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Investing in Public Infrastructure: Roads or Schools?[1]

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Abstract

Why do governments in developing economies invest in roads and not enough in schools? In the presence of distortionary taxation and debt aversion, the different pace at which roads and schools contribute to economic growth turns out to be central to this decision. Specifically, while costs are front-loaded for both types of investment, the growth benefits of schools accrue with a delay. To put things in perspective, with a "big push," even assuming a large (15 percent) return differential in favor of schools, the government would still limit the fraction of the investment scale-up going to schools to about a half. Besides debt aversion, political myopia also turns out to be a crucial determinant of public investment composition. A "big push," by accelerating growth outcomes, mitigates myopia—but at the expense of greater risks to fiscal and debt sustainability. Tied concessional financing and grants can potentially mitigate the adverse effects of both debt aversion and political myopia.

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1 Introduction

The notion that public investment in infrastructure is an important driver of economic growth can be found in much of the political and economic discourse on poor economies. It has recently gained momentum also in the case of emerging markets and advanced economies alike as a result of the Great Recession. The World Economic Forum (2004) estimates global spending on infrastructure investment to amount to US$3.7 trillion per year, and yet a spending gap of at least US$1 trillion still exists every year.

In his seminal paper, Rosenstein-Rodan (1943) argued that a "big push" of investment-led growth would enable an economy to loosen multiple constraints, benefit from economies of scale, and generate the needed demand. Since then, the literature has made a great effort in analyzing the macroeconomic impact of public infrastructure investment. Recent contributions have focused particularly on the nexus between government infrastructure spending and its effects on growth and public debt sustainability (see, e.g., Buffie et al., 2012; IMF, 2014; Abiad et al., 2015; Aruajo et al., 2016; and Melina et al., 2016).

In the empirical literature, some authors have looked at disaggregated data of public investment (see Acosta-Ormaechea and Morozumi, 2017 and references therein), but–with the exception of a few contributions (see, e.g., Devarajan et al., 1996 and Agenor, 2010)–economic models typically look at one broad measure of public infrastructure. Our paper shows, in a general equilibrium setting, that the composition of public investment has important macro-fiscal implications, and that these macro-fiscal considerations, in turn, affect its welfare-optimal composition. In particular, we distinguish between what we label "economic" and "social" infrastructure.[1]

By *economic infrastructure* we mean the capital inputs that allow the economy to function better (such as roads, railways, ports, water, power, and telecommunications). By *social infrastructure* we mean the capital that primarily delivers social services (such as schools, universities, and hospitals). In particular, this paper embeds elements that are directly related to schools and education as this is key to the sustained long-term growth of low-income developing countries (LIDCs). Therefore, for simplicity, in the remainder of the paper, we often refer to economic infrastructure as "*roads*" and to social infrastructure as "*schools*". It must be clarified that the distinction between the two categories of projects is not always clear-cut, as economic infrastructure often also has a social component, just like social infrastructure has strong economic implications as we emphasize throughout the paper.

Choosing how to best allocate public infrastructure investment is of fundamental importance for policymakers across the globe. While governments continuously face the problem of maximizing the supply of a wide variety of public goods subject to constrained

[1] To our knowledge, Hall and Jones (1999) were the first to define the concept of "social infrastructure".

budgets, focusing on schools is particularly relevant for developing economies (emerging markets and LIDCs included). Although public investment in roads is an engine of growth for LIDCs, investing in schools would appear to be an even more pressing need in light of low stocks of human capital. Yet, there is suggestive evidence that developing economies (with lower GDP per capita) spend less on schools than on roads, both in relative and absolute terms, as a fraction of GDP. This can be inferred from Figure 1, which shows data on social spending (i.e. the sum of public spending on education and health) and public investment (i.e. infrastructure-related spending) for a cross-section of countries for the 2000-2008 period.[2]

The paper, therefore, explores and tries to address the following questions: (1) Why is spending on social infrastructure not higher in developing economies? and (2) What determines the composition of public infrastructure investment? We study these issues in a model with a realistic and detailed specification of fiscal policy that includes distortionary taxation and exhibits debt aversion. In presence of these features, the difference in the pace with which roads and schools contribute to economic growth (for a given public investment plan) turns out to be of central importance to the policymaker's optimal allocation decision. We begin our analysis with the study of the macroeconomic and (public) debt sustainability implications of investment in roads versus schools in the context of an infrastructure scale-up program. The two questions above are addressed thereafter. Specifically, we look at the welfare-optimal composition of public investment and examine the role of its key determinants, in particular, the return differential, debt aversion, and political myopia.

Our analytical framework is a single-good, small-open dynamic general equilibrium model including, for the most part, rather established features. Less standard features include the accumulation of human capital, which is accrued via an optimal decision of households of postponing labor supply (and leisure) in order to spend time in schools, while the capital cost of building schools and all current expenditures to maintain them are borne by the government. Upgrading economic infrastructure increases the productivity of private firms relatively quickly, whereas the scale-up of schools raises workers' productivity mostly in the long run—albeit potentially to a larger extent—while requiring similarly large upfront costs. Additionally, social infrastructure entails larger current expenditures, including those for operations and maintenance.

Calibrating the model to an average developing economy and considering the case of a permanent increase in public expenditures, our main results are as follows. Given the scarcity of human capital, our baseline experiment assumes that the return on schools is much larger than that on roads. If public investment is made exclusively in schools, it results in a much larger long-run increase in output than in an opposite scenario in which public investment occurred exclusively in roads. Yet, for a prolonged time (around

[2] We leave out the Great Recession period due to its peculiarities.

15 years) the economy enjoys faster growth by investing only in roads, and it takes about a generation (almost 24 years) for the output obtained by investing in schools to overtake that delivered by investing in roads. This has tremendous fiscal implications, with schools causing a threefold peak increase in government debt relative to roads. The dynamic trade-off between the two types of investment becomes progressively more biased against education as the return differential in favor of schools falls.

A typical "big push," i.e. a front-loading of investment expenditures, tilts the balance in favor of investment in schools in two ways: it shrinks the delay with which output resulting from investing in schools overtakes that from investing in roads and results also in much more similar, albeit amplified, paths of public debt. However, while accelerating the transition to a higher output in the long run, on the downside, the "big push" results also in a stronger medium-run drop in output and private consumption as it amplifies the intertemporal labor substitution effect associated with a scale-up in schools.

