Modeling the Impact of Large Infrastructure Projects: A Case Study from Niger

Macroeconomic Assessment of Public Investment Options (MAPIO)

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Abstract

Evidence illustrates that investment in infrastructure is essential to accelerate inclusive growth. Indeed, a number of Sub-Saharan African (SSA) countries have begun to devote greater resources to large-scale public investment projects. Nevertheless, while massive projects can potentially generate large benefits there are considerable risks. Cost overruns, poor implementation quality, inadequate operational and maintenance capacity, and negative social or environmental impacts can severely undercut a project's anticipated social and economic returns. Moreover, projects, which are expensive to develop and maintain can impact on debt dynamics and in some cases macroeconomic stability.

Yet, given the complex nature of such projects it is often difficult to ascertain whether it is worthwhile to proceed with a project and if so, how should it be financed and implemented. Historically, computable general equilibrium (CGE) models have been used to assess the prospective impacts of large public investment projects. However, such models are a complex and time-consuming process and are often too broad to precisely capture the localized impact of specific projects.

This paper proposes a simple, but more user-friendly model. By inputting information on the project's construction, operation, and anticipated returns, the user is able to assess the project's net impact on the economy and weigh up the costs and benefits of different approaches. The model was developed in response to a request from the Nigerien authorities to assess the macroeconomic impact of Niger's Kandaji Dam project. It found that while costs would equal more than 10 percent of 2013 GDP during 2014-48, the expansion of domestic production spurred by increased demand during the construction phase would increase GDP by 0.25 percent above the baseline projection and boost fiscal revenues by an additional 0.45 percentage points of GDP.

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ACRONYMS AND ABREVIATIONS

(Franc) CFA	West African CFA Franc (Franc de la Communauté Financière Africaine)
CGE	Computable General Equilibrium
DSA	Debt Sustainability Analysis
EIRR	Economic Internal Rate of Return
EWIRR	Economy-wide Internal Rate of Return
FIRR	Fiscal Financial Internal Rate of Return
GDP	Gross Domestic Product
IMF	International Monetary Fund
IRR	Internal Rate of Return
MPC	Marginal Propensity to Consume
MPM	Marginal Propensity to Import
PIRR	Project Internal Rate of Return
SSA	Sub-Saharan Africa

Macroeconomic Assessment of Public Investment Options (MAPIO):

Modeling the Impact of Large Infrastructure Projects: A Case Study from Niger[1]

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1. Introduction

There is a broad consensus in the development literature that sustained investment in infrastructure is essential to accelerating inclusive growth. In many countries in Sub-Saharan Africa (SSA) deficiencies in basic infrastructure inhibit diversification, keeping much of the continent's population locked in subsistence agriculture and unable to reap the economic benefits of modern technology and global trade (African Center for Economic Transformation, 2014). According to recent estimates (World Bank 2010) SSA countries would need to invest US$93 billion, or 15 percent of their aggregate GDP, every year for ten years in order to catch up with Mauritius, the regional leader in infrastructure.

This renewed focus on infrastructure investment is based on numerous empirical studies identifying both a country's existing infrastructure stock and its public investment rate as key determinants of economic growth.[7] Using a neoclassical convergence framework Calderon (2009) finds that the rate at which SSA countries are converging towards a common steady-state equilibrium is significantly influenced by their respective endowments of physical infrastructure, including paved roads, railways, airports and seaports, energy generation and transmission networks, and irrigation and drainage systems. As many of these are public goods and/or natural monopolies the government must take the lead in providing them, either directly through public investment or indirectly through partnerships with the private sector.[8] In either case, it is imperative that the government ensure that the economic impact of new infrastructure projects justifies its

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[1] The model presented in this paper was prepared in response to a request from the Nigerien authorities. However, since many other countries are confronted with these same issues the authors decided to make the approach and results available to a wider audience. The authors are grateful for technical comments from participants at a workshop in Niamey in May 2014 and for editorial suggestions from Sean Lothrop and Judite Fernandes who prepared the paper for publication.

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[7] The relationship between public investment and economic growth has been confirmed using a range of different estimation methods. See Ashauer (1989), Khan and Kumar (1997) and Dessus and Herrera (2000).

[8] The public sector's role in financing investment in public goods or assets that control natural monopolies and correct market failures is well established. See Lijesen and Shestalova (2007).

fiscal cost, including both the initial capital investment and all recurrent expenditures generated by its operation.[9]

Recognizing the economic importance of infrastructure development, many SSA countries have begun to devote greater resources to public investment, with a particular emphasis on large-scale projects. In certain countries, especially those that have benefited from the Heavily Indebted Poor Countries program and the Multilateral Debt Relief Initiative, much of this investment has been financed by increased borrowing, while others have focused on boosting domestic revenues. Some resource-rich countries have pledged future exports to secure loans from non-traditional external partners, notably China. In some cases these agreements have raised questions about transparency and accountability in natural resource management. Agreements pledging future exports as collateral for development loans require careful and objective scrutiny of their terms and provisions, as well as the institutional context in which they will be implemented.

While massive investment projects have the potential to yield enormous benefits, they also entail considerable risks. Cost overruns, poor implementation quality, inadequate operational and maintenance capacity, and negative social or environmental impacts can severely undercut a project's anticipated social and economic returns. Large-scale projects can also indirectly threaten macroeconomic stability though the impact of project-related borrowing on debt dynamics, the long-term fiscal commitment posed by their operational and maintenance costs, the influence of project procurement rules on national suppliers, inflationary effects generated increased domestic spending, or the potential appreciation of the real exchange rate. Macroeconomic instability may in turn disrupt the implementation of the project or reduce its economic value. In some cases the microeconomic impact of an investment project may offset its macroeconomic consequences, but in other cases each may reinforce and exacerbate the other.

Investment policies play an important role in determining the economic ramifications of a large public project. For example, procurement rules requiring an extensive bidding process may reduce a project's total cost but increase the time required for its implementation. In some circumstances a more expensive but rapidly completed project may be preferable to a less costly project with a longer gestation period. Policymakers must weigh these tradeoffs and consider them in terms of the nature of the project and the country's unique economic context.

Governments frequently rely on debt sustainability analyses (DSAs) to evaluate the macroeconomic risks posed by different public investment strategies and to estimate the financing envelope available for new projects. DSAs typically assess the extent to which key macroeconomic variables, such as the debt-to-GDP ratio or the debt-service-to-exports ratio, are at risk of exceeding specified thresholds over a given time horizon. But while the terms at which countries borrow (their "debt-repayment profile") can be known with relative certainty, less attention is devoted to evaluating the costs and benefits of the specific projects that this borrowing finances. In most cases assessments of the marginal macroeconomic impacts of investment projects are restricted to broad assumptions about future GDP growth rates, inflation, exports and fiscal revenues; however, in order to accurately and comprehensively appraise the macroeconomic effects of large-scale investment projects a more systematic approach is required.

[9] Even infrastructure provided through public-private partnerships may still involve public resources or entail an explicit or implicit public guarantee exposing the government to potential contingent liabilities.

Computable general equilibrium (CGE) models are often used to assess the prospective impacts of large public investment projects. For example, the "MAMS model" (Bourguignon et al., 2004; Lofgren and Diaz-Bonilla, 2010) aims to capture both the effects of increased demand for investment-related goods and services (e.g. building supplies, construction services, etc.) and the supply-side effects of increased productivity in sectors that benefit from the completed project. However, CGE modeling is a complex and time-consuming process, and the resulting models are often too broad to precisely capture the localized impact of specific projects. As such they tend to be better suited to assessing the implications of national development strategies and estimating tradeoffs between competing investment-policy objectives rather than the more focused and detailed analysis required to appraise individual investments.

