For 2001–2015, data are obtained from MTC (2017) for the road network, OSIPTEL (2018) for phone lines, and MINEM (2017) for electricity availability; for labour force and total agricultural land (in sq. km), data are obtained from the World Bank (2018).

To estimate the parameters of interest, namely, the externality parameters ε_j^{infr}, we express the value-added production function in terms of capital units. From equation (i), (ii), and (iii):

$$(iv)\ \ y_{i,t} = e^{a_j urb_{i,t}} \left[\frac{Kinfr_{it}^{Telec}}{Kinfr_{it-1}^{Telec}}\right]^{\varepsilon_j^{Telec}} \left[\frac{Kinfr_{it}^{Transp}}{Kinfr_{it-1}^{Transp}}\right]^{\varepsilon_j^{Transp}} \left[\frac{Kinfr_{it}^{Energ}}{Kinfr_{it-1}^{Energ}}\right]^{\varepsilon_j^{Energ}} \tilde{l}_{i,t}^{\alpha_j}$$

With $y_{it} = va_{i,t}/k_{i,t}$ and $\tilde{l}_{i,t} = l_{i,t}/k_{i,t}$

Regarding potential endogeneity concerns for the infrastructure's indicators, although the literature treats some infrastructure as endogenous in one-level GDP regressions (e.g. Waverman et al., 2005 or Qiang et al., 2009 for telecommunications), we assume that in our multilevel setup, the i-th firm' value added has a negligible effect on each aggregate infrastructure's indicator which is thus considered here as exogenous. For the labour to capital ratio ($\tilde{l}_{it}$), things are different. Although the EEA pretends to gather information on firms across time, the resulting panel of firms ends up being highly unbalanced, making any fixed-effects approach unfeasible for addressing endogeneity concerns.

Thus, we followed an instrumental variables (IV-GMM) approach (Ackerberg et al. 2007). As usual, the instrumental variables must determine the labour to capital ratio and must not be related to y_{jt} by channels other than l_{jt} itself. Thus, we employ two natural instruments (Aschauer, 1989, Calderón and Servén, 2004). First, under the assumption of perfect competition in the inputs' markets leading to exogenous wages and interest rates, we use a cost of capital proxy given by the average interest rate in foreign currency for the Peruvian financial market. Such a capital cost is calculated from financial market data which reports this cost according to the firms' size indicator calculated by the Peruvian Central Bank by considering assets (sales) and liabilities (debt stock). Second, we use a lagged labour indicator (l_{it-1}) collected by the EEA survey along with the current year information. Because the infrastructure indicators are calculated at the regional level, we perform the statistical inference based on the clustered standard error at the regional level.

Table 1 presents the results of the externality parameters' estimates. *Energy* infrastructure appears to be non-significant in every economic sector. This finding may be explained by a saturation effect, with returns to investment decreasing sharply once the required energy supply has been met. Urrunaga and Aparicio (2012) provide similar estimates at the regional level of about 0.10.

TABLE 1 – Estimates of public infrastructure externalities on private activities' output in Peru

	Agro-industry	Commerce	Construction	Energy & Water	Oil & Mining	Manufacture	Fishing	Other Services
log (L/K)	0.291***	0.209***	0.234***	0.275***	0.201***	0.248***	0.267***	0.254***
	(0.02)	*(0.01)*	*(0.02)*	*(0.04)*	*(0.04)*	*(0.01)*	*(0.05)*	*(0.01)*
Δlog(Inftelecom.)	1.612***	1.984***	0.584	0.878	2.624***	1.747***	0.782	0.164***
	(0.39)	*(0.07)*	*(41.71)*	*(125.42)*	*(0.69)*	*(0.13)*	*(41.15)*	*(0.02)*
Δlog(InfEnergy)	8.33e-32	1.24e-16		0.0915	0.252		0.560	0.0520
	(0.00)	*(0.00)*		*(18.30)*	*(42.00)*		*(20.74)*	*(8.67)*
Δlog(InfTransport)	0.740***	0.564***	0.438***	0.479		0.707***	0.436	0.731***
	(0.22)	*(0.05)*	*(0.15)*	*(21.77)*		*(0.08)*	*(33.53)*	*(0.07)*
Urbanisation rate	2.912***	2.858***	3.371***	2.827***	2.356***	2.741***	2.487***	3.276***
	(0.34)	*(0.09)*	*(0.26)*	*(0.65)*	*(0.61)*	*(0.15)*	*(0.60)*	*(0.11)*
F-stat (weak instruments)	352.92	6579.70	603.01	65.72	140.51	3522.98	157.00	3932.55
p-value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N	1215	18256	1675	278	272	9607	825	10788
R-sq	0.143	0.0807	0.167	0.507	0.118	0.117	0.309	0.146
MSE	1.522	2.365	2.782	2.637	2.083	1.468	2.411	2.672

Note. Bootstrap standard errors clustered at the regional level in parenthesis. * p<0.05, ** p<0.01, *** p<0.001. Energy elasticities in the construction and oil & mining sectors and transport elasticity in the oil & mining sector were constrained to zero.

Although the estimates were significant, they were estimated with respect to regional economies and corresponded to a period (1980–2009) where energy supply was a binding constraint to economic growth. By contrast, the *Transport* externality parameter tends to exhibit significant results ranging from 0.44 to 0.74, and all are statistically significant except for the oil & mining and energy & water sectors. Externality parameters for *Telecommunication* exhibit heterogeneous results across the economic sectors, from non-significant in construction, energy & water, and fishing to highly statistically significant magnitudes in oil & mining, commerce, and manufacturing. The high heterogeneity of the elasticity parameters (from non-significant to significant and greater than one) may be explained by the literature. From the data of single and multiple countries, Waverman et al. (2005) and Qiang et al. (2009) have observed that the telecommunications effects decrease with the penetration rate, that is, greater effects are associated with lower penetration rates. Regarding the validity (weakness) of our instruments, the F-statistics that assess their joint significance are highly significant and greater than 10 (instrument weakness rule of thumb).

