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IMPACT OF INFRASTRUCTURE SPENDING IN MALI: A CGE MODELING APPROACH

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Abstract

In this paper we construct a standard CGE model to explore the impact of scaling up infrastructure in an African country. As the debate on the importance of scaling up infrastructure to stimulate growth and provide a push to African economies, some analyst raise concern on financing these infrastructures after construction and that external funding of these can create major distortion and have a negative impact on the trade balance of these countries. This study aims to provide so insight into this debate. It draws from the infrastructure productivity literature to postulate positive productive externalities of new infrastructure and Fay and Yepes (2003) for operating cost associated with new infrastructure. We compare various infrastructure investment funded with different fiscal tools. These investments scenarios are compared to non productive investment that can be interpreted as a business as usual scenario. Our results show that foreign aid does produce Dutch disease effects but the negative impacts are strongly dependent on the type of investments performed. Moreover, growth effects contribute to attenuate the negative effects.

JEL codes: C68, D68, E62, F35, H54.

Keywords: Investment externalities, foreign aid, exchange rate, fiscal reforms

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1. Introduction

In light of the large potential increase in Sub-Saharan African infrastructure financing by donors, this proposed work looks at the scope for such financing to be fiscally sustainable. The immediate priority of this work is to feed into the flagship study of Africa's infrastructure by highlighting the extent to which infrastructure investment choices are compatible (or not) with an objective of fiscal sustainability. A computable general equilibrium (CGE) approach is used to compare the impact of increase infrastructure spending in one African country, namely Mali. Recent studies (Gupta et al (2006), Foster and Killick (2006), Mckinley (2005)) have suggested that scaling up aid in Africa will have negative macroeconomic consequences among which the spreading of the Dutch disease. Adam and Bevan (2006) have investigated increasing aid to fund infrastructure with a computable general equilibrium (CGE) model to arrive to this conclusion. In the paper, they show that if non tradable sectors also benefit from infrastructure investment externalities, the negative effect can be attenuated. In the work they construct an aggregated model to verify this and apply it to Ugandan data.

In this paper, we extend this idea by dropping the dichotomous classification of sectors in tradable and non tradable and use more sectors that are not completely tradable or non tradable. In most African countries, we find some sectors as being non tradable (construction sector) and some mostly tradable (rent agriculture) but we generally find sectors with variable relative shares of exports over total production. We extend the idea of Adam and Beven (2006) for differentiated externalities of infrastructure spending and by disaggregating our model we allow for a matrix of externalities between productive sectors and the type of infrastructure expenditure. For this we draw on Savard and Adjovi (1998) in which they analyze the externalities of health and education investment of different productive sectors.

An important literature has demonstrated that public investment in infrastructure taken in the broad sense generates positive production externalities and improves human capital productivity

(Barro 1991)[1]. The improvement in human capital is generally associated with investments in health and education infrastructure. This phenomenon is even more important in developing countries given the starting point of health and educational indicators in these countries (Davies 2003). A few authors have attempted to take into account the impact of public expenditure in general in CGE models such as Savard et Adjovi (1998), Anderson and Martin (1998), Fougère and Mérette (1999), Dumont and Mesplé-Somps, (2000), Jung and Thorbecke (2003) and Voyvoda and Yeldan (2005),. With the exception of Adam and Bevan (2006) the authors concentrate mostly on health and education expenditure and not infrastructure investments specifically. In our case, we will focus on the implications of increasing investment in infrastructures and funding schemes to fund operating costs of the new infrastructures. As in Adam and Beven (2006), we are interested in investigating the trade impact of these investments in different modes of financings the investments. As there is more and more concern about the negative impact of scaling up aid (see McKinley (2005), Gupta et al (2006) and Foster and Killick (2006)) which is necessary for massive investment in infrastructure. Among the concerns raised by these authors we can state the impact on current account balance or exchange rate and the creation of the Dutch disease.

Our model will also introduce an additional element of imposing increases in public expenditure to maintain and repair the new public infrastructure. This will be included in the government budget constraint and various funding options will be investigated through fiscal policy, foreign aid. The model will introduce different modes of taxation will provide and interested basis for comparative analysis between different financing options.

By doing a comparative analysis we will be able to see if the results obtained by Adam and Bevan (2006) for Uganda is a special case scenario or if the same type of conclusion is robust to the economic structure of the country analyzed. The model will be disaggregated into seven sectors. These sectors will allow capturing country specificities in terms of its economic structure. We have selected to used the following seven sectors as they are quit representative of

[1] Among these authors, we can refer to Ashauer (1989), Munnell (1990), Bajo-Rubio and Sosvilla-Rivero (1993), Gramlich (1994), and Dessus and Herrera (1996) for production externalities in general as well as Barro (2001), Bils and Klenow (2000) for externalities on human capital.

what is found in most sub-Saharan countries; food crop agriculture, export agriculture, mining and oil, manufacturing, construction, private services and public services.

2. The country of application and social accounting matrix

We have selected a country which has achieved its completion point as part of the Heavily Indebted Poor Countries (HIPC) Initiative as these are the countries most likely to benefit from the important investment in infrastructure by external donors. Mali achieved this completion point in July 2003. In the following table we have presented a few indicators of Mali.