These trade-offs have clear welfare implications. First, in our baseline case, even with a large (15 percent) return differential in favor of schools, the government chooses to limit the fraction of the investment increase dedicated to schools to about three fourths, which falls to about a half with a "big push." Second, these shares drop even further if the government is debt-averse or access to debt financing is simply not feasible. Third, in the baseline case without "big push," if political leaders have a planning horizon of less than 30 years—call it "myopia"—they would not invest in schools at all; an approximately twice as large a time horizon is needed for investment in schools to be of a comparable magnitude to the case of a benevolent social planner. The costs of political myopia decrease with a "big push" due to the anticipation of some of the benefits from investing in schools—but it also exacerbates the threat of fiscal and debt sustainability.

Our paper adds to a large literature on the macroeconomic effects of public investment. The works by Barro (1990), Barro and Sala-i-Martin (1992), Futagami et al. (1993) and Glomm and Ravikumar (1994) investigate the impact of public investment in the context of endogenous growth models. Chatterjee and Turnovsky (2007), Agenor (2010), Buffie et al. (2012), among others, make important remarks on how developing countries' features affect public capital accumulation and therefore growth. Adam and Bevan (2006), Cerra et al. (2008), and Berg et al. (2010a, 2010b), on the other hand, explore the macroeconomic effects of aid-financed increases in public investment. However, all these contributions abstract from the composition of public investment. Two papers are notable exceptions: Devarajan et al. (1996) and Agenor (2010) introduce the composition of public investment into the picture. However, Devarajan et al. (1996) consider a fixed total government spending, while Agenor (2010) assumes a budget-neutral fiscal policy. In other words, neither paper allows for public debt accumulation and, hence, the relationship between investment composition and fiscal policy considerations is ruled out. All in all, our contribution to the existing literature is twofold. On one hand, the paper shows that proper consideration of government's macroeconomic and fiscal concerns can explain why policymakers may be reluctant to spend as much on schools; and on the other, it highlights that governments' concerns with debt sustainability and policymakers' myopia intuitively affect the optimal investment composition.

The remainder of the paper is structured as follows. Sections 2 describes the model. Section 3 discusses the calibration. Section 4 presents the results. Section 5 explores key determinants of the welfare-optimal composition of the public infrastructure scale-up. Finally, Section 6 concludes the paper.

2 Model

We consider a single-good, small-open production economy populated by a continuum of identical households and firms that take prices as given. Public investment in roads increases firms' productivity as, e.g., in Buffie et al. (2012). In addition, investment in schools increases the productivity of the process of human capital accumulation. While firms use both (private and public physical) capital and (human-capital adjusted) effective labor for goods production, the process for human capital accumulation uses effective labor as the only private input.

Along the balanced growth path, all non-stationary variables grow at the same rate, g, driven by the exogenous growth in firms' productivity.[3] Thus, all non-stationary variables pertaining to time t are normalized by dividing them by $(1+g)^t$ and the description that follows refers to these normalized/stationary variables.

2.1 Firms

There is a continuum of perfectly competitive firms producing good y_t by combining private capital, k_{t-1}, effective labor, $e_t^{\chi} l_t$, and government-supplied infrastructure, z_{t-1}^i, according to a Cobb-Douglas production technology:

$$y_t = A^y \left(z_{t-1}^i\right)^{\psi} \left(k_{t-1}\right)^{\alpha} \left(e_t^{\chi} l_t\right)^{1-\alpha}, \tag{1}$$

where $\alpha \in (0,1)$ and $\psi \in (0,1)$ are the (private) capital share of output and the output elasticity of public capital, respectively; parameter $\chi > 0$ determines how human capital transforms raw labor into effective units of labor; and $A^y > 0$ is total factor productivity.

Firms are perfectly competitive and maximize profits by equating the marginal product of each input to its price, which yields the following optimal decisions (or factor

[3] There is one exception that is discussed later.

demands):

$$\alpha \frac{y_t}{k_{t-1}} = r_t^k, \tag{2}$$

and

$$(1-\alpha)\frac{y_t}{l_t} = w_t e_t^{\chi}, \tag{3}$$

where r_t^k is the rental rate for capital and w_t is the wage rate per unit of *effective* labor, which—unlike all other non-stationary variables—has been normalized by dividing by $(1+g)^{(1-\chi)t}$. This implies that the wage rate per unit of *raw* labor grows at the rate g, like all other non-stationary variables.

2.2 Households

A representative household in the economy derives utility from consumption, c_t, and disutility from the time spent in non-leisure activities, n_t. Consistent with balanced growth—as suggested by King, Plosser, and Rebelo (1988)—we consider households' preferences to be non-separable in consumption and leisure. In particular, the household maximizes its lifetime utility

$$\sum_{t=0}^{\infty} \beta^t \left(\frac{\left[c_t (1-n_t)^{\zeta}\right]^{1-\frac{1}{\kappa}} - 1}{1-\frac{1}{\kappa}} \right), \tag{4}$$

where $\beta \equiv (1+\varrho)^{-1}(1+g)^{1-1/\kappa} \in (0,1)$ is the household's discount factor and ϱ is the pure rate of time preference. The elasticity of intertemporal substitution in consumption is represented by $\kappa > 0$, while $\zeta > 0$ is a preference parameter controlling the degree of substitution between leisure and consumption (the so-called Frisch elasticity of labor supply).