4. Simulating investment plans to fill Peruvian infrastructural gaps

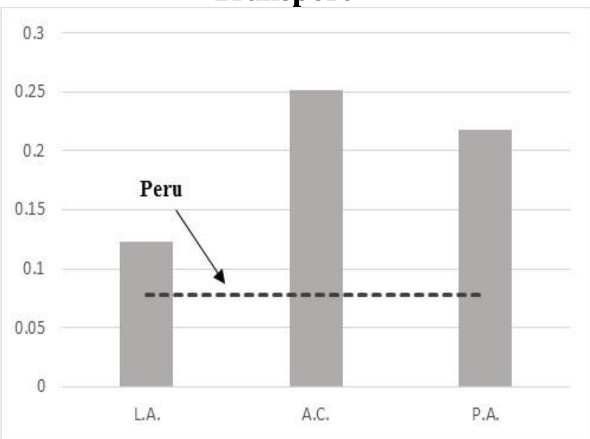
4.1 Definition of scenarios

We deliberately set a relatively short time horizon (15-year period) for the different investment scenarios to exclude potential significant structural changes in the Peruvian economy and, thus, maintain the consistency of the parameters' initial calibration of the CGE model. Following the standard procedure commonly used in dynamic CGE modelling, we first define a *Business as usual* (BAU) scenario by updating various constants and exogenous variables from one year to the next (Eq. 57–68) by using the annual population growth rate which is projected to be close to 1.1% over the period set by the INEI (2009). Second, we conduct *ex-ante* counterfactual experiments by comparing the outcome of simulations of different investment plans in infrastructure with those of the BAU scenario.

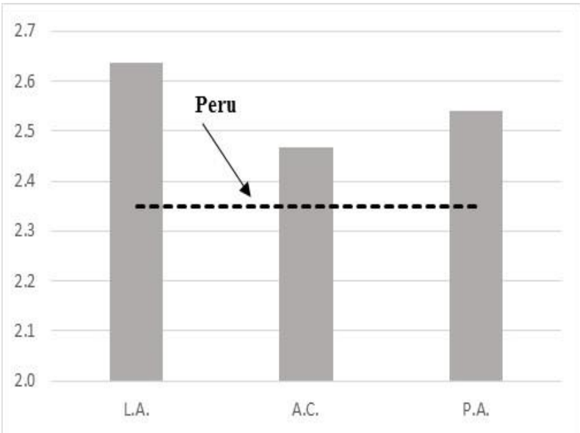
Our first group of scenario refers to vertical gaps in the infrastructure of Peru compared with the demand generated by its economic activity (Perrotti and Sánchez, 2011). The latter are estimated by AFIN (2015) for various infrastructural assets by using the methodology proposed by Fay and Yepes (2003). Their results show that Peru should invest USD 13.4 billion in telecommunications and USD 6.9 billion in its road network to fill its gaps. A lower investment level is required for Energy (USD 1.5 billion) because of the current significantly high supply in the country. Our second group of scenarios refers to Peruvian horizontal infrastructural gaps compared with some other countries. We use three benchmark groups. The first group comprises the upper-middle and high-income Latin American countries (LA) and excludes very small economies (i.e. those with a population smaller than 1 million) for which infrastructure may pose some special concerns (see e.g. Calderón and Servén, 2010). The second and third groups comprise nations of the Andean Community (AC) and Pacific Alliance (PA), respectively, which are the main trade blocs where Peru is involved. Figure 2 indicates the level of these horizontal gaps in 2016 for each infrastructural indicator with respect to the different benchmark groups.

Figure 2 – Horizontal infrastructure gaps (in physical terms) between Peru and some selected groups of countries

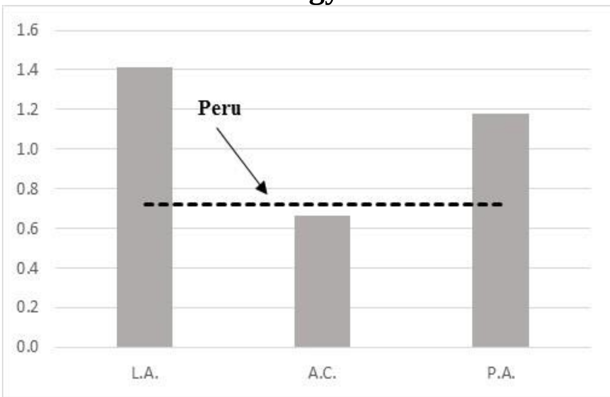
Transport (1)



Telecommunication (2)



Energy (3)



Notes: (1) Paved roads' network in km relative to agricultural land in sq. km; (2) Number of fixed and mobile lines per 1000 workers; (3) MW per 1000 workers
Sources: own calculations from CIA-World Factbook (2017)

Table 2 summarises the main hypotheses for our investments' scenarios. They are defined according to two key characteristics: the growth rate of each infrastructure physical stock that should be achieved to fill the gap at the end of the 15-year period, and the public spending required to finance the new infrastructure. It should be noted that we assume that this spending is equitably distributed over the 15-year period. Moreover, in the absence of better information, we also assume that the demand for activities that produce the capital goods required for the implementation of new infrastructure is allocated with the same fixed shares which prevailed for public investment in the initial equilibrium.