This paper proposes a simple model designed to estimate an investment project's impact on key macroeconomic variables based solely on the information contained in a standard project document. The model can be applied using a widely available spreadsheet program (e.g. Microsoft Excel) rather than more sophisticated statistical software. It requires accurate and detailed information regarding the project's construction, operation, and anticipated returns, but compared to CGE modeling its analytical capacity requirements are very modest. The model is narrowly tailored to assess the short- and long-term implications of a specific project, all of the assumptions that underpin its results are clearly indicated, and its consideration of other variables are deliberately limited. It is hoped that the availability of a simple yet accurate tool for assessing the macroeconomic implications of proposed projects will enhance the public investment management capacity of governments in SSA and help to maximize the returns to both external development financing and domestic revenues.

The model was originally developed in response to a request from the Nigerien authorities, and this working paper includes an assessment of the macroeconomic impact of Niger's Kandaji Dam project as a case study. The dam is expected to generate some 120 MKW of electricity each year, and water from its reservoir will irrigate an estimated 45,000 hectares of agricultural land. The total construction cost is projected at US$785 million, or more than 10 percent of Niger's 2013 GDP. The project will be financed by concessional loans provided by 10 of Niger's development partners, including international development banks. The model assesses the project's impact on a set of key macroeconomic variables over the 2014-48 period.

Section 2, below, presents the main equations used in the model. Section 3 applies the model to Niger's Kandaji Dam project. Section 4 discusses the model's broader applications and explores a number of related policy issues. Section 5 concludes the paper.

2. The Model

The model is designed to estimate the impact of a given investment project on a discrete set of macroeconomic variables. Like CGE models it assesses both the increase in demand that occurs as a result of the project's construction and the boost to supply generated by its completion. It also projects real price changes, revealing potential "Dutch disease" effects caused by additional demand that cannot be fully accommodated by a corresponding supply response. In its current state the model focuses solely on the direct monetary implications of the investment project. However, it could be elaborated to estimate potential multiplier effects as well.

In the baseline scenario nominal baseline $GDP_{tB\Theta}$ is the sum of its demand components: baseline consumption C_{tB}, baseline investment I_{tB}, baseline government spending G_{tB}, baseline exports X_{tB}, and baseline imports M_{tB}.

$$GDP_{tB\Theta} = C_{tB} + I_{tB} + G_{tB} + X_{tB} - M_{tB} \quad (1)$$

If the government decides to commit additional financing G_t^{*d} to a new investment program, these funds will be allocated across economic sectors j and used to purchase input types i.

$$G_t^{*d} = \sum_{ij=1}^{N} \theta_{ij}\, G_t^{*d} \quad (2)$$

The project will require a combination of the following input types:

- international labor $Li_t^{*d} = \sum_{ij=1}^{N} \theta_{1j} G_t^{*d}$
- domestic labor $Ld_t^{*d} = \sum_{ij=1}^{N} \theta_{2j} G_t^{*d}$
- international capital $Ki_t^{*d} = \sum_{ij=1}^{N} \theta_{3j} G_t^{*d}$
- domestic capital $Kd_t^{*d} = \sum_{ij=1}^{N} \theta_{4j} G_t^{*d}$

2.1 Demand-Side Effects Caused by Project Implementation

During its construction phase the project's implementation will boost demand for certain goods and services, which will impact the following macroeconomic variables:

- Consumption
- Investment
- Imports
- Tax revenues
- GDP
- The GDP deflator

Demand-side effects can be estimated by making simple assumptions about the marginal propensity to consume α_{ij} for input types i across 5 selected sectors j, namely construction, agriculture, transportation, manufacturing and services.

$$C_t^{*d} = \sum_{ij=1}^{N} \alpha_{ij} \left({Li_t}^{*d} + {Ld_t}^{*d} + {Kd_t}^{*d} + {Ki_t}^{*d} \right) \quad (3)$$

This equation can be broken down further to estimate the demand function for each input type.

The marginal propensity to consume for international labor is calculated as the residual after deducting the marginal propensity to import, δ_{1j} across j economic sectors.[10]

$$\sum_{ij=1}^{N} Li_t^{*d}\alpha_{1j} = \sum_{ij=1}^{N} Li_t^{*d}(1-\delta_{1j}) \quad (3.1)$$

It is assumed that a portion of domestic labor income will be subject to taxation, where τ_{1j} is the marginal rate of taxation, while an additional share of labor income will be allocated to domestic savings, where ω_{ij} is the marginal propensity to save. The marginal propensity to consume (MPC) is typically high from domestic labor income, and some of the increase in consumer demand will be satisfied by imports.

$$\sum_{ij=1}^{N} Ld_t^{*d}\alpha_{2j} = \sum_{ij=1}^{N} Ld_t^{*d}\,(1-\tau_{1j}-\delta_{2j}-\omega_{1j}) \quad (3.2)$$

Most large-scale public investment projects in SSA involve some amount of international capital, and this share tends to increase for projects that are especially massive or complex. Since all imported capital δ_{3j} is equal to one, the MPC is zero for international capital.

$$\sum_{ij=1}^{N} Ki_t^{*d}\alpha_{3j} = \sum_{ij=1}^{N} Ki_t^{*d}\,(1-\delta_{3j}) \quad (3.3)$$

Finally, it is assumed that domestic capital Kd_t^{*d} will be supplied by domestic firms. The MPC for domestic capital can therefore be calculated by deducting taxes, savings, imports and investment, where β_{1j} equals the marginal propensity to invest.

$$\sum_{ij=1}^{N} Kd_t^{*d}\alpha_{4j} = \sum_{ij=1}^{N} Kd_t^{*d}\,(1-\tau_{2j}-\delta_{4j}-\omega_{2j}-\beta_{1j}) \quad (3.4)$$

Thus we can calculate the effect on the following variables:

Additional investment, $I_t^{*d} = \sum_{ij=1}^{N} Kd_t^{*d}\,\beta_{1j}$ (4)

Additional imports, $M_t^{*d} = \sum_{ij=1}^{N} \delta_{ij}\,(Li_t^{*d} + Ld_t^{*d} + Ki_t^{*d} + Kd_t^{*d})$ (5)

Additional tax revenue, $T_t^{*d} = \sum_{ij=1}^{N} \tau_{ij}\,(Kd_t^{*d} + Ld_t^{*d})$ (6)

This enables us to estimate the overall increase in demand generated by the project's construction, which is the sum of consumption and investment.

[10] The marginal propensity to save is included in the estimate of the marginal propensity to import, since any savings are assumed to be held overseas. It should be noted that the balance of payments will indicate higher imports and larger current transfers. However, these equations reveal the actual net effect on imports.

$$TD_t = C_t^{*d} + I_t^{*d} \quad (7)$$

Once total demand estimates have been obtained for the projected implementation period it is assumed that firms will have complete information about changes in demand and act rationally. Therefore, their supply response will be based on the average increase in total demand over the period. Simple assumptions are made regarding the elasticity of supply($\frac{dQS_{jt}}{dP_{jt}} * \frac{P_{jt}}{Q_{jt}}$) over time and across sectors.[11]

The elasticity of supply for each sector reflects a number of factors. Supply is more likely to be elastic if:

- There is excess capacity in the sector;
- Sector producers hold significant inventories or stocks of raw materials;
- Factors of production (labor and capital) can be easily substituted; or
- The project's implementation period is long enough that producers are able to fully adjust to new demand conditions.