There are two productive uses of household's time n_t: they devote time l_t for producing goods and time u_t to accumulate human capital (by going to school). Thus, we have

$$n_t = l_t + u_t. \tag{5}$$

The household derives income from supplying labor and capital to firms. In addition, it also receives firms' profits Φ_t and transfers $\mathcal{T}_t$ from the government. The savings left after consumption are used to invest amount I_t in private capital that depreciates at rate $\delta_k \in (0,1)$ and pays income r_t^k, and to buy domestic bonds b_t^d that pay a real interest rate r_t^d. Thus, the household faces the following intertemporal budget constraint:

$$(1+\tau_t)\, c_t + I_t + b_t^d \;\; \leq \;\; w_t e_t^{\chi} l_t + r_t^k k_{t-1} + \left(1 + r_{t-1}^d\right) \frac{b_{t-1}^d}{1+g} + \mathcal{T}_t + \Phi_t, \tag{6}$$

where τ_t is the value-added tax on consumption, while the accumulation of private capital evolves according to the following law of motion:

$$(1+g)\,k_t = (1-\delta_k)\,k_{t-1} + I_t. \tag{7}$$

2.2.1 Human Capital Accumulation

Recall that, besides physical capital, the household can also accumulate human capital by spending time u_t in schools. The process of schooling combines government-provided schools, z^e_{t-1}, and effective time spent to produce human capital, $e^{\chi}_t u_t$, according to the following technology:

$$A^e \left(z^e_{t-1}\right)^{\phi} \left(e^{\chi}_t u_t\right)^{\nu}, \tag{8}$$

where $A^e > 0$, $\phi > 0$, and $\nu > 0$. In particular, ϕ is the elasticity of human capital output with respect to government-provided education infrastructure, i.e., schools, while ν is the elasticity with respect to effective schooling time.

The human capital accumulated via schooling increases the effectiveness of labor. However, in the model—as in the real world—it does so gradually given that various cohorts of school-going agents become part of the labor force over time. Notice that this delay in availability for productive use occurs only for the human capital and not for physical capital.[4] The inertia in human capital accumulation is captured in the model by adding, in the first stage, the output resulting from the human capital production process to an intermediate stock of human capital, ξ_t, that is currently trapped in schools. This stock evolves according to:

$$(1+g)\,\xi_t = (1-\omega)\,\xi_{t-1} + A^e \left(z^e_{t-1}\right)^{\phi} \left(e^{\chi}_t u_t\right)^{\nu}. \tag{9}$$

of which, a fraction ω moves from schools to the labor force in every period, in the second stage. On average, newly accumulated human capital becomes productive with a delay of $1/\omega$ periods. In particular, the productive human capital in the economy—i.e., that

[4] To be specific, it occurs only for human capital accumulated via schooling, which we seek to model here. For example, it would not be the case for the accumulation of human capital through on-the-job training. It is worth clarifying that this delayed effect of accumulated human capital on output is distinct from time-to-build arguments. Time-to-build delays in public capital would imply that investments in roads and schools would become part of their productive stocks with some delay. Typically models with time-to-build lags for economic capital (see, e.g., Leeper et al, 2010) are calibrated at a quarterly frequency and look at much shorter delays relative to human capital acquired via schooling. If we modeled time-to-build lags for roads and schools, such delays would affect both types of investments symmetrically. In contrast, as our objective is to bring out a key difference between roads and schools more sharply: once a road is completed, it can be immediately used in a productive manner, while having built a school does not automatically translate into more human capital available to the economy; it will take several more years to train students who will become productive workers in the future. As such, we abstract from time-to-build considerations.

has finished schooling—evolves according to:

$$e_t = (1 - \delta_e) \frac{e_{t-1}}{1+g} + \omega \xi_{t-1}, \tag{10}$$

where δ_e is the depreciation rate of the human capital.

2.2.2 Household's Optimization

To simplify the household's optimization problem, we eliminate I_t from (6) using (7) to obtain:

$$\begin{aligned}(1+\tau_t)\,c_t + (1+g)\,k_t + b_t^d \;\; \leq \;\; & w_t e_t^{\gamma} l_t + (1 + r_t^k - \delta_k) k_{t-1} + \\ & \left(1 + r_{t-1}^d\right) \frac{b_{t-1}^d}{1+g} + \mathcal{T}_t + \Phi_t.\end{aligned} \tag{11}$$

The representative household chooses c_t, l_t, u_t, e_t, ξ_t, b_t^d, and k_t to maximize (4)—after eliminating eliminating n_t using (5)—subject to (9), (10), and (11). Let $\lambda_{1,t}$, $\lambda_{2,t}$, and $\lambda_{3,t}$ be the Lagrange multipliers corresponding to these constraints. The first-order conditions for the problem are then given by:

$$c_t: \quad \frac{\left[c_t(1-l_t-u_t)^{\zeta}\right]^{1-\frac{1}{\kappa}}}{c_t} = \lambda_{1,t}\,(1+\tau_t)\,, \tag{12}$$

$$l_t: \quad \frac{\zeta\left[c_t(1-l_t-u_t)^{\zeta}\right]^{1-\frac{1}{\kappa}}}{1-l_t-u_t} = \lambda_{1,t} w_t e_t^{\chi}, \tag{13}$$

$$u_t: \quad \frac{\zeta\left[c_t(1-l_t-u_t)^{\zeta}\right]^{1-\frac{1}{\kappa}}}{1-l_t-u_t} = \lambda_{2,t} \frac{\nu A^e \left(z_{t-1}^e\right)^{\phi} \left(e_t^{\chi} u_t\right)^{\nu}}{u_t}, \tag{14}$$

$$k_t: \quad (1+g)\,\lambda_{1,t} = \beta \lambda_{1,t+1} \left(1 + r_{t+1}^k - \delta_k\right), \tag{15}$$

$$b_t: \quad r_t^d = r_{t+1}^k - \delta_k, \tag{16}$$

$$\xi_t: \quad (1+g)\,\lambda_{2,t} = \beta\left[(1-\omega)\,\lambda_{2,t+1} + \omega \lambda_{3,t+1}\right], \tag{17}$$

$$e_t: \quad \lambda_{3,t} = \lambda_{1,t} \chi \frac{w_t e_t^{\chi} l_t}{e_t} + \lambda_{2,t} \frac{\chi \nu A^e \left(z_{t-1}^e\right)^{\phi} \left(e_t^{\chi} u_t\right)^{\nu}}{e_t} + \beta \lambda_{3,t+1} \frac{1-\delta_e}{1+g}. \tag{18}$$

The first five equations (12)-(16) are fairly standard. Equation (17) states that the value of a unit of human capital in school (on the left-hand side) is equal to the sum of the present discount value of the $(1-\omega)$ units of human capital left in school and ω units of human capital (available to transform raw labor into effective labor) in the next period. Similarly, equation (18) equates the value of one unit of human capital to the sum of its benefit in terms of higher current wage income, the marginal value in production of new human capital, and the present discount value of the undepreciated social capital for the next period.