TABLE 2 - Scenarios for bridging Peruvian infrastructure gaps

	Vertical gaps	Horizontal gaps		
		With LA countries	*With AC countries*	*With AP countries*
Transport				
Physical gap to fill	55%	58%	224%	181%
investment needs (Billion USD)	6.9	7.9	30.3	24.5
Telecommunication				
Physical gap to fill	110%	25%	17%	21%
investment needs (Billion USD)	13.4	3.9	2.6	3.1
Energy				
Physical gap to fill	5%	119%	12%	83%
investment needs (Billion USD)	1.5	41.8	4.1	29.0
Total spending needs (Billion USD)	21.8	53.6	37,0	56.6

Sources: Own estimates with data from the AFIN (2015) for the vertical gap and from CIA-World Factbook (2017) for horizontal gaps

4.2 Simulations results

Table 3 presents selected results of the different scenarios' simulations. For each indicator, these outcomes represent the average annual deviation (in percentage) from the BAU scenario over the 15-year period.

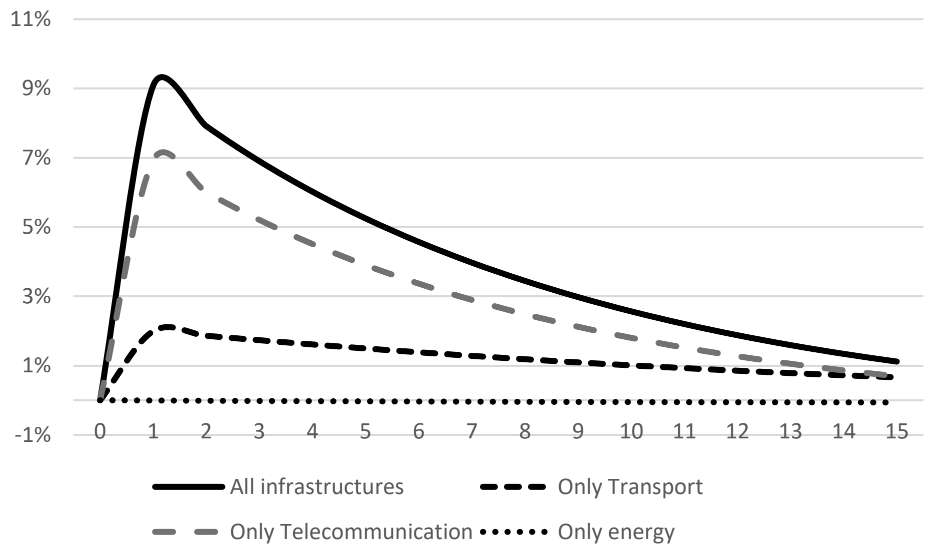
TABLE 3 - Selected general equilibrium effects of investment plans dedicated to bridging infrastructural gaps of Peru

	Vertical gaps				**Horizontal gaps**		
	All infrastructure	*Only Transport*	*Only Telecom.*	*Only Energy*	*With LA countries*	*With AC countries*	*With AP countries*
Macroeconomic indicators(1)							
Real GDP	3,98%	1,20%	2,93%	-0,04%	1,04%	3,29%	2,47%
Total factor productivity	9,49%	1,97%	7,17%	0,04%	5,59%	7,68%	8,03%
National prices index	-16,24%	-4,47%	-13,11%	0,10%	-5,88%	-12,26%	-10,21%
Real domestic absorption	1,41%	0,96%	0,48%	0,04%	2,46%	3,14%	3,54%
Import (volume)	-6,05%	-0,98%	-5,34%	0,04%	-1,30%	-3,01%	-2,24%
Export (volume)	10,61%	1,85%	9,02%	-0,05%	2,84%	5,90%	4,76%
Real trade balance	1,42%	1,22%	0,37%	-0,02%	0,72%	2,95%	2,26%
Real private investment	-18,78%	-3,45%	-14,25%	-0,33%	-17,46%	-16,75%	-20,93%
Real public investment	16,74%	4,51%	9,88%	0,94%	35,86%	26,64%	39,87%
Real government income	1,93%	1,21%	0,85%	-0,02%	1,05%	3,19%	2,60%
Public debt	229,04%	41,38%	173,64%	3,43%	194,95%	203,05%	245,15%
Real disposable income	0,68%	0,73%	0,11%	-0,02%	0,17%	1,61%	1,08%
Public spending effectiveness indicators on GDP(2)	*4,73*	*4,54*	*5,65*	*-0,64*	*0,49*	*2,29*	*1,11*

Notes: (1) Average annual deviation from the BAU scenario over the 15-year period;
(2) $\sum_t (GDP_t^{SIM} - GDP_t^{BAU}) / \sum_t IGInfr_t$
Source: Own calculations with GAMS software

The first simulation considers a comprehensive plan where all infrastructure is scaled-up simultaneously to bridge vertical gaps of Peru. Results show that this plan could strongly impact the economy. Over the period, the latter could experience an average annual increase of its real GDP by 3.98% relative to the BAU scenario. Figure 3 shows that this positive impact could be the highest for the first periods of the simulation and then could decrease progressively over the next periods. In our scenario, public spending on infrastructure is indeed equitably distributed over the 15-year period, leading to a decreasing rate of growth of infrastructural assets and thus decreasing supply effects on private activities. The investment plan could also lead to a strong average reduction in domestic prices by -16.24% relative to the BAU scenario. This reduction in price could then boost domestic demand and increase exports while decreasing imports, leading to an improvement in the trade balance. Notably, crowding-out effects of public investments could appear particularly strong with a reduction in real private investments relative to the BAU scenario by -18.78%.