Table 1: Characteristics of Mali

Statistics of Mali (2001)	Value
Size (km2)	1240000
Population (million)	12.3
GDP (billion $)	1.56
GDP/capita	900 $
Investment rate	20,50%
Private investment share	60%
FDI (million $)	79
Gross foreign aid (% of GDP)	9.8%
Gross foreign aid (million $)	299.7
Main production	Agriculture
Main imports	Machine (30%), Oil (20%)
Main export	Gold (55%), Cotton (20%)
Geography	Landlock

Mali is a landlocked country that has experience good GDP growth rate since 2000 (around 5%). The private investment share in total investment is above average in the sub region. Agriculture is the main contributor to the GDP and has remained relatively constant over the last 10 years (between 40 and 48%). The mining sector expended significantly in the early 2000 but has been relatively stable since then. It has gone from a 2.2% contribution to the GDP to 9% contribution over a period of 10 years (DNSI 2007).

Our analysis will focus on a number of items *inter alia*, differential sectoral impact of the investments, budgetary impact, welfare changes for all agents of the model (households, government, firms and rest of the world), and other macro and sectoral variables of the model. The choice of the macroeconomic closure of the models will in part determine which variables

will be analyzed. Though based on the usual micro-macro foundations, the model is calibrated on social accounting matrix of 2001 for Mali. Different aspect of infrastructure investment are analysed and the different funding scenarios will be simulated to investigate the most efficient mode to finance operating cost of infrastructure investment. We also assume that infrastructure investment will contribute to increasing the production in the different sectors of the economy.

3. The model

As we mentioned previously, we draw on Adam and Bevan (2006) by using a CGE model to analyse the impact on major investment in infrastructure on a developing economy but we extend there analysis by using a more disaggregated model. Hence, we can validate if their conclusions still hold on an economy with a different structure and investigating the impact on more variables of interest. The basic elements of the model are drawn from model EXTER of Decaluwé et al (2001) and adjustments were made to introduce infrastructure production externalities.

The basic idea we will exploit here is to introduce a function with a sector specific externality elasticity of infrastructure investment on the different production sectors by drawing on the literature referred to earlier. We have adapted our model to take into account four types of investment. However, it is quit trivial to adjust to consider other types of investments. The four types of investments we will be analyzing in our paper are investment for road infrastructure, health infrastructure, education infrastructure and telecom infrastructure.

The main hypotheses of our model are that production is determined in the first place through a 3-level system: total production of the branch (*XS*) is made up of fixed shares for value-added (*VA*) and intermediate consumptions (*CI*) as is generally assumed in standard CGE modeling. The relationship determining the level of *VA* is a Cobb-Douglas type of function between composite labor (*LD*) and capital (*KD*). It is in this function that we introduce our infrastructure production externality. This value added function is multiplied by the externality function which is a ratio of new investment over past investment with a sector specific elasticity. We will describe this function below. Producers minimize their cost of producing *VA* subject to the production function (Cobb-Douglas). Optimal labor demand equations are derived from this

minimization process. We have assumed that capital is fixed between sectors as it is quit difficult in the medium term in Africa to convert capital to be used in a new production sector following a policy shock. Intermediate consumptions have been modeled as fixed shares from the input/output ratios calculated on the basis of SAM.

Given the characteristics of the Malian economy, we posit hypothesis of a small open economy such that world prices of imports and exports are exogenous to the model. We assumed the Armington (1969) hypothesis for import demand where domestic consumers can substitute domestically produced goods with imports (imperfectly) with a sector specific elasticity of substitution. In sectors where local consumers are indifferent between consuming imported goods versus local goods we will have a high elasticity of substitution and inversely a small elasticity of substitution where consumers prefer one good versus the other. A high elasticity in one sector will imply that a change in relative price between the locally produced good (competing with the imported good) and the imported good will have a strong substitution effect between the two goods. For example, if the price of the locally produced good increases compared to the imported good price, the local consumers will make an important substitution towards the imported good. If the elasticity of substitution is low, this change the same change in relative price will have only a slight substitution effect between the two goods. The elasticity of substitution depends *inter alia* on differentiation of the goods, and preference or taste of local consumers. The relative price of the two goods is the other determinant of the ratio of imported goods versus local goods demand. On the export side, the producers can sell the goods on the local market or export their production and are influenced by relative prices on each market and by their elasticity of transformation of the good for one or the other market.

The different agents' income equations are consistent with the structure presented in SAM. In this model, factor endowments are exogenous and factor payments are endogenous. As capital is fixed by sector we have 6 rental rates for capital and one wage. Dividends paid to households are also endogenous and depend of firm's income after taxes. The private firm's income is the balance of capital remuneration not paid to households to which must be added government subsidies and transfers from the rest of the world. We will describe the government income below. The Government spends its budget in different forms such as consumption public goods,

transfers to households, subsidies to private firms and transfers to the rest of the world and saving. The government savings will be used completely for public investment expenditures.

In our model, we use only one representative household. The demand function for this household is derived from a utility maximization process (Cobb-Douglas utility function). This process generates demand functions which are fixed value share for each goods. Investment demand is decomposed into private and public investment. Private investment is determined by the sum of savings by households, rest of the world and private firms. On the other hand, the public investment is exogenous as we will establish public investment targets to fund new infrastructure and is directly funded by government savings. As we will see, we will allow for different modes to fund the increase in government savings. The two types of investment demand are also specified with a fixed value share function[2]. The final element of demand concerns intermediate consumption. We have already described the demand for intermediate goods which are fixed volume shares based in input-output matrix coefficients.