2.3 Government

The government makes investment g_t^i in economic infrastructure (roads) and g_t^e in social infrastructure (schools), which augments their stocks according to:

$$(1+g)\,z_t^j = (1-\delta_z^j)z_{t-1}^j + g_t^j, \qquad \text{for} \quad j = e, i, \tag{19}$$

where $\delta_z^j \in (0,1)$ is the rate of depreciation of the corresponding stock of infrastructure.[5]

We follow Adam and Bevan (2014) and include operation and maintenance costs of public capital and model these expenditures, m_t, as a constant proportion of the stock of the public capital so that

$$m_t^j = \gamma_z^j z_{t-1}^j \tag{20}$$

where $\gamma_z^j > 0$. This extension is motivated by the need to capture empirically relevant differences in the size of these expenditures for roads versus schools, which have implications for the (relative) time profile of the costs and benefits of the two types of public investments.

In addition to investing in and maintaining infrastructure, the government also makes transfers $\mathcal{T}_t$ to households. Its revenues come from from a value-added tax on consumption, $\tau_t c_t$, and grants and other revenues, $\mathcal{G}_t$. The deficit is financed through either domestic borrowing $\Delta b_t^d = b_t^d - b_{t-1}^d$ or external concessional borrowing $\Delta b_t^x = b_t^x - b_{t-1}^x$. Thus, the government's budget constraint is

$$\Delta b_t^x + \Delta b_t^d = m_t^z + g_t^z + \mathcal{T}_t + \left(r_{t-1}^d - g\right)\frac{b_{t-1}^d}{1+g} + \left(r_{t-1}^x - g\right)\frac{b_{t-1}^x}{1+g} - \tau_t c_t - \mathcal{G}_t, \tag{21}$$

where

$$m_t^z \equiv m_t^e + m_t^i, \tag{22}$$

$$g_t^z \equiv g_t^e + g_t^i, \tag{23}$$

are total operations and maintenance (current) and investment (capital) expenditures.

While the government may initially have both domestic and foreign debt, we assume that it only issues either new domestic or foreign debt, but not both at the same time.

[5] Some contributions have emphasized that, especially in developing economies, investment spending can be inefficient and typically a significant fraction does not translate into public capital (see, e.g., Pritchett, 2000 and Dabla-Norris et al., 2012). While some papers (see, e.g., Buffie et al., 2012) incorporate public investment inefficiencies in the model, here we abstract from this additional feature because such considerations would apply symmetrically to both social and economic investment and our goal is to emphasize their distinguishing features.

Thus,

$$\Delta b_t^x = 0 \quad or \quad \Delta b_t^d = 0. \tag{24}$$

The (real) interest rate r_t^x on external debt/borrowing is given by

$$r_t^x = r^f + \upsilon_g e^{\eta_g \left(\frac{b_t^x}{y_t} - \frac{b_o^x}{y_o}\right)}. \tag{25}$$

where $\upsilon_g > 0$ and $\eta_g > 0$ are parameters and r^f is the risk-free world real interest rate. Thus, the economy faces an upward sloping supply of foreign funds. This is one of the standard ways of eliminating the (only) unit root in dynamic behavior of this small-open economy as suggested by Schmitt-Grohe and Uribe (2003).

2.3.1 Fiscal Adjustment

We next turn to the fiscal adjustment mechanism of the government. Given the path of public investment, we can rearrange the government's budget constraint and express the government's fiscal gap before policy adjustment ($\mathfrak{Gap}_t$) as

$$\mathfrak{Gap}_t = g_t^z + m_t^z + \left(r_{t-1}^d - g\right) \frac{b_{t-1}^d}{1+g} + \left(r_{t-1}^x - g\right) \frac{b_{t-1}^x}{1+g} + \overline{\mathcal{T}}_t - \overline{\tau}_t c_t - \mathcal{G}_t. \tag{26}$$

It corresponds to the excess of expenditures (including interest payments) over revenues, keeping transfers and taxes constant at *reference* values $\overline{\tau}_t$ and $\overline{\mathcal{T}}_t$ which evolve as follows:

$$\overline{x}_t = x_f + \rho_x \left(\overline{x}_{t-1} - x_f\right), \qquad \text{for} \quad x = \tau, \mathcal{T}, \tag{27}$$

where $\overline{x}_{-1} = x_o$, and x_o and x_f denote initial and final steady-state values of x. While τ_f is determined endogenously, we set $\mathcal{T}_f = \mathcal{T}_o \times (y_f/y_o)$ so that transfers scale with output across steady states.

The definition of fiscal gap in equation (26) can be used to write the budget constraint in terms of its financing as

$$\mathfrak{Gap}_t = \Delta b_t^x + \Delta b_t^d + (\tau_t - \overline{\tau}_t)\, c_t - \left(\mathcal{T}_t - \overline{\mathcal{T}}_t\right). \tag{28}$$

Equation (28) shows that the gap $\mathfrak{Gap}_t$ can be covered by domestic and/or external borrowing, and fiscal adjustment through taxes and/or transfers. However, to keep debt sustainable, the borrowing (domestic or external) can be used only in the short or medium term. Thus, eventually, the VAT rate and transfers must adjust to cover the entire gap. The reaction functions that accomplish the required adjustments include the following debt-stabilizing values for VAT and transfers

$$\tau_t^{target} = \overline{\tau}_t + (1-\lambda)\frac{\mathfrak{Gap}_t}{c_t}, \tag{29}$$

and

$$\mathcal{T}_t^{target} = \overline{\mathcal{T}}_t - \lambda \mathfrak{Gap}_t, \tag{30}$$

where $\lambda \in [0,1]$ is a policy parameter controlling the division of the fiscal adjustment between taxes and transfers. When $\lambda = 0$ the burden of adjustment falls fully on taxes and vice versa for $\lambda = 1$.