FIGURE 3 – Average deviation from BAU of real GDP over the period for different vertical infrastructural gaps scenarios



Source: Own calculations with GAMS software

Moreover, although the government could expect an increase in its real income by 1.93%, it appears insufficient to compensate for the costs of new investments. The latter should thus be funded with an increase in the public debt by 229%. Finally, in this new general context, the real income per capita could improve sharply on average by 0.68%. To address the critical question of public spending effectiveness, one additional indicator is also introduced in Table 3: the ratio of the absolute deviation in real GDP over the period to the cost of investments. On these bases, results show that USD 1 in expenditures invested in public infrastructure could generate USD 4.73 of additional GDP.

In the next three simulations, we separate the effects of scaling-up for each infrastructural asset to bridge its respective vertical gap. Results show that investing in *Telecommunication* could potentially have the strongest effects and the highest public spending effectiveness: for instance, on average, the real GDP could deviate annually from the BAU scenario by 2.93% (compared with 1.20% for the *Transport* scenario and -0.04% for the *Energy* scenario). Investments in *Telecommunication* indeed represent greater spending (USD 13.4 billion) compared with the needs for other infrastructural assets (USD 6.9 billion and 1.5 billion for *Transport* and *Energy*, respectively) and, thus, generate higher multiplier and crowding-out effects. Moreover, investments in *Telecommunication* also have higher supply effects in the economy.

First, because the physical growth rate target for this infrastructural asset is higher (110%) compared with other assets (55% and 5% for *Transport* and *Energy*, respectively). Second, as shown in section 1, because *Telecommunication* infrastructure has higher positive average externalities on private activities and affects a larger part of the Peruvian economy (88% of total national private value added compared with 77.5% for *Transport* and even 0% for *Energy*). Finally, three simulations show the potential impacts on the Peruvian economy of investment plans dedicated to bridging its horizontal infrastructural gaps with respect to the different benchmark groups retained in the scenarios. Results confirm those previously obtained for vertical gaps. In each scenario, we observe that annual relative average real GDP increases, domestic prices decrease, trade balance improves, private investments decrease, public debt increases, or income per capita increases. However, the magnitude of these impacts is differentiated between the scenarios because levels of public spending and allocations across the different assets differ. For instance, filling infrastructural gaps with respect to nations of the AC, which is the less-expensive scenario (USD 37.0 billion) and concerns mainly *Transport*, (USD 30.3 billion, for a 224% growth rate achieved at the end of the period), could appear to have the strongest effect on growth (+3.29%, relative to BAU) and, thus, higher public spending effectiveness indicators. For the horizontal gap scenario with respect to LA, which represents USD 53.6 billion mainly allocated to *Energy* (USD 41.8 billion), the relative impact on growth could be only 1.04%. For the scenario with respect to the nations of the PA, which is the most expensive (USD 56.6 billion, mainly allocated to *Energy* and *Transport* and achieving growth rates of 83% and 181%, respectively, for these infrastructural assets), the average relative annual growth deviation from BAU scenario could be 2.47%.

4.2 Alternative funding schemes for investments

In previous simulations, given the savings-investment constraint in the CGE model, new public investments in infrastructure were implicitly supposed to be exclusively funded with private saving (and public debt), generating strong crowding-out effects on private investments. However, some CGE studies in the economic literature (see e.g. Boccanfuso et al., 2014) demonstrate that in a general equilibrium framework, the choice of funding schemes related to public spending is a key topic which could potentially affect the returns of new public investments. Accordingly, we investigate three alternative funding options for previous investments scenarios, namely, an increase in the households' income tax rate (*tdh*), an increase in production tax rates (tip_j), and an increase in sale tax rates on commodities (tic_i). In each case, the new levels of tax rates are determined to fully fund new investments. Results of the simulations with these new funding schemes' hypotheses are in Table 4. For an easier comparison, the results are now presented as the relative deviation with the same scenario where new infrastructure is funded with only public debt.

Whatever type of tax considered, it should be first noted that funding public investments with additional taxes instead of private savings could significantly modify their potential impacts, that is, it could particularly increase their positive effect on GDP and, thus, the public spending effectiveness on the growth of such policies. For the vertical gaps scenario, the average annual deviation of real GDP could, for instance, be close to +0.5% over the period, compared with the same scenario with private savings funding. For horizontal gaps scenarios, this deviation could be close to +1%. Using alternative funding schemes could also strengthen the downward impacts on national prices of investment in new infrastructure. However, as expected, the stronger deviations could be observed for the government income and public debt. In the vertical gaps scenario, the former could be annually higher by close to +4%. This increase could even be close to + 9%, 6%, and 10% for LA, AC and AP horizontal scenarios, respectively. The public debt could be annually reduced by close to -15% in the vertical scenario, and close to -35%, -26%, and -34% for the LA, AC, and AP horizontal scenarios, respectively. Accordingly, the crowding-out effect on private investments could, therefore, be strongly reduced (without, however, being cancelled). For the vertical gaps scenario, private investments could be annually higher close to +4% over the period. For horizontal gaps scenarios, private investments could be close to +10%, +7%, and +11% for the LA, AC, and AP scenarios, respectively. However, in this new context, living conditions could degrade sharply for Peruvian households, who would suffer, in all scenarios, an average decrease in their income.

If we compare the simulation outcome of each type of tax, the results secondly show that the income tax option seems to produce higher average deviation, although the differences are small between alternative funding schemes. The main differences are observed for prices and household income. For the income tax option, the increase in taxation decreases indeed directly affects the income of households and, thus, their consumption and saving. For the production tax and sales tax options, the effects are indirectly from increases in prices, which only reduces the decreases induced by the supply effects of new infrastructure without fully compensating them.