The price equations are quite standard. We have used the GDP deflator as a price index and it is fixed and used as the numeraire. As stated earlier herein, world prices for imports and exports are exogenous; accordingly the country has no impact on world market prices.

The key assumptions of this model rely on the infrastructure spending which produces positive externalities and these new infrastructure will require increase in government budget to assure appropriate maintenance. Hence, it is important to present the equations directly related to these elements. As other equations are relatively standard we will not put more emphasis on a detailed presentation for them[3]. We can first look at the government income sources (equation 1.1). The government draws its revenues from indirect sales taxes (*Ti*), direct taxes on household (*Td*) and firms (*Tde*) and import duties (*Tim*).

$$1.1 \quad Yg = \sum_{m} Ti_{m} + Td + Tde + \sum_{im} Tim_{im} + Trg + Teg + Tgm$$

[2] In fact, the public investment demand is composed of the construction sector which supply this investment good. This is the origin of the public investment. The benefits of the investment will be captured by our infrastructure externality elasticity parameter.

[3] The complete set of equations, variables and parameters can be supplied by the authors upon request.

The others sources of income are transfers from other agents, these can be negative of positive depending on the observed data in the social account matrix. The three other agents provide transfers to the government, namely the households (*Tgm*), the firms (*Teg*) and the rest of the world (*Trg*). The transfers are always net transfers. Generally the *Tgm* is a negative value, representing various forms of subsidies paid by the government to the households. In countries where public firms are still important the transfers from the firms to the government can be positive if the aggregate public firm makes profits and negative if it runs a deficit. The variables also include subsidies from the government to private and firms. As for the transfers from rest of the world, we represent the net transfers of which we have the foreign aid paid to the Malian government of which we subtract interest payment made by the government to the rest of the world. All of the variables contributing to the government income can be use to achieve the investment target that will be established for our simulations.

This first equation (1.1) does not provide the full picture of the story as the investment will also be linked to government expenditure on public services. The next equation (1.2) is the government budget constraint.

$$1.2 \quad Sg = Yg - G$$

The government spends its income (*Yg*) either on public goods and services (*G*) or on savings (*Sg*). The government savings will entirely be used for public investment (*Itp*).

$$1.3 \quad Itp = Sg$$

At this point, the closure rule used for balancing this budget constraint will be a key element for our analysis. We will introduce an additional assumption that a percentage increase in public investment on infrastructure will require an increase in operation and maintenance cost of these new infrastructures. Hence, the level of government expenditure (*G*) on public goods and services will be a function of its original level of expenditure (*Go*) to which we add the new operation and maintenance cost for the new infrastructures. Since, empirical studies have shown that new public infrastructure generates an additional operation and maintenance cost which varies from regions to type of infrastructure investment, we will have a specific share parameter for each forms of investment. Hence, we will multiply the specific share parameter (ω) to the increase in public investment (*Itp* – *Itpo*), where *Itpo* is the public investment at the reference

period. The value will represent the increase in operation and maintenance cost for the new infrastructure to which we add the original government expenditure that is held fixed in the model. The total government expenditure will (G) will be determined by the following equation:

$$1.4 \quad G = Go + \omega(Itp - Itpo)$$

To determine the value to be attributed to our ω parameter we draw on Fay and Yepes (2003) who measured needs in investments and operation and maintenance cost for different types of public infrastructure investments for 2005-2010 in sub-Saharan Africa. To obtain our share parameters we simply computed that ratio between investment needs and operation and maintenance cost.

Table 2: Value for ω

ω paramters	
Road	0,84
Electricity	0,9
Telecom	0,74

These assumptions postulated for our total public expenditure is equivalent to fixing public expenditure since we will fix an investment objective for each simulation, the public investment (Itp) will also be exogenous and implicitly the government savings (Sg) will also be exogenous given the identity of equation 1.3. Given these assumptions, only one element can adjust to clear the government budget constraint (equation 1.2) and that is the government income (Yg). As this variable is not free in the model since it is determined by; the income generated from other agents, level of production in different branches and level of imports and exports, we will need to free one variable of this equation. In practice, we could use any one of the variables or subvariables on the right hand side of equation 1.1 to balance the government budget constraint. One option would be to leave the Trg endogenous which would mean that the objectives for public infrastructure investment will be achieved by an increase in foreign aid. Another option is to leave one of the tax rates (household income tax, firms' income tax, sale tax and import duties) endogenous. Finally, the transfers from households and firms could also be left endogenous. A joint option could also be simulated by assuming an exogenous increase of foreign aid (Trg) and let one of the tax rates to adjust to complete the funding needs to meet the public investment objectives and increase in operation and maintenance cost.

The other specific assumption in our CGE model to analyze a scaling up of infrastructure investments is the externality equation (1.4) and its role in increase total productivity of factors of the value added (equation 1.5). For this we draw on the vast literature linking public infrastructure to private sector factor productivity and we use the approach proposed by Dumont and Mesplé-Somps (2000) in a CGE context. Our approach differs slightly from theirs as we do not use private investment in our externality function. The externality function externality is defined by the following function:

$$1.5\ \theta_i = \left(Itp / Itpo \right)^{\xi_i}$$

where θ_i is the externality or sectoral productivity effect which is a function of the ratio of new public investment (*Itp*) over public investment (*Itpo*) at the reference period with a sector specific elasticity (ξ_i). Values selected for ξ_i are presented in Table 3.