Once the elasticity of supply has been estimated it is possible to calculate changes in real economic output GDP_t^{*d} arising from average demand effects $\overline{TD_j}$.

$$GDP_t^{*d} = \sum_{tj=1}^{N} \overline{TD_j} * \left(\frac{dQS_{jt}}{dP_{jt}} * \frac{P_{jt}}{Q_{jt}}\right) \quad (8.1)$$

The equation below is used to estimate the price increase P_t^{*d} that occurs as a result of additional demand. This is particularly important for determining the impact on the GDP deflator, which is calculated in the equation below.

$$P_t^* = \sum_{j=1}^{N} TD_{jt} * \left(1 - \frac{dQS_{jt}}{dP_{jt}} * \frac{P_{jt}}{Q_{jt}}\right)) \quad (8.2)$$

The increase in nominal output $GDP_{t\Theta}^{*d}$ generated by these demand effects can therefore be calculated as:

$$GDP_{t\Theta}^{*d} = \sum_{j=1}^{N} P_{jt}^* + (GDP_{jt}^{*d} * DEF_{jtB}) \quad (9)$$

The next step is to calculate changes in real and nominal GDP by adding the additional nominal and real GDP values to their respective baselines.

$$GDP_{t\Theta}^{d} = GDP_{t\Theta}^{*d} + GDP_{tB\Theta} \quad (10.1)$$

$$GDP_t^{d} = GDP_t^{*d} + GDP_{tB} \quad (10.2)$$

[11] The elasticity of supply is often empirically difficult to measure due to incomplete or inaccurate data. It is also not possible to isolate firms' pricing and supply decisions due to the demand effects of the investment project.

This provides us with a revised estimate of the GDP deflator DEF_t^d, which is obtained by dividing nominal GDP by real GDP across economic sectors j. The estimate reflects the demand effects of the investment project on prices in different sectors, and indicates potential second-order effects on other variables such as exports and private investment.

$$DEF_{tj}^d = \left(\frac{GDP_{t\Theta}^d}{GDP_t^d}\right) \tag{10.3}$$

Changes in the consumer price index CPI_t^d can then be estimated by assuming a simple relationship with the baseline GDP deflator, in which:

$$CPI_t^d = \left(\frac{CPI_{tB}}{DEF_{tB}}\right) * DEF_t^d \tag{11}$$

2.2 Supply-Side Effects Generated by the Completed Project

Once the construction of the project has been completed it will produce additional increases in real GDP by fulfilling its economic functions. The increase in nominal GDP is obtained by multiplying real GDP by the baseline GDP deflator.

$$GDP_{t\Theta}^{*s} = \sum_{j=1}^{N} DEF_{jtB} * GDP_{t\Theta}^{*s} \tag{12}$$

After deducting tax revenues the resulting increase in nominal GDP will create additional consumption, investment, exports and import substitution effects M_t^{*s} as a result of the increased productive capacity of the domestic economy. This is calculated as:

$$GDP_{t\Theta}^{*s} = \sum_{ij=1}^{N} GDP_{t\Theta}^{*s}\Phi_{ij} + \mu G_t^{*s} \tag{13}$$

where Φ_{ij} is the proportion of GDP that goes to demand components i, consumption C_t^{*s}, investment I_t^{*s}, exports X_t^{*s}, import substitution M_t^{*s} and tax revenue T_t^{*s}, across economic sectors j. Meanwhile, μ is the share of additional tax revenue that goes to increased public spending. It is assumed additional tax revenue resulting from supply-side effects will not be spent by the government, and hence μ is equal to zero.

Adding the increase in nominal output generated by supply-side effects $GDP_{t\Theta}^{*s}$ to the demand-related increase $GDP_{t\Theta}^d$ obtained above yields the total nominal increase in output $GDP_{t\Theta}$.

$$GDP_{t\Theta}^d + GDP_{t\Theta}^{*s} = (C_t^{*s} + C_t^d) + (I_t^{*s} + I_t^d) + (X_t^{*s} + X_{tB}) + G_t^d + T_t^{*s} + M_t^{*s} \tag{14}$$

Dividing nominal output and its demand components by the baseline GDP deflator produces an estimate of real GDP and its demand-related components.

2.3 Overall Effects on Key Macroeconomic Variables

The impact of the investment project on the specified range of macroeconomic variables is summarized below:

Consumption, $C_t = C_t^{*s} + C_t^d$ (15.1)

Investment, $I_t = I_t^{*s} + I_t^d$ (15.2)

Exports, $X_t = X_t^{*s} + X_{tB}$ (15.3)

Imports, $M_t = M_t^{*s} - M_t^d$ (15.4)

Total demand, $TD_t = C_t + I_t$ (15.5)

Tax revenue, $T_t = T_t^d + T_t^{*s}$ (15.6)

Total revenue, $TR_t = T_t + U_t$, where $U_t = u_t G_t^*$ (15.7)

U_t are total user fees, and u_t are user fees as a proportion of additional government spending.

The revised GDP deflator resulting from demand and supply effects can then be calculated as:

$$DEF_t = \frac{GDPt_{\Theta}}{GDP_t} \quad (15.8)$$

2.4 The Impact of the Investment Project on Debt Dynamics

The impact of public investment projects on debt dynamics is an important consideration for any government, and it is an especially critical concern when a significant share of investment spending is financed by borrowing, even if much of that borrowing is on concessional terms.

Nominal debt can be estimated using the following equation, where current debt D_t depends on last year's debt D_{t-1} multiplied by the average interest rate i_t on foreign and domestic debt minus the primary balance PB_t and seignorage revenue ΔM_t. This can be expressed as

$$D_t = D_{t-1}(1 + i_t) - (PB_t + \Delta M_t) \quad (16)$$

where, the average interest rate $i_t = \varrho i_d + (1 - \varrho) i_f$ (16.1)

and, $\varrho = D_{dt}/D_t$ represents the share of domestic debt in total debt, while i_f and $i_d$are the interest rates on foreign and domestic debt, respectively.[12]

Debt sustainability is estimated by dividing the current debt stock by nominal GDP. Debt as a proportion of GDP d_t depends on debt dynamics υ_t, along with last year's debt stock, d_{t-1}, the primary balance and seigniorage as a percentage of GDP:

$$d_t = \upsilon_t d_{t-1} - (pb_t + m_t) \quad (17)$$

[12] It is assumed that foreign debt is denominated in euros or in a euro-backed currency such as the CFA franc, and therefore an exchange-rate term is not required.

where $\upsilon_t = \frac{(1+i_t)}{(1+g_t)(1+\pi_t)}$ (18)

An investment project's anticipated impact on debt dynamics should be a major consideration for national policymakers and their development partners. If $\upsilon_t > 1$, then debt as a proportion of GDP is likely to be unsustainable. Therefore, if the expected borrowing cost of the investment project represents a significant share of GDP, it is important from the outset to compare the interest rate on new debt with the projected growth rate of real GDP g_t and the GDP deflator, π_t.

2.5 The Internal Rate of Return

Finally, the internal rate of return (IRR) for the program can be estimated based on:

- The fiscal financial internal rate of return (FIRR);
- The economic internal rate of return (EIRR);
- The economy-wide internal rate of return (EWIRR); and,
- The IRR for indirect costs and benefits generated by the project (PIRR).