TABLE 4 – Selected general equilibrium effects of alternative funding schemes for investment policies dedicated to bridging infrastructural gaps of Peru

	Vertical gaps (All infrastructure)			Horizontal gaps With LA countries			With AC countries			With AP countries		
	tdh	tip_j	tic_i	tdh	tip_j	tic_i	tdh	tip_j	tic_i	tdh	tip_j	tic_i
a. Macroeconomic indicators[(1)]												
Real GDP	0,49%	0,47%	0,45%	1,08%	1,04%	0,99%	0,78%	0,75%	0,71%	1,19%	1,15%	1,10%
Total factor productivity	-0,49%	-0,48%	-0,43%	-1,07%	-1,05%	-0,94%	-0,78%	-0,76%	-0,68%	-1,18%	-1,15%	-1,03%
National prices index	-1,55%	-1,01%	-0,92%	-3,23%	-2,06%	-1,94%	-2,45%	-1,60%	-1,48%	-3,70%	-2,43%	-2,29%
Real domestic absorption	0,27%	0,37%	0,27%	0,65%	0,84%	0,63%	0,43%	0,57%	0,41%	0,67%	0,88%	0,65%
Import (volume)	-0,26%	0,03%	-0,24%	-0,51%	0,13%	-0,50%	-0,44%	0,02%	-0,42%	-0,65%	0,03%	-0,65%
Export (volume)	0,84%	0,59%	0,77%	1,80%	1,26%	1,71%	1,38%	0,99%	1,30%	2,10%	1,51%	1,99%
Real trade balance	-0,38%	-0,76%	-0,87%	-0,86%	-1,71%	-1,91%	-0,66%	-1,29%	-1,44%	-0,99%	-1,93%	-2,14%
Real private investment	4,80%	4,64%	4,40%	10,47%	10,16%	9,61%	7,48%	7,22%	6,84%	11,84%	11,47%	10,87%
Real public investment	0,14%	0,05%	0,03%	0,63%	0,29%	0,25%	0,36%	0,16%	0,13%	0,76%	0,35%	0,31%
Real government income	4,47%	3,89%	3,77%	9,97%	8,60%	8,36%	7,17%	6,20%	6,01%	10,92%	9,40%	9,14%
Public debt	-15,54%	-14,53%	-14,28%	-38,49%	-35,78%	-35,02%	-27,58%	-25,61%	-25,14%	-36,40%	-33,81%	-33,17%
Real disposable income	-0,87%	-0,58%	-0,68%	-1,95%	-1,29%	-1,51%	-1,44%	-0,97%	-1,13%	-2,18%	-1,46%	-1,70%
Public spending effectiveness indicators On GDP[(2)]	*0,67*	*0,64*	*0,62*	*0.59*	*0,57*	*0,54*	*0,63*	*0,60*	*0,57*	*0,62*	*0,60*	*0,57*

Notes: (1) Average annual deviation over the 15-year period from the same scenario with public debt funding; (2) $\sum_t (GDP_t^{SIM} - GDP_t^{Debt})/\sum_t IGInfr_t$
Source: Own calculations with GAMS software

5. Conclusion

In the current context of major infrastructure deficits, this study aimed to value the potential outcome that scaling-up infrastructure could generate in Peru. First, using a microeconomic database at the firm level, we empirically estimated the positive contribution of different types of infrastructure on Peruvian private sectors. Our results show that, although energy infrastructure has no significant effects on firms' production, telecommunication infrastructure exhibits highly significant externalities; similarly, road infrastructure's contribution to production is statistically significant across many economic activities. Second, numerical simulations of investment plans over a 15-year period have been performed with a CGE model including these positive externalities of public infrastructure on private activities. Our simulation outcome confirms that investing in new infrastructure in Peru could appear to be a worthwhile strategy to achieve growth; however, these benefits also depend on how these investments are funded. For instance, funding new infrastructure with household income taxation could have the strongest effects on economic growth performances but also the least effects on household income. If this study expands the literature on the infrastructure-growth nexus in a developing country such as Peru, caveats must be considered and caution exercised when interpreting the absolute magnitudes of these results.

First, regarding our empirical estimates, our period of analysis is characterised by a saturation effect of the energy supply that threatens the econometric identification of infrastructure elasticities. As a consequence, such parameters had to be constrained to zero in the construction and manufacture activities. By contrast, the important growth in telecommunications infrastructure and the low technological penetration rates across Peruvian firms during our period of analysis implied high externalities across economic activities that might overestimate the long-run supply effect of such infrastructure.

Second, regarding the definition of our investment scenarios, the links between public spending and infrastructure' stocks have not been really investigated. However, a growing body of literature underscores that such links are mediated by the institutional framework and the quality of governance of each country and that public expenditure can offer a misleading proxy for the trends in infrastructure stocks (see e.g. Calderon, 2014). This phenomenon is particularly true for Peru, where infrastructure projects have often been derailed by bureaucratic impediments and lingering weaknesses in the public investment management system (IMF, 2014, 2016).

Third, regarding the type of infrastructure chosen for this study, we focused on only selected economic “core” infrastructure generally perceived as a priority in many investment surveys; however, the impacts of investments in social infrastructure, such as health or education, should also be investigated. On the one hand, they provide externalities that enhance the labour productivity which drives long-term growth; on the other hand, they are often considered one of the most effective tools for generating inclusive growth and fighting poverty or inequalities (see e.g. ECLAC, 2015b).