Table 3: Value for ξ

ξ paramters						
Sectors / Investment	**Crop agriculture**	**Export agriculture**	**Mining & Gas**	**Industries**	**Construction**	**Private Services**
Road	0.05	0.075	0.085	0.035	0.055	0.025
Electricity	0.001	0.015	0.02	0.1	0.075	0.055
Telecom	0.02	0.025	0.015	0.015	0.045	0.035

We do not model direct private sector eviction effect tied to increase in public investment. The externality of public infrastructure investment produces an increase in total factor productivity. This link to the value added (*Va*) is taken into account in the Cobb-Douglas function of the following equation:

$$1.6\ Va_i = \theta_i A_i Ld_i^{\alpha_i} Kd_i^{1-\alpha_i}$$

where A_i is the scale parameter for sector i, Ld_i, the labor demand for sector i, Kd_i, the capital used in sector I, and α the Cobb-Douglas parameter. Hence, an increase in θ_i represents in Hicks' neutral productivity improvement such as modeled in Yeaple and Golub (2004)[4]. With this

[4] This formulation is also commonly used in the literature estimating parameters of the externalities of public infrastructure on total factor productivity such as Ashauer (1989), Munnell (199), Bajo-Rubio and Sosvilla-Rivero (1993), Gramlich (1994), and Dessus and Herrera (1996) among others.

formulation, the infrastructure investment can thus act as a source of comparative advantage since the function is sector specific. An increase in infrastructure investment will generate positive production externalities on the different production sector in the economy. The sector specific elasticity allows us to capture the different impact the investment will have on specific sectors. For example, road investment will benefit more the export agriculture compared to the construction sector.

Model equilibrium conditions are also standard. The commodity market is balanced by an adjustment of the market price for each commodity. The labor market balances out with an adjustment of the nominal wage. One should also note that labor supply is fixed and that there is no unemployment[5]. The current account balance is fixed and the nominal adjust to allow the real exchange rate to clear the current account balance.

It is important to highlight an element before moving on to the simulations. In our model, we will simulate what are the increases in taxes and transfers to achieve the investment objectives and operation and maintenance cost. In a standard CGE model, the funding needs would be greater then our simulated results as these models assume that infrastructure investments do not produce production externalities. The externalities generate a growth effect and the extra output will produce more income for the government. We will present a table with the contribution of this growth factor to reduce the pressure on tax rates and transfer increases.

4. The pros of the approach:

There are numerous advantages of using CGE model as an analytical tool for impact assessment of increasing in public investment on public infrastructure and various funding options. The Malian model uses a larger number of agents compared to more standard macro type models. We explicitly have four agents in the model, namely households, the firms, the government and the rest of the world. The other main advantage of this model compared to the Adam and Beven

([5]) This does not mean that we assume that there is zero unemployment in the Malian economy but simply that unemployment is exogenous to the model.

(2006) model is that we have a richer presentation of production sectors. In their study, they explicitly introduce an import competing sector, an export sector and non tradable. This is interesting for illustrative purposes. However, as illustrated by most disaggregated social accounting matrix in Africa, not all sectors can be classified as pure tradable or non tradable sectors. Most often, sectors will have exhibit variable degrees of openness to trade. Generally the construction sector, subsistence agriculture and services are mostly non tradable, and manufacturing and export agriculture are tradable but country specificities and terms of the degree of openness for different sectors could lead to mitigating the negative Dutch disease effects observed in Adam and Beven (2006).

The CGE model presented here has the advantage of being fully coherent where all accounts must be balanced such as government (described at length earlier), current account balance, private firms and households. This model will also allow us to identify the winners and losers of the different scenarios to be analysed, simulate various fiscal policies to fund the investment and provide a comparative analysis in terms of winners and losers. As we have disaggregated the production sectors in seven sectors, we will be able to highlight the winners and losers in this front as well as from the agents' side.

5. Simulation description

In order to analyse the impact of scaling up investment in infrastructure and different funding mechanisms, we isolate three types of productive infrastructure investment and perform a set of simulations on unproductive investment to provide a reference point. In this context we present four sets of simulation. The first one representing the investment in road infrastructure, the second on electricity, the third set in telecom sector and the last one on unproductive investment. We then perform five simulations within each sets of the productive investment and four in the unproductive investment set. The productive investments are distinguished uniquely by the externality parameters. The value of the public investment on the infrastructure is maintained constant throughout the simulations. We perform an increase of 20% of public investment for each set of infrastructure investment scenarios.

Let us describe these five funding options analysed. In the first funding scheme, we reduce other non productive public expenditure to fund the investment and their operation and maintenance

cost. It is important to reiterate the fact that the productive externalities will contribute to increasing the economic activity and hence will increase government revenues and therefore the funding requirements are not equal to the investment cost and operation and maintenance costs. In the second funding option, we increase the sales tax rate in the economy, in the third, we increase import duty rates, in the fourth foreign aid is the source of funding and finally the last option the funds are raised through an increase in income tax rates. This comparative analysis will allow us to highlight the most efficient funding mechanism and explore the effect on different macroeconomic and other variables. We present the simulations in a synthetic form in the following table:

Table 4: Presentation of the simulation

1- Road	1-a) Reduction in other public expenditure
	1-b) Funding through Sales
	1-c) Funding through Import duties
	1-d) Funding through Foreign Aid
	1-e) Funding through Income tax
2- Electricity	2-a) Reduction in other public expenditure
	2-b) Funding through Sales
	2-c) Funding through Import duties
	2-d) Funding through Foreign Aid
	2-e) Funding through Income tax
3- Telecom	3-a) Reduction in other public expenditure
	3-b) Funding through Sales
	3-c) Funding through Import duties
	3-d) Funding through Foreign Aid
	3-e) Funding through Income tax
4- Non productive expenditure	4-a) Funding through Sales
	4-b) Funding through Import duties
	4-c) Funding through Foreign Aid
	4-d) Funding through Income tax

6. Impact analysis of scenarios

In this section we will concentrate on the macroeconomic variables to simplify the presentation but will highlight the main sectoral effects. We will proceed by doing a detailed comparative analysis of one type of infrastructure investment to investigate the efficiency of different funding modalities. We will then perform a brief comparative analysis of the three productive investment options with the unproductive one. As we have assumed that our total endowment of productive

factors as exogenous, growth in GDP is generated directly by our production externalities of our public investment. The relative importance of this increase between the sets of simulation is directly determined by the externality elasticities we have selected. Anther key hypothesis to keep in mind when looking at result is the fact that we have maintained our current account balance fixed. Hence, the inflow of foreign aid to fund public investment will be accompanied by an adjustment of the nominal exchange rate to respect our current account balance rigidity. Finally, in our results, we present the nominal exchange rate but it can also be interpreted as the real exchange rate since our price index is exogenous.

6.1 The investment in road infrastructure

In general, by looking at the first column on Table 5, we note that the increase in investment with the reduction of supply of public goods and services produces a positive effect through the growth effect. The real GDP increases by 0.84%. This increase will be the same for all funding scenarios; differences will be on other macro and sectoral variables. The decrease in other government expenditure (*Go*) (outside operation and maintenance cost) needed to finance the investment is 2.52%. The increase in expenditure for the new infrastructure is 1.46% (from other funding scenarios) and the total government expenditure (*G*) is 1.07%. The wage increases by 0.76% given the productivity gains and the real exchange rate appreciates by 0.61%. Hence, increasing investment does produce a slight Dutch disease effect without external funding. Now moving to the impact on the different agents in the economy, we will perform this analysis by using the change in an agents' real income or equivalent variation for households relative to the real *GDP* change. In this first scenario, the winners are the private firms with an increase in real income greater than the *GDP* increase. The government is the loser and the aggregate household is also a relative loser with a real income increase of 0.76%.

The four other funding scenario produce a stronger positive effect on the real wage and therefore the positive effect is stronger for households in terms of the real income. The exception comes from the income tax when using the equivalent variation (*EV*) as this takes into account the decrease in disposable income due to the higher tax rates for households paying income taxes.

Table 5: Macroeconomic results of funding options for road investments

Road invesments (variation in %)							
Variables	**Definition**	**Reference**	**Reduction in other public expenditure**	**Sales tax**	**Import duties**	**Foreign Aid**	**Income tax**
Ym	***Aggregate household income***	149,55	0,76	0,82	0,83	0,87	0,84
EV	***Equivalent variation***		0,76	0,81	0,83	0,89	0,37
s	***Wage***	1	0,76	1,29	1,45	1,77	1,49
yg	***Government income***	278,13	0,61	2,93	2,93	2,93	2,93
ye	***Firms income***	479,53	0,87	0,68	0,62	0,51	0,61
sg	***Government savings***	22,18	20	20	20	20	20
g	***Total government expenditure***	255,96	-1,07	1,46	1,46	1,46	1,46
	Other government expenditure		-2,52				
It	***Total private investment***	439,51	1,08	0,9	0,83	0,71	0,71
Itp	***Total public investment***	22,18	20	20	20	20	20
e	***Nominal exchange rate***	1	-0,61	-0,64	-1,19	-2,25	-0,81
GDP	***GDP***	1819,41	0,84	0,84	0,84	0,84	0,84

In that case, the increase in *EV* is only 0.37%. The privates firms benefit less in all four simulations with increase in real income ranging from 0.51% to 0.68%. The increase in government income is the same in all four scenarios since this is the income required to fund the investment and extra operation and maintenance cost. The simulation that produces the strongest positive effect for households is the foreign aid option whether the real income or *EV* are used to measure the gains. On the other hand, this is the option that produces the weakest positive effect on firms and the strongest appreciation of the real exchange rate. The worst option for the households seems to be the income tax increase as their equivalent variation only increases by 0.37% and when other public expenditure are used to fund the investment program the increase in *EV* is 0.76%. In the case of private firms, they can be considered "winners" only in one scenario namely the public expenditure adjustment where their income increases by more (0.87%).

Coming back to the real exchange rate since it is a major concern in the scaling up of aid and infrastructure. We note that all scenarios contribute to an appreciation of the real exchange rate and this confirms to the Dutch disease effect of scaling up road infrastructure investment described in Adams and Bevan (2006). However, we note that the intensity of real exchange rate

adjustment is relatively small for most scenarios with the strongest effect observed for the foreign aid scenario. This is not surprising as this option imposes a direct adjustment on the real exchange rate to balance out the current account balance. The weakest effect on the exchange rate is with the public expenditure adjustment. The sales tax increase also produces weak effect on the real exchange rate and the import duties produce effects twice as large compared to what is observed for the sales tax. In this context, the most favourable option is certainly the sales tax as a funding option.