The fiscal reaction functions themselves are

$$\tau_t = \tau_{t-1} + \lambda_{\tau,1}\left(\tau_t^{target} - \tau_{t-1}\right) + \lambda_{\tau,2}\frac{\left(b_{t-1}^x + b_{t-1}^d\right) - \left(b^x + b^d\right)^{target}}{y_t}, \tag{31}$$

and

$$\mathcal{T}_t = \mathcal{T}_{t-1} + \lambda_{\mathcal{T},1}\left(\mathcal{T}_t^{target} - \mathcal{T}_{t-1}\right) + \lambda_{\mathcal{T},2}\frac{\left(b_{t-1}^x + b_{t-1}^d\right) - \left(b^x + b^d\right)^{target}}{y_t}, \tag{32}$$

where $(b^x + b^d)^{target}$ is the new (steady state) level of government debt that is specified exogenously.

Our fiscal adjustment mechanism reduces to that of Buffie et al. (2012) when the shock is temporary and reflects the desire of the government to smooth out policy changes as rapid fiscal adjustment is painful. As a result, in response to a change in policy (or any shock), the government will typically reach fiscal policy targets consistent with a zero fiscal gap over time. In the meantime, it will adjust its borrowing to meet fiscal obligations. However, it also implies that the later part of the transition is characterized by smaller transfers and higher taxes than target values to generate fiscal surpluses to pay down the accumulated debt.

The complete specification of the government policy also requires specifying the path of total expenditure, $g_t^z + m_t^z$, and its breakup between spending on roads and schools. Let ϖ^e be the share going to schools (and $\varpi^i = (1-\varpi^e)$ for roads), then we have the total spending on schools given by

$$g_t^e + m_t^e = \varpi^e\left(g_t^z + m_t^z\right), \tag{33}$$

and since current expenditures on schools, m_t^e, are a fraction of the stock of social infrastructure, we can rewrite the total capital expenditures on schools as

$$g_t^e = \varpi^e\left(g_t^z + m_t^z\right) - m_t^e.$$

2.4 Market Clearing and External Balance

Combining the household's budget constraint (6) and the government's budget constraint (21), and using the homogeneity of the production function in private factors yield the following external balance (or balance of payments) condition for the economy

$$-\left(b_t^x - \frac{b_{t-1}^x}{1+g}\right) = y_t + \mathcal{G}_t - \frac{r_{t-1}^x}{1+g} b_{t-1}^x - \left(m_t^z + g_t^z + c_t + I_t\right), \tag{34}$$

where the left-hand side is the negative of the capital/financial account and the right-hand side is the current account.

Goods market clearing requires aggregate output to equate aggregate demand

$$y_t = c_t + I_t + g_t^z + m_t^z + nx_t, \tag{35}$$

where nx_t represents net exports. Using these two, we can obtain the current account

$$ca_t = nx_t + \mathcal{G}_t - r_{t-1}^x \frac{b_{t-1}^x}{1+g}. \tag{36}$$

Finally, the assumptions of competitive markets and constant returns to scale in production in private factors imply zero firms' profits, so that

$$\Phi_t = 0. \tag{37}$$

The economy's behavior is described by the system consisting of 35 equations: (1-3), (5), (7), (9-10), (12-18), (19a-19b), (20a-20b), (22-26), (27a-27b), (28-37) in the following 35 variables: y_t, c_t, I_t, k_t, n_t, l_t, u_t, e_t, ξ_t, b_t^d, b_t^x, Φ_t, r_t^k, w_t, r_t^d, r_t^x, $\lambda_{1,t}$, $\lambda_{2,t}$, $\lambda_{3,t}$, z_t^i, z_t^e, g_t^i, g_t^e, m_t^i, m_t^e, m_t^z, τ_t, $\mathcal{T}_t$, $\overline{\tau}_t$, $\overline{\mathcal{T}}_t$, τ_t^{target}, $\mathcal{T}_t^{target}$, nx_t, ca_t, and $\mathfrak{Gap}_t$, given the exogenous value of $(b^x + b^d)^{target}$ and exogenous paths for g_t^z and $\mathcal{G}_t$.

3 Calibration

The model is simulated at an annual frequency, with the calibration reflecting a mixture of observable data, estimates, and guesstimates for an average low-income country. Table 1 summarizes the baseline calibration used throughout the computation.

- *Elasticity of intertemporal substitution* (κ). Most estimates for LIDCs lie between 0.10 and 0.50 (see Agenor and Montiel, 1999). Our base case value, 0.34, is the average estimate for LIDCs in Ogaki et al. (1996).

- *Proportion of non-leisure time and leisure preference parameter* (n_o, ζ). We chose to set the proportion of non-leisure time to 0.36 in the initial equilibrium—a practice common in the real business cycle literature. This results in $\zeta = 1.1648$. The implied Frisch elasticity of labor supply is 1.0051, which is within the range of empirical estimates.

- *Capital's share in value added* (α). Data on factor shares may be found in social accounting matrices (for example, see those from the Global Trade Analysis Project (GTAP) and the International Food Policy Research Institute (IFPRI)). The GTAP5 database for SSA suggests a capital share of 55-60% in the non-tradable sector and 35-40% in the tradable sector. The data in Thurlow et al. (2004) and Perrault et al. (2010) suggest similar numbers, although with a lot of variation (see Thurlow et al., 2008). As the size of the two sector is typically approximately equal, we set $\alpha = 0.475$, the average of the mid-point of the estimates for the two sectors.

- *Return to economic infrastructure and elasticity of output with respect to the stock of economic infrastructure* $(R^i_{z,o}, \psi)$. Both micro and macro evidence on the balance points to a high average return on economic infrastructure, although actual estimates vary a lot. A comprehensive study of World Bank projects from around 2001 found the median rate of return of 20% in SSA that varied from 15% to 29% for various sub-categories of economic infrastructure investment. The macro-based estimates in Dalgaard and Hansen (2005) paint a similar picture with most estimates in 15%-30% range for a wide array of different estimators. Some micro estimates from Foster and Briceno-Garmendia (2010) suggest returns for electricity, water and sanitation, irrigation, and roads ranging from 17% to 24%. Hulten et al. (2006), Escribano et al. (2008), Calderon et al. (2009), and Calderon and Serven (2010) supply additional evidence of high returns.[6] Thus, high returns appear to be the norm and we consider a high-return scenario as the base case by setting $R^i_{z,o} = 0.25$ at the initial equilibrium. Our initial values and parameters pin down ψ, which is found to be 0.1123.