Finally, the aggregated level of our CGE model prevents us from considering one of the main characteristics of infrastructure in Peru, that is, the unbalanced geographical localisation of assets between the region of Lima and the rest of the country (CEPLAN, 2011, 2015). In this context, investment plans dedicated to bridging Peruvian infrastructural gaps, thus, involve rival location choice concerns beyond the scope of this study that might be a key factor when attempting to obtain a more accurate assessment of the potential impacts of such plans.

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APPENDIX - DRCGE MODEL FOR PERU

A.1. - Institutional desegregation and model sets

1. Institutions' desegregation

Activities or products

Agriculture
Fishing
Mining
Manufacture
Electricity and water
Construction
Trade
Other private services
Public administration (Pub)

Agents

Households (H)
Government (G)
Rest of the world (Row)

2. Sets and indexing

Activities or products

J or I = {All activities or products}
(indexed j or i)
BUS or BUS= {Private activities or products} ⊂ J or I
(indexed bus)

Infrastructure

INFR = {Transport, Telecommunication, Energy}
(indexed infr)

Time periods

T = {0,1, ..., 15}
(indexed t)

A.2 - Model equations

1. Within-period specifications

1.1. Production

1. $VA_{j,t} = \theta_{j,t}^{INFR}.A_j^{VA}.LDC_{j,t}^{\alpha_j^{VA}}.K_{j,t}^{1-\alpha_j^{VA}} \quad \forall j$
2. $VA_{j,t} = v_j.XST_{j,t} \quad \forall j$
3. $CI_{j,t} = io_j.XST_{j,t} \quad \forall j$
4. $LDC_{j,t} = \dfrac{\alpha_j^{VA}.PVA_{j,t}.VA_{j,t}}{WC_{j,t}} \quad \forall j$
5. $LDC_{j,t} = B_j^L.\left[\beta_j^L.LDu_{j,t}^{\rho_j^L} + \left(1-\beta_j^L\right).LDsk_{j,t}^{\rho_j^L}\right]^{\frac{1}{\rho_j^L}} \quad \forall j$
6. $LDu_{j,t} = LDsk_{j,t}.\left[\dfrac{1-\beta_{j,t}^L}{\beta_{j,t}^L}.\dfrac{Wu_t}{Wsk_t}\right]^{\sigma_j^L} \quad \forall j$

1.2. Income and savings

Households

7. $YH_t = RTL_t + RTK^H{}_t + RTR^H{}_t$
8. $RTL_t = \sum_j Wu.LDU_{j,t} + \sum_j Wsk_t.LDSk_{j,t}$
9. $RTK^H{}_t = \lambda_K^H \sum_j R_{j,t}.K_{j,t}$
10. $YDH_t = YH_t - TDH_t$
11. $TDH_t = PIXCON_t.tdh^o{}_t + tdh^1{}_t.YH_t$
12. $CTH_t = YDH_t - SH_t$
13. $SH_t = PIXCON_t.sh^o{}_t + sh^1{}_t.YDH_t$

Government

14. $YG_t = RTK^G{}_t + RTR^G{}_t + TDH_t + TIMT_t + TICT_t + TIPT_t$
15. $RTKG_t = \lambda_K^G \sum_j R_{j,t}.K_{j,t}$
16. $TIMT_t = \sum_i tim_i.PWM_{i,t}.ER_t.IM_{i,t}$
17. $TICT_t = \sum_i tic_i.PL_{i,t}.DD_{i,t}$
18. $TIPT_t = \sum_j tip_j.PP_{j,t}.XST_{i,t}$
19. $SG_t = YG_t - G_t$

1.3. Demand

Investment

20. $INV_{i,t} = INVP_{i,t} + INVG_{i,t} + \sum_{infr} INVG_{i,t}^{infr} \quad \forall i$
21. $PC_{i,t}.INVG_{i,t} = \gamma_i^{IG}.IG_t \quad \forall i$
22. $PC_{i,t}.INVP_{i,t} = \gamma_i^{IP}.IP_t \quad \forall i$
23. $PC_{i,t}.INVG_{i,t}^{infr} = \gamma_i^{IG}.\overline{IG_t^{infr}} \quad \forall i$

Intermediate consumption

24. $DI_{i,t} = \sum_j aij_{i,j}.CI_{j,t} \quad \forall i$

Final Consumption

25. $PC_{i,t}.CG_{i,t} = \gamma_i^{CG}.G_t \quad \forall i$

26. $PC_{i,t}.C_{i,t} = PC_{i,t}.C_{i,t}^{Min} + pmc_i.\left[CTH_t - \sum_{i' \neq i} C_{i',t}^{Min}.PC_{i'}\right] \forall i$

1.4. International trade

Exports and domestic sales

27. $XST_{j,t} = XS_{i,t} \quad \forall i \in I \approx j \in J$

28. $XS_{i,t} = B_i^X.\left[\beta_i^X.EX_{i,t}^{\rho_i^X} + \left(1-\beta_i^X\right).DS_{i,t}^{\rho_i^X}\right]^{\frac{1}{\rho_i^X}} \quad \forall i$

29. $EX_{i,t} = DS_{i,t}.\left[\frac{1-\beta_{i,t}^X}{\beta_{i,t}^X}.\frac{PE_{i,t}}{PL_i}\right]^{\sigma_i^X} \quad \forall i$

30. $EXD_{i,t} = EXD_i^O.pop(t).\left[\frac{ER_t.PWX_{i,t}}{PE_{i,t}}\right]^{\sigma_i^{XD}} \quad \forall i$

Imports and domestic sales

31. $Q_{i,t} = B_i^M.\left[\beta_i^M IM_{i,t}^{-\rho_i^M} + \left(1-\beta_i^M\right)DD_{i,t}^{-\rho_i^M}\right]^{-\frac{1}{\rho_i^M}} \quad \forall i$