Another interesting variable to investigate is the total private investment. The total private investment is a function of households, firms and rest of the world savings. As we have seen the foreign savings or current account balance is exogenous and therefore, the two key variables al play are the households' savings and firms' savings. As we have already stated, these two agents experience increases in income and therefore private investment increases in all options. The most favourable situation for private investment is the reduction of other public expenditure (1.08%) and the worst option is with the income tax and foreign aid options (0.71%). Without going into great detail for the sectoral analysis, let us highlight the main winners and losers in terms of a few key sectoral variables such as output, market price and rental rate of capital.

First, it is interesting to investigate the impact on output since the relative effects are almost identical in all funding options with the exception of the reduction in other public expenditure (first option). The construction sector is the biggest winner in all scenarios and this is explained by the fact that the public investment is realized through an increase in the construction sector. The second "winners" it the mining and gas sector in all scenarios but for the foreign aid scenario we observe the export agriculture in second position. The sector gaining the least in all scenarios is the private services and this is explained by the lower externality elasticity for this sector.

For the market prices, the crop agriculture seems isolated from this investment. The only exception is when income tax is used to fund the investment where the price decreases by 0.39%. The sector experiencing the biggest price decreases is the mining and gas sector and the biggest increase is in the private service sector.

Table 6: Sectoral results of funding options for road investments

Road Investments							
Variables	**branches**	**Reference**	**Reduction in other public expenditure**	**Sales tax**	**Import duties**	**Foreign Aid**	**Income tax**
Va **(Value added or output)**	**Crop agriculture**	21,52	0,92	0,86	0,84	0,81	0,79
	Export agriculture	6,47	1,37	1,33	1,31	1,26	1,3
	Mining and Gas	2,13	1,54	1,45	1,32	1,16	1,42
	Industries	6,35	0,83	0,6	0,64	0,78	0,57
	Construction	9,56	2,25	1,49	1,67	1,96	1,78
	Private Services	1,79	0,5	0,32	0,37	0,33	0,32
	Public services	13,62	-1,43	0,59	0,5	0,61	0,65
pq **(Market prices)**	**Crop agriculture**	1,01	-0,12	-0,04	0	-0,01	-0,39
	Export agriculture	1,02	-0,59	-0,54	-0,59	-0,83	-0,88
	Mining and Gas	1,09	-0,97	-1,11	-1,27	-1,64	-1,28
	Industries	1	-0,36	-0,11	0,09	-1,38	-0,44
	Construction	1,04	0,03	0,67	0,42	0,01	0,18
	Private Services	1,01	0,38	0,88	0,67	0,66	0,46
	Public services	1	0,4	0,85	0,94	0,76	0,78
r **(rental rate of capital)**	**Crop agriculture**	1	0,8	0,8	0,77	0,87	0,38
	Export agriculture	1	0,71	0,59	0,35	-0,02	0,34
	Mining and Gas	1	0,55	0,16	-0,95	-2,26	0,11
	Industries	1	1,24	1,19	1,46	2,12	1,3
	Construction	1	2,53	1,98	2,4	3,14	2,59
	Private Services	1	0,97	0,66	1,05	1,22	0,88

As we have mentioned in the previous section, our model introduces externalities for investment at the source of growth in our model. This growth contributes to decreasing the needs of funding the investment and for it O&M costs. We have simulated our scenarios without externalities to isolate the contribution of growth in the funding of investment and O&M costs. In the following table we present the tax rate increases required with externalities and without externalities.

Table 7: Rates changes for funding needs

Road investments Rate increase required to fund investment and O&M costs (% variation)			
Variables	**Definition**	**With growth effects**	**Without growth effects**
tx	***Sales tax***	16.5	20.3
tm	***Import dutes***	5.3	6.5
F-A	***Foreign Aid***	7.7	9.4
tyh	***Income tax***	44.9	55.2

We note that to achieve the 20% increase in public investment for road construction the tax rates increases would have to be 22 to 23% higher if we assumed no production externalities. This is quit important as neglecting this effect would lead one to conclude that tax rate increases would need to be much higher and therefore more difficult to implement such reforms[6].

6.2 The investment in electricity infrastructure

In this section, we will focus our analysis on the main differences between investment in electricity and road investment. The first point we can make is that the different funding options seem to produce relatively similar effects compared to what was observed for the road investment. The income tax option is the least interesting for the households and the foreign aid the most favourable option. For the firms, the best option is the decrease in other public expenditure and the worst option is the foreign aid option. It is also interesting to highlight the fact that since the externalities are not as strong for electricity investment which is seen by the lower increase in GDP (0.63% compared to 0.84%), the government income needs to increase more to fund the investment. Other positive effects are also smaller on most macroeconomic and sectoral variables for the same reason.

[6] In fact, if we assumed that new road investment combined with the growth could lead to increasing the formal economy. This would further reduce the pressure on rate increases required to meet the investment objectives. We plan to investigate this issue in an extension of this paper by using Fortin *et al* (1997) to model the movement between the informal and formal sectors.