The FIRR provides us with the IRR for the government, as it calculates the public costs of the project minus the revenues it will generate. To obtain the FIRR project financing is split into loans and grants:

$$G_t^{*d} = G_t^{*d}(\chi_{1t} + \chi_{2t}) \quad (19.1)$$

where χ_{1t} and χ_{2t} represent the relative share of project spending financed by loans and grants, respectively. Defining the total loans required for the investment project as $l_t = G_t^{*d}\chi_{1t}$, and $GR_t = G_t^{*d}\chi_{1t}$ enables us to calculate the program's FIRR as:

$$FIRR = \sum_t^N \frac{l_t(r_t+a_t)+(RC_t-U_{t)}-T_t^*}{(1+IRR)} \quad (19.2)$$

where, r_t and a_t denote the interest rate and amortization costs of all project loans, while RC_t represents the project's recurrent costs and U_t indicates user fees levied by the government to cover a share of the project's recurrent costs.

The EIRR is estimated by subtracting additional public investment spending G_t^{*d} and recurrent costs RC_t from the project-related increase in GDP determined above.

$$EIRR = \sum_t^N \frac{GDP_t^* - [\,G_t^{*d} + RC_t]}{(1+IRR)} \quad (19.3)$$

Similarly, the economy-wide IRR is estimated by deducting private investment costs PI_t and additional public investment and recurrent costs from the project-related increase in GDP. This indicator measures of the impact of the program on the broader national economy.

$$EWIRR = \sum_t^N \frac{GDP_t^* - [\,G_t^{*d} + PI_t + RC_t]}{(1+IRR)} \quad (19.4)$$

Finally, we can estimate the IRR for indirect project costs and benefits by deducting private investment costs $\mathrm{PI_t}$ from the increase in GDP generated by demand-side effects $\mathrm{GDP_t^{*d}}$. This indicates the returns to the private sector resulting from the project's implementation.

$$\mathrm{PIRR} = \sum_{t}^{N} \frac{\mathrm{GDP_t^{*d}} - \mathrm{PI_t}}{(1+\mathrm{IRR})} \tag{19.5}$$

3. Case Study: The Kandadji Dam in Niger

The following section uses the model described above to assess the prospective macroeconomic impact of a large public investment project currently underway in Niger. The construction of the Kandadji Dam on the Niger River will significantly increase the country's electricity supply and provide irrigation to surrounding farmland. Applying the model requires making assumptions regarding the various parameters outlined in the previous section. These parameters will vary by sector and by country, and the assumptions used in this section are not necessarily applicable to other projects. This section discusses how the model incorporates the data for a specific project as well as selected values for the estimated parameters. In all cases the effectiveness of the model will depend in large part on the accuracy and availability of detailed macroeconomic statistics and basic project-related information, both of which will differ by country. As the parameter assumptions will also impact the reliability of the model, a sensitivity test evaluating the impact of changes in certain key parameters is included.

3.1 Context: Niger and the Construction of the Kandadji Dam

Niger is a large, landlocked country in Sahelian West Africa, with a total land area of 1.267 million square kilometers and a population of about 16 million. Niger currently ranks 186th out of the 187 countries included in the UN Human Development Index, and in 2010 its GDP per capita (purchasing power parity) was US$720.

The model was developed in response to a request from the Nigerien authorities, and the anticipated launch of the Kandadji Dam project provides a natural opportunity for a case study. Moreover, Niger is an especially appropriate country in which to apply the model. Despite repeated shocks, including droughts, flooding and regional instability, Niger has managed to steadily increase its per capita GDP since 2000. This trend has been underpinned by a relatively high rate of public investment, which reached x percent of GDP in 2013. In addition, macroeconomic analysis in Niger is facilitated by its fixed exchange rate,[13] which simplifies the calculation of domestic price changes and effectively eliminates potential monetary policy adjustments as an exogenous variable.[14]

Over the next decade the Nigerien authorities are planning to undertake a number of new public investment projects with significant macroeconomic implications. In recent years the bulk of Niger's public investment budget has been devoted to rehabilitating and expanding the road network, but the government is now rapidly diversifying its investment program.

The Kandaji Dam is one of the largest public investment projects ever undertaken in Niger, and its economic benefits are expected to be substantial. At present, Niger's agricultural sector, which accounts for around 60 percent of GDP and employs 80 percent of the population, is heavily dependent on the Niger River basin, the country's only reliable source of water. The construction of the Kandaji Dam and its reservoir will not only significantly boost agricultural production and enhance the sector's resilience to droughts, it will also

[13] Niger is a member of the West African Economic and Monetary Union (WAEMU) and uses its common currency, the West African CFA franc. The CFA is pegged to the euro, and monetary policy is managed at the regional level by the Central Bank of West African States (*Banque Centrale des États de l'Afrique de l'Ouest* – BCEAO).

[14] The model is easier to manage in a fixed exchange-rate environment but it can also be used in countries with other monetary and exchange-rate policies.

dramatically increase the country's electricity-generation capacity, opening new production possibilities both within and beyond the agricultural sector.[15]

The Kandadji Dam is the first large project to be implemented under a new public investment program set forth in Niger's most recent poverty reduction strategy paper. The present analysis treats the dam as an individual project, but the model could also be used to assess the impact of the public investment program as a whole. Provision is made in the model to outline the stream of costs and benefits project-by-project, taking into account cross-spillover effects.

This approach would be useful in cases where multiple projects generated complementary benefits, making their combined impact greater than the sum of their individual returns, or in cases where simultaneous implementation increases pressure on domestic supply, compounding the macroeconomic impact of the construction phase. The model allows projects to be analyzed individually and then integrated into a single set of investment variables, so that an entire investment program can be assessed as though it were a single project.

3.2 Methodological Approach and Assumptions

The values used below were determined through a standard financial programming model. The baseline reflects a set of macroeconomic projections that exclude the investment project. The historical data used in the macroeconomic framework are taken from the IMF website, however the projections are unique to this analysis. The model excludes a significant proportion of the public investment program, which not only lowers the estimated fiscal expenditures but also reduces the economic growth and imports projections. For example, future agricultural output is extrapolated from the average growth rate during 2000-13, which was below 4 percent. The authorities' current agricultural growth projections are significantly higher than this, as they assume a significant increase in public and private investment in the sector. This paper's baseline projections deliberately exclude changes in investment in order to isolate the impact of the project.

The set of assumptions regarding the national accounts are described in Table 1, below. These assumptions are made on the basis of accuracy, simplicity and proportionality; they include (i) the allocation of public resources to different input types; (ii) each input type's contribution to domestic consumption, imports, investments, savings and tax revenues; and (iii) firms' supply decisions and price responses to increases in demand, which vary by sector.[16]

[15] Since the 1970s Niger has repeatedly experienced severe droughts, and the variability of the Niger River has constrained agricultural production, exacerbated food insecurity, and disrupted the country's water supply.

[16] Sectors that are relatively slow to adjust supply, such as construction, tend to exhibit larger price effects that persist over a longer period than more responsive sectors, such as services.