32. $IM_{i,t} = DD_{i,t}.\left[\frac{\beta_i^M}{1-\beta_i^M}\frac{PD_{i,t}}{PM_{i,t}}\right]^{\sigma_i^M} \quad \forall i$

33. $IM_{i,t} = DD_{i,t}.\left[\frac{\beta_i^M}{1-\beta_i^M}\frac{PD_{i,t}}{PM_{i,t}}\right]^{\sigma_i^M} \quad \forall i$

1.5. Private investment functions

34. $IND_{bus,t} = \phi_{bus}.\left[\frac{R_{bus,t}}{U_{bus,t}}\right]^{\sigma_{bus}^{INV}}.K_{bus,t} \quad \forall bus$

35. $U_{bus,t} = PK_t\left(\delta_{bus} + \overline{IR_t}\right) \quad \forall bus$

36. $PK_t = \frac{1}{A^K}.\prod_i\left[\frac{PC_{i,t}}{\gamma_i^K}\right]^{\gamma_i^K}$

37. $IP_t = PK_t.\sum_{bus} IND_{bus,t}$

38. $IG_t = PC_{Pub,t}.IND_{Pub,t}$

1.6. Closure rules

Product markets

39. $Q_{i,t} = \sum_h C_{i,h} + CG_{i,t} + INV_{i,t} + DIT_{i,t} \quad \forall i$

40. $DS_{i,t} = DD_{i,t} \quad \forall i$

Labour market

41. $LSu_t = \sum_j LDu_{j,t}$

42. $LSsk_t = \sum_j LDsk_{j,t}$

Capital market

43. $IP_t + IG_t + \sum_{infr} \overline{IG_t^{infr}} = \sum_h SH_{h,t} + SG_t - CAB_t$

Current account balance

44. $CAB_t = \sum_i PE_{i,t}.EX_{i,t} - \lambda_K^{Row}.\sum_j R_{j,t}.KD_{j,t} - RTR^{ROW}{}_t$
$- ER_t.\sum_i \overline{PWM_{i,t}} IM_{i,t}$

Numeraire

45. $ER_t = 1$

1.7. Price system

46. $PP_{j,t}.XST_{j,t} = PVA_{j,t}.VA_{j,t} + \sum_i PC_{i,t}.DI_{i,j,t} \quad \forall j$

47. $PT_{j,t} = \left(1+tip_{j,t}\right).PP_{j,t} \quad \forall j$

48. $PVA_{j,t}.VA_{j,t} = WC_{j,t}.LDC_{j,t} + R_{j,t}.K_{j,t} \quad \forall j$

49. $P_{i,t} = PT_{j,t} \quad \forall i \in I \approx j \in J$

50. $P_{i,t}.XS_{i,t} = PE_{i,t}.EX_{i,t} + PL_{i,t}.DS_{i,t} \quad \forall i$

51. $PD_{i,t} = \left(1+tic_{i,t}\right).PL_{i,t} \quad \forall i$

52. $PM_{i,t} = \left(1+tic_{i,t}\right).\left(1+tim_{i,t}\right).ER_t.\overline{PWM_{i,t}} \quad \forall i$

53. $PC_{i,t}.Q_{i,t} = PM_{i,t}.IM_{i,t} + PD_{i,t}.DD_{i,t} \quad \forall i$

54. $PIXCON_t = \frac{\sum_i PC_{i,t}.\sum_h C_{i,h}^O}{\sum_{ii'} PC_{i',t}^O.\sum_h C_{i',h}^O}$

2. Between-period specifications

Capital accumulation in each activity

55. $KD_{j,t+1} = KD_{j,t} \cdot \left(1 - \delta_{j,t}\right) + IND_{j,t} \quad \forall j$

Supply effect of infrastructure on private activities

56. $\theta_{j,t+1}^{INFR} = \prod_{Infr} \left(\frac{KINFR_{t+1}^{infr}}{KINFR_{t}^{infr}} \right)^{\varepsilon_j^{infr}} \quad \forall j \in BUS$

With

$\frac{KINFR_{t+1}^{infr}}{KINFR_{t}^{infr}} = f\left(\overline{IG_t^{infr}}\right)$ $\forall$*infr depending on scenarios simulated*

Updating rules for exogenous variables and for parameters

57. $pop_{t+1} = pop_t \cdot \left(1 + n_t\right)$ *with* $pop_0 = 1$
58. $LU^S{}_t = LU^S{}_0 . pop_t$
59. $LSk^S{}_t = LSk^S{}_0 . pop_t$
60. $IND_{Pub,t} = IND_{Pub,0} . pop_t$
61. $CAB_t = CAB_0 . pop_t$
62. $G_t = G_0 . pop_t$
63. $C_{i,h,t+1}^{Min} = C_{i,h,0}^{Min} . pop_t$
64. $sh^o{}_t = sh^o{}_0 . pop_t$
65. $tdh^o{}_{h,t} = tdh^o{}_{h,0} . pop_t$
66. $RTR^H{}_t = PIXCON_t . TRH^0 . pop_t$
67. $RTR^G{}_t = PIXCON_t . TRG^0 . pop_t$
68. $RTR^{ROW}{}_t = PIXCON_t . TRROW^0 . pop_t$