Table 8: Macroeconomic results of funding options for electricity investments

Electricity investments (variation in %)							
Variables	**Definition**	**Reference**	**Reduction in other public expenditure**	**Sales tax**	**Import duties**	**Foreign Aid**	**Income tax**
Ym	***Aggregate household income***	149.55	0,53	0,59	0,61	0,65	0,62
EV	***Equivalent variation***		0,53	0,57	0,59	0,65	0,16
s	***Wage***	1	0,32	0,83	0,99	1,31	1,02
yg	***Government income***	278.13	0,81	3,03	3,03	3,03	3,03
ye	***Firms income***	479,53	0,74	0,56	0,50	0,39	0,49
sg	***Government savings***	22,18	20,00	20,00	20,00	20,00	20,00
g	***Total government expenditure***	255,96	-0,85	1,56	1,56	1,56	1,56
	Other government expenditure		-2,41				
It	***Total private investment***	439,51	0,90	0,73	0,67	0,55	0,54
Itp	***Total public investment***	22,18	20,00	20,00	20,00	20,00	20,00
e	***Nominal exchange rate***	1	0,61	0,58	0,06	-0,98	0,42
GDP	***GDP***	1819,41	0,63	0,63	0,63	0,63	0,63

The other variable of interest is the real exchange rate. Interestingly, the effects are quit different compared to the road investments. We now observe increases in the exchange rate which corresponds to a depreciation of the local currency in all scenarios but the foreign aid option. This is explained by the fact that road investment favoured the two main export sectors namely export agriculture and mining and gas, whereas the electricity investment favours the industrial sector, the construction sector and private services and these sectors are not important exporters in Mali. Hence, the Dutch disease does not emerge as in the previous set of simulations albeit the foreign aid produces a slight Dutch disease effect but less than half of what road investment funded by foreign aid produced (-0.98% compared to -2.25%).

When looking at the sectoral effects, as in the first set of simulation (road investment), they are dominated by the externality elasticities and by the fact that the construction sector directly benefits from the investment for the construction of power generation plants and distribution lines. The strongest effects in all scenarios are in the construction sector followed by the industry sector and then by the private services.

Table 9: Sectoral results of funding options for electricity investments

Electricity Investments							
Variables	**branches**	**Reference**	**Reduction in other public expenditure**	**Sales tax**	**Import duties**	**Foreign Aid**	**Income tax**
Va **(Value added or output)**	**Crop agriculture**	21,52	0,07	0,01	-0,01	-0,04	-0,06
	Export agriculture	6,47	0,31	0,27	0,24	0,2	0,24
	Mining and Gas	2,13	0,5	0,41	0,29	0,13	0,39
	Industries	6,35	1,39	1,17	1,21	1,34	1,14
	Construction	9,56	2,38	1,65	1,82	2,1	1,93
	Private Services	1,79	1,06	0,88	0,93	0,89	0,88
	Public services	13,62	-0,9	1,03	0,95	1,09	1,1
pq **(Market prices)**	**Crop agriculture**	1,01	0,61	0,69	0,73	0,72	0,35
	Export agriculture	1,02	0,4	0,45	0,4	0,17	0,12
	Mining and Gas	1,09	1,07	0,93	0,78	0,41	0,77
	Industries	1	0,02	0,26	0,46	-0,96	-0,06
	Construction	1,04	-0,27	0,34	0,11	-0,28	-0,12
	Private Services	1,01	-0,46	0,01	-0,18	-0,19	-0,38
	Public services	1	0,07	0,5	0,59	0,42	0,43

In this interesting to note that in this set of simulations we observe some negative effects in one of the sector, namely in the crop agriculture albeit the reduction in output is very small for three simulations (for import duties, foreign aid and income tax scenarios). Without going in detail we can mention that the price effects here are quit different between the funding options. For example, the industry sector the price increases by 0.26% for the sales tax option and it decreases by 0.96% for the foreign aid option.

In Table 8 we present the gains obtained by growth to fund the infrastructure and O&M for electricity investment. In this case the gains are greater compared to road investments. The reduction in tax rates increases are between 31 and 34 percent (they were around 22% for road investment. This is a consequence of the beneficiaries of externalities are mostly formal sectors and hence the government benefits more in terms of tax collection compared to road investments.

Table 10: Rates changes for funding needs

Electricity investments Rate increase required to fund investment and O&M costs (% variation)			
Variables	**Definition**	**With growth effects**	**Without growth effects**
tx	***Sales tax***	15.8	21.0
tm	***Import dutes***	5.0	6.7
F-A	***Foreign Aid***	7.4	9.7
tyh	***Income tax***	43.0	57.1

6.3 The investment in telecom infrastructure

For the telecom investments, we do not observe changes in most preferred options between agents compared to the two previous sets of simulations. However, we observe a negative impact on one of the agents. In fact, the income tax funding option produces a very slight decrease of 0.01% for the *EV* for the aggregate household. We can also highlight that the externalities of this option are smaller compared to the two other options (see Table 3) and the operation and maintenance cost for telecom are weaker compared to the two other options (see Table 2) as estimated by Fay and Yepes (2003), hence, the funding requirements are not as strong as in the two previous options.