Table 1: Selected assumptions used in the model

Table X. Selected assumptions for the model

	Coeff.	Value	Source/ justification
		in percent of resource types	
Resource share: inter. Labor	θ_{1j}	23	Based on program costs.
Local labor	θ_{2j}	9	Based on program costs.
Inter. capital	θ_{3j}	54	Based on program costs.
Local capital	θ_{4j}	14	Based on program costs.
MPC: inter labor	α_{1j}	30	Based on estimates of accomodation, living expenses, savings, and
Local labor	α_{2j}	80	taxes as a proportion of incomes.
Inter. capital	α_{3j}	0	
Local capital	α_{4j}	70	
MPI	β_{ij}	10	
		in percent of total resources	
MRT	τ_{ij}	0.02	Assume low taxes due to tax evasion.
MPM (in percent of total res.)	δ_{ij} ω_{ij}	72	Assume high MPM due to large capital imports for the program.
MPS		6	
		other assumptions (in percent)	
Average int. rate	i_t	2.5	Program is primarily financed by concessional foreign loans.
Elasticity of supply	$dQS_{jt}/dP_{jt} * P_{jt}/Q_{jt}$		
Const.: short-run		10	Supply response constrained by fixed capital and lack of substitution with
long-run		90	
Agriculture: short-run		15	Supply is fixed in the short-run. Assumption of 15% stocks.
long-run		90	
Transport: short-run		30	Significant spare capacity in the short-run.
long-run		90	
Manufacturing: short-run		40	Moderate spare capacity to increase output.
long-run		90	
Services: short-run		75	Labor constitute large proportion of output.
long-run		95	

3.3 Impacts on Key Macroeconomic and Fiscal Indicators

As noted above the total cost of constructing the Kandadji Dam is estimated at US$785 million, or more than 10 percent of Niger's GDP in 2013. During the construction phase the implementation of the project will make a significant contribution to aggregate demand over a period of several years. This impact is likely to be concentrated in certain sectors, such as construction and transportation, while semi-subsistence agricultural production will be less affected. The model identifies the additional demand for some sector-specific goods and services and assesses the extent to which this demand will met by increased supply or by higher prices. Once completed, the dam will boost both agricultural output and electricity generation capacity as reported in the cost-benefit analysis prepared by the project team. The model projects the completed project's impact on net exports, domestic savings and investment, but it begins by examining changes in prices and domestic supply generated during the construction phase.

Impact on prices: The results indicate a low overall impact on the GDP deflator, but substantial fluctuations are observed across sectors and over time. A significant increase in construction prices is observed at the start of the implementation phase, but after the project is completed the GDP deflator drops below the baseline. This is due to both the completed project's impact on economic productivity, as well as the increase in supply prompted by additional demand during its construction.

Impact on supply: As described above, the project is expected to increase aggregate supply in two ways—by boosting aggregate supply during the construction phase and then by expanding the productive capacity

of the economy once it is complete. The model estimates that the overall effect on supply will yield a 1.4 percent increase in real GDP at the end of the construction phase. This supply expansion will put downward pressure on prices once the dam becomes operational, and an increase in the quantity demanded will restore equilibrium. During the construction phase the most significant increases in supply are projected to occur in the construction and agricultural sectors. At the end of the implementation phase the productive capacity of the construction sector is projected to increase by 3.9 percent. The model assumes that the additional capacity developed during the construction phase will be put to other uses after the project is completed, and that learning-by-doing will produce a lasting increase in the competitiveness of the sector.

The completion of the project is expected to significantly increase long-term agricultural output and electricity generation. The cost-benefit analysis prepared by the project team projects that agriculture sector will grow by 0.33 percent of GDP and that the electricity supply will rise by 0.55 percent.

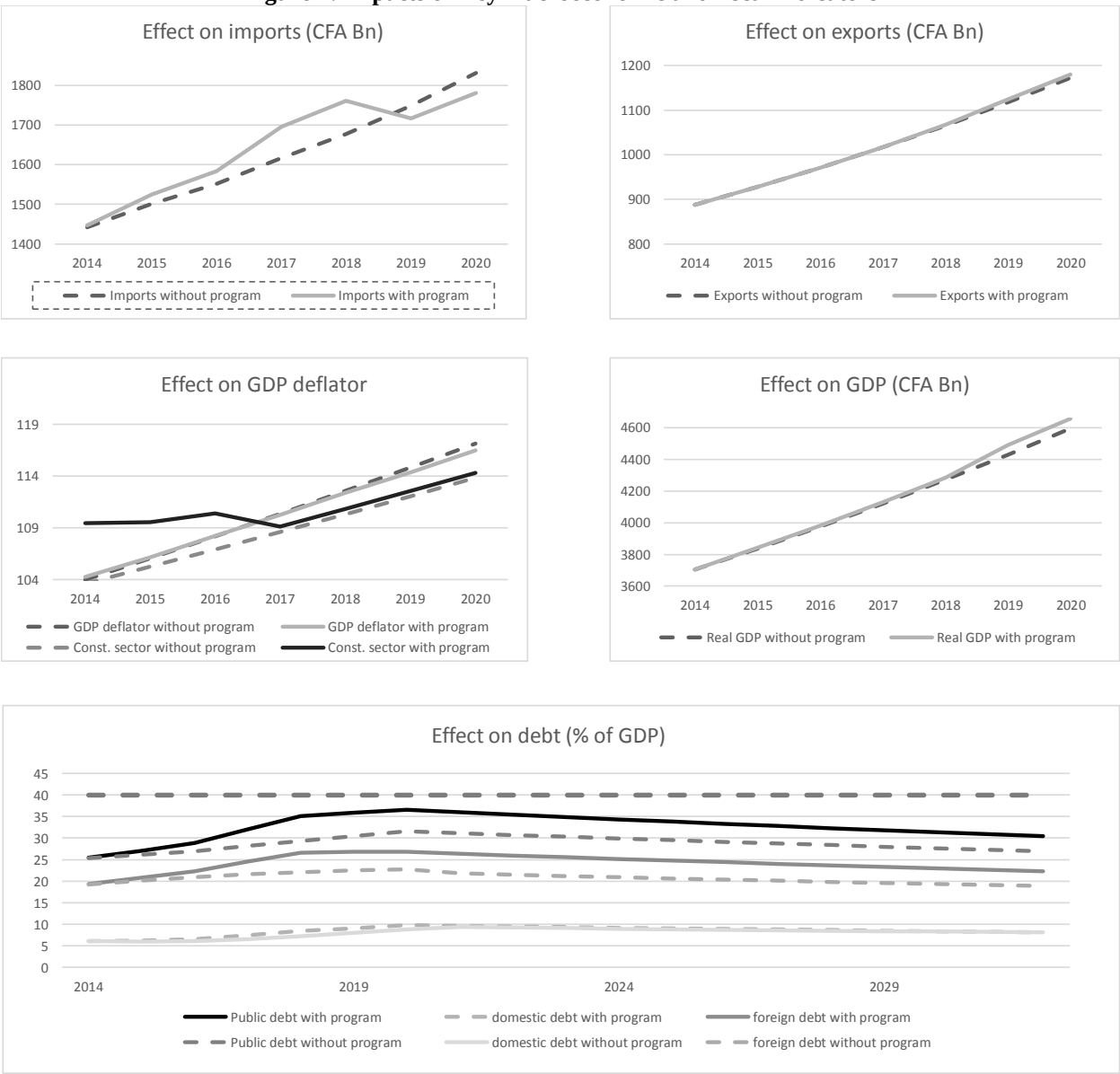
The model does not capture multiplier effects that may result from the expansion of the agricultural and electricity sector, and the supply-side projections should be regarded as lower-bound estimates. This approach is deliberately conservative and reflects incomplete data on which to base estimates of the project's prospective multiplier effects. If these data were available, it could be integrated into the model; this would increase the project's estimated rate of return and lessen its impact on debt sustainability.