- *Speed of transition of human capital from schools to the labor force* (ω). Under the assumption that education infrastructure in the model refers to schools from K-12 (i.e. 12 years of schooling), $\omega = 0.08$, so that human capital becomes part of labor force after an average delay of $1/\omega \approx 12$ periods after acquisition.

- *Return to schools and parameters of the human capital accumulation process* $(R^e_{z,o}, \chi, \phi, \nu)$. Estimates on the macroeconomic return on education/schools are scant. However,

[6] For a critique of studies using infrastructure stock arrived at using perpetual inventory method which find low or insignificant returns, unlike those based on physical measures, see Straub (2008).

it is frequently argued that the return on public investment in schools is much higher than that on investment in roads—as a result of too little relative investment in schools in practice and a poor stock of human capital in LIDCs (as discussed in the Introduction). While such claims may be disputable, to give as much leeway as possible to having such claims upheld, we assume a much higher return to schools and, accordingly, set $R^e_{z,o} = 0.40$ in the initial equilibrium so that government, without doubt, would make additional investment solely in schools in absence of distortions. We augment this baseline analysis with a sensitivity analysis for a range of differential in returns between roads and schools by varying $R^e_{z,o}$. As shown below, our results get stronger when this differential shrinks.[7] In addition, we make an agnostic assumption that (the non-stationary counterparts of) the total factor productivity in both goods and human capital production, A^y and A^e, grow at the same rate. Finally, we fix the proportion of non-leisure time devoted to schooling $\left(\frac{u_o}{n_o}\right)$ to .10 in the initial equilibrium. These three restrictions imply $\chi = 0.6911$, $\phi = 0.5467$, and $\nu = 0.5838$.

- *Depreciation rates* $(\delta_k, \delta^e_z, \delta^i_z, \delta_e)$. Given the paucity of data on depreciation rates in LIDCs, we use a value of 5% for physical capital (private, roads, and schools), which is a typical value for the developed countries. Due to the lack of additional information, we also choose the same value for δ_e, the depreciation rate for human capital.

- *Trend growth rate* (g). The trend growth rate is set at 1.5%, the 1990-2008 per-capita growth rate for SSA based on African Development Indicators as reported in Buffie et al. (2012).

- *Real interest rate on domestic bonds and (gross) real return on private capital* (r^d_o, r^k_o). Real interest rates vary considerably across countries and over time. We set the domestic real interest rate at 10% in the initial steady state consistent with Fedelino and Kudina's (2003) estimates for SSA as well as with the return on private capital estimated by Dalgaard and Hansen (2005). With this choice, the domestic debt in low- and middle-income countries is more expensive than external debt in accordance with the stylized facts. The real return on private capital is a markup over the domestic real interest rate equivalent to the capital's depreciation rate (i.e. 15 %). The real interest rate on domestic debt and the (net of depreciation) real return on private capital equal $(1+\varrho)(1+g)^{\kappa} - 1$ in the steady state, where ϱ is

[7] Recall, the effect of schools on output through increased effectiveness of labor (via e) happens slowly over time or with a gradual delay, which is in contrast to the effect of economic infrastructure on output. The computation of the return to schools takes this delay into account. In particular, we calculate the stream of additional output (net of depreciation) resulting from an initial one unit increase in investment in schools in the initial equilibrium. The stream is discounted to the initial period using the domestic market interest rate (r^d). The return to schools is then simply r^d times this present value.

the subjective discount rate. With values of κ and g chosen above, the target for real interest rate yields the value of ϱ.

- *Risk-free world real interest rate, real interest rate of foreign borrowing, and debt risk premium parameters* $(r^f, r_o^x, \upsilon_g, \eta_g)$. We fix the world real interest rate at the standard value of 4%. It also approximates the historical averages of the real returns on stocks and government bonds (3-10 year T-bills) in the United States. In 2015, Angola and Gabon issued B+ rated eurobonds amounting to about US$1.5 billion and US$500 million with interest rates of 9.5% and 6.96%, respectively. Their average is close to Gueye and Sy's (2010) estimate: according to them, SSA, excluding Seychelles and South Africa, pays an average interest rate of 8.55% on international debt. After assuming a 2.5% world (traded goods) inflation, this yields a 6% (initial) real interest rate in dollars which equals the value for r_o^x in the initial equilibrium and, in turn, implies $\upsilon_g = 0.02$. Thus, the risk premium is set at 2%. While van der Ploeg and Venables (2011) provide a positive estimate $\eta_g = 1.89$, we keep the risk premium constant so that $\eta_g = 0$ as in practice it makes little difference for our results.

- *Public domestic debt* (b_o^d). As there is a lot of variation across studies, our choice of 20%, is based on the average of the figures reported in Panizza (2008), IMF (2009), and Arnone and Presbitero (2010).

- *Public external debt* (b_o^x). We assume that initially the economy has no access to foreign borrowing implying that $b_o^x = 0$.

- *Grants and other revenues* $(\mathcal{G}_o)$. The grants are assumed to be 4% of GDP in the initial equilibrium, which is close to the average for LIDCs in the last decade. We also assume that other revenues, such as those from natural resources, are zero.

- *Initial ratio of capital investment and current spending to GDP for roads and schools* $\left(\frac{g_o^i}{y_o}, \frac{g_o^e}{y_o}, \frac{m_o^i}{y_o}, \frac{m_o^e}{y_o}\right)$, *current expenditure on roads and schools as fraction of the stocks of roads and schools* (γ_z^i, γ_z^e), and *fraction of government expenditure on roads* (ϖ^i). We set the initial total public expenditure on infrastructure (current and capital) to be equal to 6% of GDP, close to the LIDC SSA average of 6.09% for 2008 according to Briceno-Garmendia et al. (2008). As they note, this figure also includes the net investment associated with trend growth and current expenditure (the outlays on operations and maintenance (O+M)), which average about 3.4% of GDP for the LIDCs in SSA. We assume that two-thirds of the investment is made in roads and one third in schools. Adam and Bevan (2014) note considerable variation in the ratio of (re)current expenditure to installed capital, with the number being (much) larger for social infrastructure like schools than for economic infrastructure like roads.