Table 11: Macroeconomic results of funding options for telecom investments

Telecom investments (variation in %)							
Variables	**Definition**	**Reference**	**Reduction in other public expenditure**	**Sales tax**	**Import duties**	**Foreign Aid**	**Income tax**
Ym	***Aggregate household income***	149.55	0,38	0,44	0,46	0,5	0,46
EV	***Equivalent variation***		0,38	0,43	0,45	0,5	-0,01
s	***Wage***	1	0,26	0,77	0,94	1,26	0,97
yg	***Government income***	278.13	0,5	2,77	2,77	2,77	2,77
ye	***Firms income***	479,53	0,51	0,32	0,26	0,15	0,25
sg	***Government savings***	22,18	20	20	20	20	20
g	***Total government expenditure***	255,96	-1,19	1,28	1,28	1,28	1,28
	Other government expenditure		-2,48				
It	***Total private investment***	439,51	0,62	0,44	0,38	0,26	0,25
Itp	***Total public investment***	22,18	20	20	20	20	20
e	***Nominal exchange rate***	1	0,24	0,21	-0,32	-1,39	0,05
GDP	***GDP***	1819,41	0,44	0,44	0,44	0,44	0,44

In this case the needs are to increase government income by 2.77% compared to the 2.93% required for the road investments and the 3.03% needs for the electricity investments. As for the real exchange rate, we have two cases of appreciation namely for the import duty and foreign aid funding options. The impact on the exchange rate is intermediate compared to the first two sets of simulations. Once again, this relatively small Dutch disease impact is explained by the fact that tradable sectors are not the most favoured by these types of investments. In fact, it is the private services sector that is the one most favoured by the telecom investment (see Table 3).

When analysing the changes in tax rate changes required to finance investments and O&M the gap between the growth option on non growth option is smaller compared to the two other set of simulations. In fact, in this case, abstracting from the growth effect would require rates 17% higher on average.

Table 12: Rates changes for funding needs

Telecom investments Rate increase required to fund investment and O&M costs (% variation)			
Variables	**Definition**	**With growth effects**	**Without growth effects**
tx	***Sales tax***	16.3	19.1
tm	***Import dutes***	5.2	6.1
F-A	***Foreign Aid***	7.6	8.9
tyh	***Income tax***	44.2	52.0

6.4 The investment in non-productive infrastructure

Finally, an analysis of increasing non-productive investments reveal that the household makes very slight gains in the first three options and lose in the income tax option. This positive effect on household welfare originates from the relatively important increase in nominal wage (from 0.49% to 1.14%). This increase in wage is a consequence of the increase in production of the construction sector that is labour intensive in Mali. Firms are losers in all four simulations of this set of simulations. It is also interesting to see that the absence of growth reveals an eviction effect in terms of private versus public investment. This is not surprising as the simulation consist in transferring resources from other agents to the government. Coming back at our three previous sets of simulations, in these cases we reversed this eviction effect through the growth

effect generated by production externalities in the private sector production process. The new revenue from this growth generates more private saving than the loss in savings from the eviction effect.

Table 13: Macroeconomic results of funding options for non-productive investments

Non productive invesments (variation in %)						
Variables	**Definition**	**Reference**	**Sales tax**	**Import duties**	**Foreign Aid**	**Income tax**
Ym	***Aggregate household income***	149.55	0,06	0,08	0,13	0,09
EV	***Equivalent variation***		0,06	0,08	0,14	-0,55
s	***Wage***	1	0,49	0,72	1,14	0,76
yg	***Government income***	278.13	3,19	3,19	3,19	3,19
ye	***Firms income***	479,53	-0,18	-0,26	-0,41	-0,27
sg	***Government savings***	22,18	20,00	20,00	20,00	20,00
g	***Total government expenditure***	255,96	1,73	1,73	1,73	1,73
It	***Total private investment***	439,51	-0,17	-0,25	-0,41	-0,42
Itp	***Total public investment***	22,18	20,00	20,00	20,00	20,00
e	***Nominal exchange rate***	1	0,03	-0,70	-2,13	-0,19
GDP	***GDP***	1819,41	0,00	0,00	0,00	0,00

Interestingly, the appreciation in the real exchange rate is stronger for all simulations of road investment compared to this non productive investment. However, the two other sets (electricity and telecom) produce weaker Dutch disease effects compared to these non productive investments. Like other sets, the strongest appreciation is with the foreign aid, followed by the import duties, income tax and for the sales tax we have a small depreciation of the local currency.

7. Conclusions

In this paper we investigate the macro and sectoral impact of scaling up infrastructure investment in a landlocked African economy, namely Mali. We investigate if negative consequences on the exchange rate and creation of the Dutch disease found in Adam and Bevan (2006) and reported in Gupta et al (2006) is robust and a country with different characteristics compared to Uganda where Adam and Bevan (2006) applied their CGE model. The negative impact of the Dutch disease in many developing countries is exacerbated by the fact that tradable sectors are less

labour intensive compared to non-tradable sectors. The export sectors in Mali are mostly agricultural sectors and mining. The most important agricultural export is cotton and in Mali, this sector is extremely labour intensive.

Our results show that scaling up infrastructure does not always produce a Dutch disease effect. Scaling up aid to fund infrastructure produced the Dutch disease in our four types of investment. However, for the foreign aid scenarios, the intensity of the Dutch disease varies from one type of investment to the other. It is not clear that tradable sectors will always be the most favoured by investments in infrastructure as this is dependent on the type of investments. Another important result is that the size of the negative social impact of the Dutch disease will depend on degree of labour intensity in the tradable sectors. The other important conclusion is that in seventeen of our nineteen scenarios, the welfare of aggregate households measured by the equivalent variation increase. This comes from the growth effect of the positive production externalities of infrastructure investment. This positive growth effect compensates other negative effects among which the Dutch disease in included.

In a subsequent paper we will use the same model and same scenarios and perform a comparative analysis in six African countries. This will allow us to isolate the importance of the economic structure of the African economies in mitigating or amplifying the Dutch disease effect.

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