Impact on imports: Imports initially increase during the project's construction phase. The increase in additional imports due to the project is estimated at around 0.4 percent during the first year of implementation; it then rises in each subsequent year, ultimately reaching 5 percent in the year of the project's completion. This effect is reversed once the project is operational, as expanding domestic production significantly reduces import demand.

Impact on exports: The impact on exports are limited, since it is assumed that the large proportion of project benefits will result in an increase in import substitution.

Fiscal impact: As with exports the public revenue impact of the project is observed only after its completion. Expenditures increase during the project's construction, and while some of these investment costs are covered by grants, the fiscal deficit significantly widens. Higher fiscal costs continue after the project is completed, due to the demands of its operation and maintenance, but the government also starts to receive user fees and additional tax revenues generated by increased production. However, the net impact on the fiscal deficit remains negative over the projection period, as almost all additional tax revenues are devoted to resettling communities displaced by the dam and reservoir.

Figure 1: Impacts on key macroeconomic and fiscal indicators



Debt impact: The impact on debt dynamics is projected to be limited based on the assumptions regarding grants and concessional loans. Initially, debt is expected to increase as a percentage of GDP, rising to 37 percent in 2020 compared to a baseline projection of 32 percent. However, the completion and operation of the project will ultimately reduce the debt-to-GDP ratio, which is projected to fall to 30 percent by 2032. In the baseline projection the debt-to-GDP ratio drops to 27 percent, somewhat lower than in the project scenario, but the decline is less steep. In the project scenario the debt-to-GDP ratio falls by around 500 basis points after the dam is completed, whereas in the baseline scenario it drops by just 460 basis points. The cost of the investment generates a net increase in the stock of public debt at the end of the implementation

period; however, the debt stock decreases over time due to the assumed primary surplus of 2 percent of GDP during the period. The overall impact on the public debt is presented in the debt sustainability analysis, the conclusions of which are summarized below.

Table 2: Internal rate of return (IRR) by type

Type	Internal rate of return
Fiscal financial (FIRR)	4
Economic (EIRR)	17
Economy-wide (EWRR)	14
Project's indirect costs and benefits (PIRR)	12

3.4 Sensitivity Analysis

A sensitivity analysis was applied to the model to assess how it responds to different values for the coefficients described above, particularly the fiscal financial internal rate of return. The table below summarizes the results of sensitivity tests on three coefficients: the interest rate of foreign financing i_f the marginal propensity to import $\delta_{ij,}$ and the elasticity of supply $dQS_{jt}/dP_{jt} * P_{jt}/Q_{jt}$.

Table 3: Sensitivity tests of coefficient assumptions, in percent

Coefficient	Assumed value	Sensitivity value 3/	Internal rate of return (IRR) 2/			
			FIRR	EIRR	EWIRR	PIRR
i_f, REP 1/	2.5, 40	18, 20	-	17	14	12
δ_{ij}	72	40	4	21	18	-
$dQS_{jt}/dP_{jt} * P_{jt}/Q_{jt}$ 2/	10, 90	5, 5	4	14	12	-

Notes

1/ These coefficients, represent the terms of the foreign financing of the program, namely the interest rate on foreign debt, i(f) and the repayment period of the loan, REP. Their respective assumed values assuming IDA loan terms are in column i.

2/ The short-run and long-run supply response to an increase in demand are reported for the elasticity of supply. Respective values are in column i.

3/ The sensitivity value makes changes to the respective assumed values of the variables to estimate the impact on the internal rates of return.

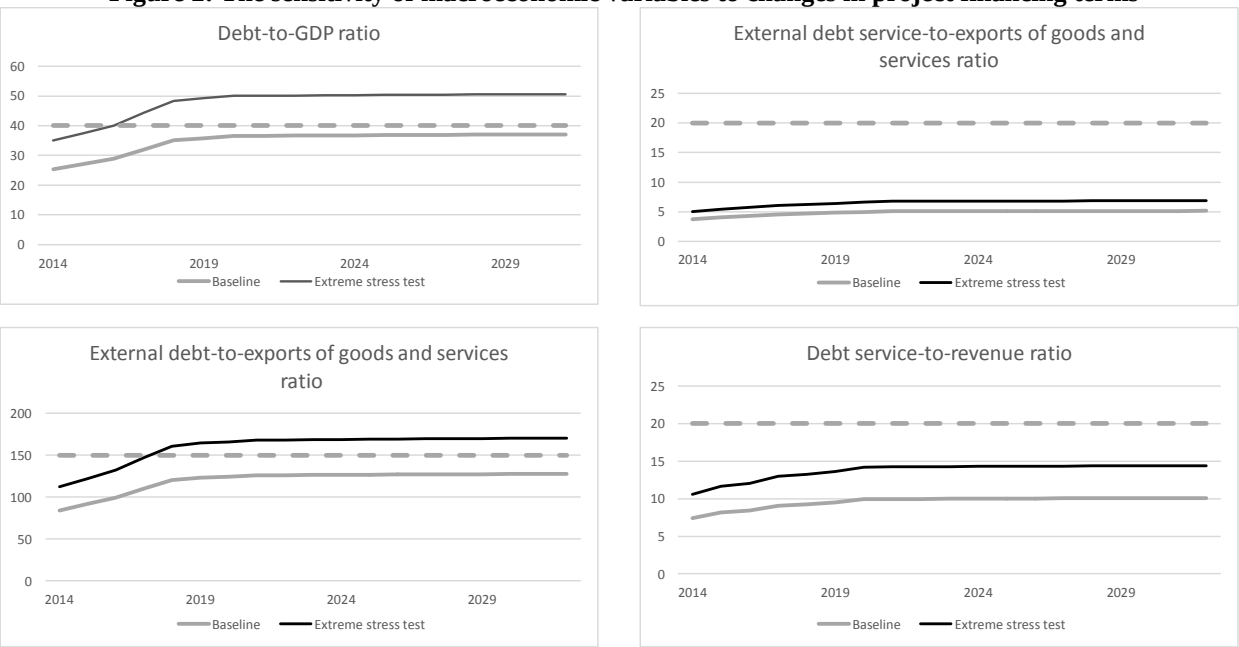
Scenario 1: Sensitivity to External Financing Terms

The terms on which the project's external financing is obtained have a limited impact on macroeconomic variables. Project costs represent a small share of total debt, peaking at roughly 15 percent of debt. Even under adverse loan terms the effect on debt financing is not severe enough to prompt the government to increase taxes or reduce spending, and as a result its impact on most macroeconomic variables is negligible.

While negligible impacts are not shown here, some of the more significant effects of adverse loan terms are described below. Figure 2 shows a slight increase in debt ratios towards the end of the program period as opposed to the decline observed in the original results. In a more extreme stress test the debt breaches its

threshold, both as a share of GDP and as a percentage of exports of goods and services. This would require the adoption of austerity measures to return the debt to a sustainable level, with second-order effects on macroeconomic variables.

Figure 2: The sensitivity of macroeconomic variables to changes in project financing terms



Scenario 2: Sensitivity to the Marginal Propensity to Import (MPM)

A reduction in the MPM parameter has a moderate impact on IRR indicators and macroeconomic variables, particularly GDP, the GDP deflator and imports. The effect on debt dynamics is insignificant and is not reported here. An increase in tax revenue is observed, but this effect is very small.