Accordingly, we set this ratio to 70% for schools and 50% for roads, which yields the average value of 56.7% as in data. The chosen values are within the range of estimates in Heller (1991). The values of (γ_z^i, γ_z^e) follow in a straightforward manner from the initial ratios for capital investment and current spending on infrastructure and schools. In particular, $\gamma_z^i = 0.0650$ and $\gamma_z^e = 0.1517$. Finally, the fraction of government expenditures on roads (ϖ^i) turns out to be 76.92% in the initial equilibrium.

- *Consumption VAT* (τ_o). The consumption VAT rate in the model proxies for the average indirect tax rate. Our rate of 15% at the initial steady state is comparable to the average VAT rate of 15.8% for LIDCs for 2005-06 estimated from data by the International Bureau of Fiscal Documentation.

- *Net Transfers* ($\mathcal{T}_o$). At the initial steady state, transfers are set to ensure that the budget constraint of the government holds. This translates into $\mathcal{T}_o = 7.94\%$ of GDP. Given the definition of the other fiscal variables, this concept of transfers includes other taxes different from VAT as well as non-capital expenditures such as public wages.

- *Division of fiscal adjustment between expenditure cuts and tax increases* (λ). For the purpose of the simulations reported below we assume that only taxes share the burden of fiscal adjustment ($\lambda = 0$).

- *Speed of adjustment of reference values for computing the fiscal gap* ($\rho_\tau, \rho_\mathcal{T}$). To be consistent with a slow adjustment of the economy to the new steady state equilibrium, these autoregressive parameters are set to very close to 1. Specifically, both are assigned a value of 0.99.

- *Policy reaction parameters* ($\lambda_{\tau,1}, \lambda_{\tau,2}, \lambda_{\mathcal{T},1}, \lambda_{\mathcal{T},2}$). There are no estimates of these parameters for LIDCs. We set $\lambda_{\tau,1} = \lambda_{\mathcal{T},1} = 0.25$ and $\lambda_{\tau,2} = \lambda_{\mathcal{T},2} = 0.02$ to allow the government to finance a substantial part of the investment scale-up via debt. Sensitivity analysis is done for a range of tax reactivity.

With the calibration set forth above, we perform numerical simulations that closely track the global nonlinear saddle path of the model. Thus, the solution is free of the errors that may be introduced by linearization. As there is no uncertainty in the model, the solution is based on perfect foresight. Moreover, as our experiments (described in following sections) involve at least a one-time permanent change in policy, the economy converges to a different steady state than the initial one.[8]

[8]While a number of tools are available to solve such dynamic models with perfect foresight, our numerical simulations are generated using a set of programs written in Matlab and Dynare (see http://www.cepremap.cnrs.fr/dynare).

4 Roads or Schools: Implications for Growth and Debt Sustainability

The paper compares the effects of a public investment scale-up in schools and roads. We consider an increase in combined public investment and current expenditure to the tune of 1% of initial GDP. This implies a scaling up of 16.7% in real terms, which is modest relative to a 50% scaling up from 6% to 9% of GDP considered in Adam and Bevan (2014) or the levels considered in Buffie et al. (2012). Qualitative implications are, however, independent of the size of the scale-up. Similar to Adam and Bevan (2014), the scale-up in expenditures considered is permanent (long-term), whereas Buffie et al. (2012) focus on the (short-term) temporary case. A permanent scaling up, that is, a longer-term perspective in expenditure planning, is deemed to be more appropriate and natural in the current setting of a choice between roads and schools, since the effects of better schools on output through the accumulation of human capital operate gradually over a long time span.[9] Subsection 4.1 show the trade-offs between a scale-up of public investment exclusively in roads versus one that occurs entirely in schools. Subsection 4.2 extends the analysis to include a "big-push." The optimal composition of the scale-up and its determinants are analyzed in Section 5.

4.1 A Permanent Scale-Up of Public Investment

In this subsection we undertake a positive comparative analysis of public investment scale-up in roads and schools. Two scenarios are examined: one in which the scale-up occurs entirely in roads; and the other in which it happens entirely in schools. This exercise is intended to shed light on how a rise of investment in roads or schools individually affects the macroeconomic dynamics. In order to make the two cases comparable, we keep the increase in total government expenditure (including both capital and current expenditures) the same across the two cases.

Given that the investment in schools has higher returns, it is expected to result in higher growth in the long run. At the same time, we show some serious trade-offs during the transition. Qualitatively, the trade-off is fairly intuitive: while investment in schools is more attractive and would result in higher output in the longer run, the increase occurs only gradually when compared to the alternative of investing in roads. This, in turn, forces the government to rely more on debt financing when investing in schools, exacerbating debt sustainability concerns. In Section 5 we show that the trade-off becomes

[9]To be specific, as the economy grows at rate g, a permanent increase of 1% of initial GDP in normalized terms implies that the expenditure also grows over time at the same rate.

more stringent when the return on schools is smaller and that our results hold *a fortiori* if the assumption of higher returns on schools is relaxed.

The intuition described above is confirmed by the model simulations reported in Figure 2 and 3, where total government infrastructure expenditures rise from 6% to 7% of GDP. Figure 2 clarifies how the scale-up is apportioned to the various spending items. Let us first consider the scenario with the investment scale-up occurring entirely in roads. In this case total expenditure on roads rises permanently from 4% to 5% of GDP. As current expenditures are initially unchanged, the increase shows up entirely as an increase in capital expenditures in roads, which rise from 2% to 3% of GDP. However, the gradual increase in current expenditures, concomitant with the rise in the stock of roads, causes some of the committed resources to be directed away from capital expenditures (augmenting the stock of roads) and into current expenditures. In the long run, both investment and current expenditures on roads evenly split the 1% increase (both rise from 2% to 2.5% of GDP). Let us now turn to the scenario with the entire investment scale-up occurring in schools. Since maintaining schools requires proportionately larger current expenditure, in the long run, the split between capital and current expenditures is 30%-70%, respectively (with investment increasing from 0.6% to 0.9% and current expenditures jumping from 1.4% to 2.1% of GDP).