A.3. List of variables and parameters

Variables

$C_{i,t}$	Consumption of commodity *i* by households (volume)
$C_{i,t}^{Min}$	Minimum consumption of commodity *i* by households (volume)
CAB_t	Current account balance
$CG_{i,t}$	Public consumption of commodity *i* (volume)
$CI_{j,t}$	Intermediate consumption of industry *j* (volume)
CTH_t	Consumption expenditures of households
$DD_{i,t}$	Domestic demand for commodity *i* produced locally (volume)
$DI_{i,j,t}$	Intermediate consumption of commodity *i* by industry *j* (volume)
$DS_{i,t}$	Quantity of product *i* sold in the domestic market (volume)
ER_t	Exchange rate
$EX_{i,t}$	Quantity of product *i* exported (volume)
$EXD_{i,t}$	World demand for exports of product *i* (volume)
G_t	Total government consumption (volume)
$IM_{i,t}$	Quantity of product *i* imported (volume)
$IND_{j,t}$	New type capital investment to sector *j* (volume)
$INV_{i,t}$	Demand of commodity *i* for investment purposes
$INVP_{i,t}$	Demand of commodity *i* for private investment purposes (volume)
$INVG_{i,t}$	Demand of commodity *i* for public investment purposes (volume)
$INVG_{i,t}^{infr}$	Demand of commodity *i* for investing in type *infr* infrastructure (volume)
$K_{j,t}$	Capital stock by industry *j*
$KINFR_t^{infr}$	Physical stock of type *infr* infrastructure
IR_t	Interest rate
IP_t	Total private investment expenditures
IG_t	Total public investment expenditures (except for infrastructure)
$\overline{IG_t^{infr}}$	Total public investment expenditures for each type *infr* of infrastructure
$LDu_{j,t}$	Industry *j* demand for unskilled labour
$LDsk_{j,t}$	Industry *j* demand for skilled labour
LSu_t	Supply of unskilled labour
$LSsk_t$	Supply of skilled labour
$PC_{i,t}$	Purchaser price of composite commodity *i* (including all taxes)
$PD_{i,t}$	Price of product *i* sold locally (including all taxes)
$PE_{i,t}$	Price of exported product *i* (in national currency)
$PIXCON_t$	Consumer price index
PK_t	Price of new private capital in private sector
$PM_{i,t}$	Price of imported product *i* (in national currency)
$PP_{j,t}$	Basic price of activity *j*'s output
$PT_{j,t}$	Basic price of activity *j*'s output (including taxes on production)
$P_{i,t}$	Basic price of product *i*
$PVA_{j,t}$	Price of industry *j* value added
$PWM_{i,t}$	World price of imported product *i* (in foreign currency)
$PWX_{i,t}$	World price of exported product *i* (in foreign currency)
$Q_{i,t}$	Demand of composite commodity *i* (volume)
$R_{j,t}$	Rental rate of capital in industry *j*
$RTK^{G}{}_{t}$	Capital income of Government
$RTK^{H}{}_{t}$	Capital income of households
RTL_t	Labour income of households
$RTR^{G}{}_{t}$	Net transfers income of Government
$RTR^{H}{}_{t}$	Net transfers income of households
$RTR^{Row}{}_{t}$	Net transfers income of rest of the world
SG_t	Government savings
SH_t	Households' savings
TDH_t	Income taxes of type *h* households
$U_{j,t}$	User cost of capital in industry *j*
$VA_{j,t}$	Value added of industry *j*
$WC_{j,t}$	Wage rate in industry *j*
Wu_t	Wage rate for unskilled labour
Wsk_t	Wage rate for skilled labour
$XST_{j,t}$	Total output of industry *j* (volume)
YDH_t	Households' disposable income
YG_t	Government total income
YH_t	Households' total income
$\Theta_{j,t}^{INFR}$	Factor productivity parameter linked to infrastructure levels

Parameters

io_j	Leontief coefficient for intermediate consumption
v_j	Leontief coefficient for value added
A_j^{VA}	Scale parameter for value-added production function
α_j^{VA}	Elasticity parameter for value-added production function
B_j^L	Scale parameter for CES – composite labour function
β_j^L	Share parameter for CES – composite labour function
ρ_j^L	Elasticity parameter for CES – composite labour function
$aij_{i,j}$	Input-output coefficient
λ_K^H	Share of capital income received by households
λ_K^G	Share of capital income received by the Government
λ_K^{Row}	Share of capital income received by the rest of the world
sho_t	Savings function intercept for households
$sh1_t$	Savings function slope for households
$tdho_t$	Taxation function intercept for households
$tdh1_t$	Marginal income tax rate of households
tim_i	Rate of taxes and duties on imports of commodity i
tic_i	Tax rate on commodity i
tip_j	Tax rate on production j
pop_t	Population index
Pmc_i	Marginal share of commodity *i* in households' consumption budget
λ_i^{CG}	Share of commodity *i* in total current public expenditures
λ_i^{IP}	Share of commodity *i* in total private investment expenditure
λ_i^{IG}	Share of commodity *i* in total public non-infrastructure investment expenditure
B_i^X	Scale parameter for CET – Export function
β_i^X	Share parameter for CET – Export function
ρ_i^X	Elasticity parameter for CET – Export function
σ_i^X	Elasticity of transformation for CET – Export function
σ_i^{XD}	Price-elasticity of the world demand for exports of product i
B_i^M	Scale parameter for CES – Import function
β_i^M	Share parameter for CES – Import function
ρ_i^M	Elasticity parameter for CES – Import function
σ_i^M	Elasticity of substitution for CES – Import function
A^K	Scale parameter for private investment demand function
ϕ_{bus}	Scale parameter (allocation of investment to private industries)
σ_{bus}^{INV}	Elasticity of private investment demand relative to Tobin's q
n_t	Annual population rate growth
$\delta_{j,t}$	Depreciation rate for capital for industry j
$\varepsilon_{j,t}^{Infr}$	Elasticity of value added relative to type *infr* infrastructure