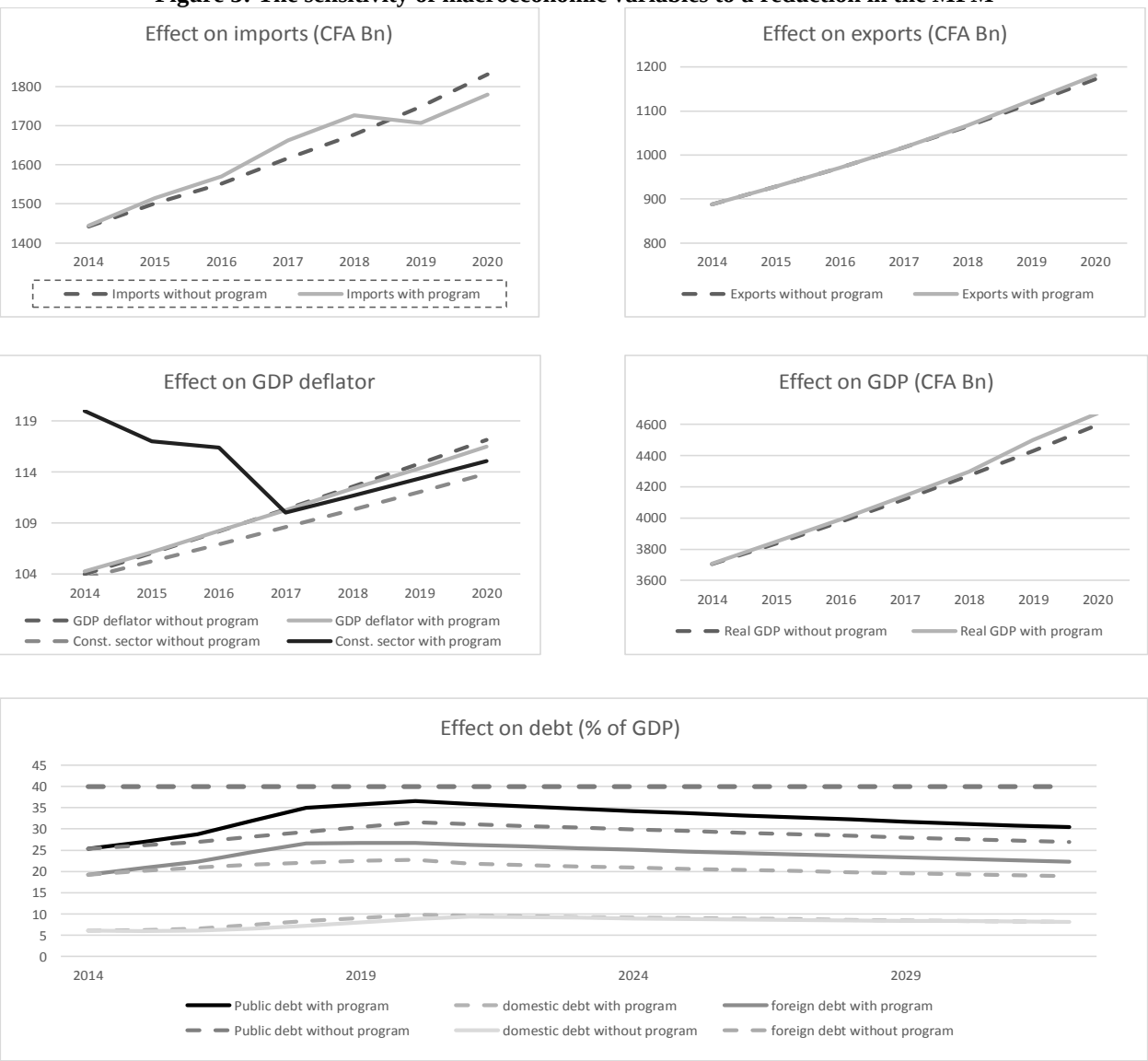
Reducing the MPM implies a large-scale substitution of local labor θ_{2j} for international capital θ_{3j}. This is more likely in the case of relatively labor-intensive projects such as road construction as opposed to the capital-intensive Kandaji Dam. In some situations it may be possible to replace international capital with domestic labor, but this would likely increase the time required for project implementation.

Substituting domestic labor for imported capital increases the marginal propensity to consume and therefore intensifies domestic demand for goods and services during implementation. This increases the demand-side effects of project implementation, permanently raising the annual GDP growth rate by around 0.2 percent. It also magnifies the initial price increase in the construction sector (as shown below), which then declines in subsequent years as the expanding supply of construction services lower prices.[17] Finally, rising demand pressure generates a modest increase in the IRR.

[17] The effect of the price increase in the construction sector is assumed not to affect exports, since the construction sector does not export goods and services.

This scenario demonstrates the limitations of the model, which excludes the resource-allocation effects of traditional CGE modeling. While this model reveals how the project will affect the construction sector directly it ignores the indirect impact of changing construction prices on other sectors. Consequently, any potentially negative effects caused by the reallocation of productive resources are omitted. It is possible that the presence of idle or under-utilized assets would allow the construction sector to expand without negatively impacting other sectors, but this is unlikely given the highly specialized and scarce construction skills and services required by the Kandadji Dam project.

Figure 3: The sensitivity of macroeconomic variables to a reduction in the MPM

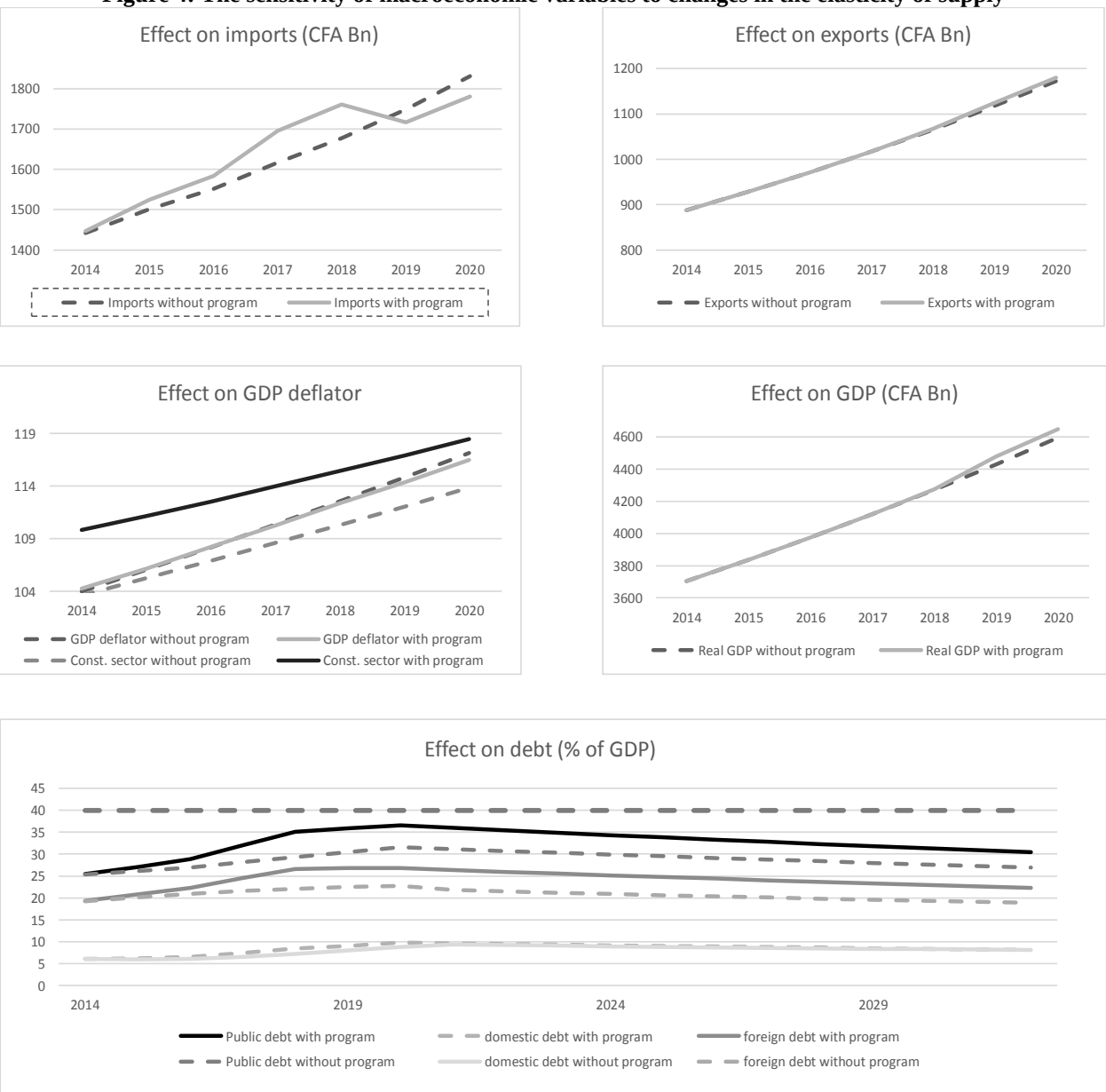


Scenario 3: Sensitivity to the Elasticity of Supply

A significant reduction in the elasticity of supply results in minor changes in the IIRs and in macroeconomic variables, particularly GDP growth. For the purposes of the sensitivity test the elasticity of supply was

assumed to be close to zero (.05) in order to reduce the supply response and increase the price response to demand effects stemming from the project's implementation. Under this scenario the GDP growth rate fell by just 0.2 percent during the construction phase, as the impact of demand effects on real GDP were virtually eliminated. This affected the IRRs, which fell by an average of 3 percentage points. Effects on other macroeconomic variables were generally limited. While the change in the overall GDP deflator was minor, an initial price shock increased prices in the construction sector. However, the impact of this price shock diminished quickly over time.

Figure 4: The sensitivity of macroeconomic variables to changes in the elasticity of supply



4. Policy Applications

Large public investment projects typically involve many policy decisions both before and after a given project is selected. This section discusses how the model described in the working paper can be used to assess the macroeconomic impact of different policy options. For instance, the model can be used to compare a baseline strategy for implementing the project with an alternative that is less expensive, but that increases the time required. This is merely one example designed to illustrate the model's policy applications, but it could be used to compare the Kandaji Dam project's construction plan with those of similar projects elsewhere in SSA, such as the Renaissance Dam in Ethiopia. The Kandadji Dam is being built according to World Bank-sanctioned competitive procurement policies that reduce project costs but lengthen construction time. By contrast, the Renaissance Dam used single-source contracting that accelerated construction but increased project costs.

The model presents the results for both a baseline and an alternative scenario in which competitive procurement practices reduce costs by 20 percent but increase construction time by 50 percent. The IRRs for the baseline and alternative scenarios are presented in Table 4, below. The results are broadly similar, indicating that a 20 percent reduction in costs may justify a 50 percent increase in construction time. The FIRR is significantly better under the alternative scenario, and there are noticeable differences between the EIRR and EWIRR. The effect on macroeconomic variables is also limited, and the results are not presented here. Extending the construction time cuts GDP growth by around 0.14 percentage points, but all other macroeconomic impacts are insignificant. Overall, policies that promote the swift completion of the project tend to become more attractive the higher the interest rate on new debt and the larger the economic impact of the completed project.

Table 4: Internal rates of return under the baseline and alternative scenarios

	Scenario	
	Current	Altern.
FIRR	3.8	4.3
EIRR	17.0	18.5
EWIRR	14.1	14.6

5. Conclusion

The model described in the working paper allows policymakers to assess the impact of public investment projects on a range of current and future macroeconomic variables. It estimates the macroeconomic costs and benefits of a given project and projects its economic effects both during construction and after completion. By conditioning macroeconomic projections under alternative investment scenarios the model can be used to inform investment policy decisions both over time and between sectors. It can also shed light on the implications of using different methods to implement a single project.

Nevertheless, the model requires accurate information about the project and key macroeconomic indicators, and analysts must make informed judgments regarding the coefficients and estimated parameters used. The data on elasticities, for example, are exogenous. The extent that data are available to inform these judgments will vary by country, and the results are particularly sensitive to the following assumptions: (i) the supply response of the domestic economy during the construction phase; (ii) the increase in output generated by the completion of the project; and, (iii) the origin and terms of project financing. Costly financing mechanisms, even for projects with long-term benefits, may significantly increase debt service payments during the construction phase. Although increased economic productivity and/ or user fees may ultimately offset these costs, an initial spike in debt service could threaten to breach the debt sustainability thresholds defined by the World Bank and IMF.

The case study presented for the Kandadji Dam project indicates that its total cost will equal more than 10 percent of 2013 GDP during the 2014-48 period examined by the model. However, the expansion of domestic production spurred by increased demand during the construction phase is projected to push 2018 GDP some 0.25 percent above the baseline projection, boosting fiscal revenues by an additional 0.45 percentage points of GDP. Imports would be 5 percent above the baseline, assuming that the project's marginal propensity to import was around 72%. Ceteris paribus, the marginal propensity to import will be lowest for low-tech, labor-intensive projects with a clear impact on demand, such as a rural road expansion, and highest for high-tech, capital-intensive projects with limited ties to the broader national economy, such as an offshore oil platform. The Kandaji Dam essentially splits the difference, combining a substantial degree of import content with the mobilization of local productive factors.

The model is designed for simplicity and ease of use. It is based on an excel spreadsheet rather than more sophisticated statistical software, and all assumptions and formulas are directly visible to the analyst. The model uses standard definitions for national accounts statistics, and its projections are designed to be consistent with existing policy classifications. The model presents the set of macroeconomic variables typically used in a debt sustainability analysis (DSA), including those highlighted in the DSA framework used by the World Bank and IMF.

However, despite being user friendly the model has a number of limitations:

- First, this is a static model and does not consider through feed-through effects, particularly at the macroeconomic level. As a result, the model is particularly unsuitable for projects that have significant spillover effects or which are likely to induce rapid structural change. Such projects would call for a more traditional general equilibrium approach. This type of structural change could be indicated by one sector expanding much more rapidly than any other, but the example of the Kandadji Dam did not reveal such an expansion in the baseline scenario.

- Second, in estimating the impact of a project/ program on the macroeconomic variables the model is highly dependent on robust impact estimates.
- Third, the equations underpinning the model describe the broad effects of the project on the macroeconomic variables. While these mainly hold true, care should be taken to customize these to particular country contexts.
- Fourth, following on from the previous point this the model does not consider exchange rate effects, since most trade is within a fixed exchange rate regime (CFA).
- Fifth, given the limited number of equations, the model is highly sensitive to assumptions underpinning the model. This was noted in sensitivity tests of some of the coefficients.

Nevertheless, there is considerable scope to expand the model while keeping its user friendliness. For example, incorporating second and third order spending effects into the model.

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