Figure 3 illustrates the macroeconomic implications of the two alternative scenarios. The trade-off is rather stark and clear. Investment in schools results in a long-run increase in output (above the underlying trend) of 24% compared to a much smaller increase of 5% obtained with an exclusive investment in roads. Yet, for the first 13 years, the economy enjoys faster growth rates (over and above the exogenous growth rate of g) when the public investment is made in roads rather than in schools. In fact, growth dips below its trend for about 9 years with investment in schools, whereas it stays above trend if the investment is made in roads. The initial disadvantage of investment in schools accumulates over time and it takes 24 years for the (additional) output obtained by investing in schools to overtake that delivered by investing in roads.

In the initial 20 years or so of the simulations, the difference in private consumption across the two scenarios is, however, much more moderate. The reason lies in that relatively larger future increases in productivity generated by investment in schools result in a stronger wealth effect (due to the larger increase in permanent income) and intertemporal substitution of labor towards the future, increasing the time households spend in schools in the first 20 years or so. Since output rises only slowly over time and agents cannot borrow from abroad, private investment falls in the short run. In short, (relatively) lower output with investment in schools is matched by a (relatively) lower private investment demand with consumption responding marginally.

As government ramps up investment, and consumption (its tax base) and revenues responds little on impact, the resulting fiscal deficit increases public debt.[10] The latter in turn results in current account deficits. As public debt builds up over time, the fiscal rule implies an increase in the consumption tax rate. While the described mechanism operates in a similar manner across both scenarios, the quantitative effects differ significantly. While public debt rises by about 2% of GDP for investment in roads, investment in schools results in an almost threefold increase of 6% of GDP.[11] Perhaps more importantly, investment in schools results in a more persistent increase in public debt as a fraction of GDP, posing more prolonged risks to debt sustainability. In our example, while investment in roads increases the debt burden for a period of 30 years, investment in schools leads to an increase in public debt that lasts around 60 years.

4.2 A Permanent Scale-Up with a "Big Push"

Typically, policy shifts signaling greater public investment are accompanied by a "big push" in the short run. Increases in public investments of the order of 5 to 10 percent of GDP for several years are not uncommon. A number of papers have analyzed growth and debt sustainability implications of these big pushes.[12] In this subsection, we study how the comparative analysis of growth and debt sustainability implications of long-run investment in roads versus schools is affected in the likely scenario of an accompanying "big push" in the short run.

We use a second-order delay function as in Melina et al. (2016) to model the short-run "big push." In particular, we set the short-run increase, as a percent of GDP, over and above the long-run 1% rise, as $14(e^{-.2t} - 2e^{-.9t})$. The results with "big push" are shown in Figure 4. The "big push" nearly doubles public expenditure from 6% to almost 13% in the first 2 years and it remains over 8% for about 14 years.

Some aspects of the simulations results are straightforward, others need some explanation. As expected, the "big push" generates additional investment and hence a quicker transition to the long-run growth outcome. For instance, for the case of invest-

[10] Since we consider the case in which the government finances deficits only via international borrowing, the increase is in public external debt.

[11] If the model featured an income/output-based tax instead of a consumption-based tax, the differences would be larger because output differences are much larger across the two scenarios than consumption differences. Putting it differently, relative to income-based taxation, consumption-based taxation reduces the disadvantage of investment in schools in terms of debt sustainability implications.

[12] Djibouti ramped up public investment from about 12-14% of GDP to as much as 30% of GDP over 2013-2015 (see IMF, 2016a). See IMF (2016b) for the analysis of the Maldives' currently undergoing investment of 35%-38% of GDP to upgrade its tourism infrastructure over a period of 4 year from 2016 onwards. Andreolli and Abdychev (2016) analyze debt sustainability implication of Lesotho's construction of an hydropower plant with total investment of about 31% of GDP over a period of 7 years. In the context of big-push scenarios, Ghazanchyan et al. (2016) study how improving the efficiencies of capital spending and of tax revenue collection affect growth and debt sustainability in Cambodia, Sri Lanka, and Vietnam.

ment in schools, the transition is almost complete in 60 years compared to more than 100 years in absence of the "big push." Interestingly, in the medium run the "big push" takes growth well above the long-run outcome for investment in roads. Moreover, it is noteworthy that—with the "big push" under the scenario of all investment in schools—output, private consumption, and private investment overtake their counterparts derived from investing all in roads 4-5 years earlier (in about 20 years) than in the scenarios without the "big push."

In the same vein, the "big push" tilts the balance in favor of investment in schools when viewed from the perspective of taxes and debt. True, it results in a higher tax and debt burden in the initial years of the policy change. However, first, the duration for which taxes and debt rise is much shorter in both scenarios. In particular, public debt (as a fraction of GDP) comes back to the original level, and below, within 20 years, and this happens because GDP rises much faster. Second, and most importantly, the pronounced differences between the paths for consumption taxes and public debt presented in Figure 3 (with no "big push") vanish in Figure 4. In other words, the handicap of schools vis-a-vis roads from a fiscal perspective almost vanishes with a "big push."

A very important caveat is that while investment in schools overtakes investment in roads earlier in terms of various criteria in the presence of a "big push," the short-run costs in terms of private consumption (and output) are much higher. This has significant welfare implications, as we show below. The "big push," by accelerating the benefits of investment in education, significantly strengthens the intertemporal (labor) substitution effects causing labor supply to decline sharply in the medium run than with a permanent policy shift alone. The consequent decline in output also reduces private consumption.

5 Roads or Schools: "Optimal" Composition and Its Key Determinants

The analysis in the previous section highlights the tension between investment in roads versus schools. One provides smaller—but immediate returns with less challenges to debt sustainability—while the other results in larger gains far out into the future with associated risks to debt sustainability. Given that these two extreme scenarios provide such different profiles of benefits and costs, it may be useful to consider an intermediate scenario that can leverage strengths of both to deliver a better overall outcome. In particular, we consider a government policy choosing a constant split of the scale-up of infrastructure between roads and schools such that households' welfare is maximized.

Figure 5 shows how households' welfare varies with the share of expenditure allocated to schools. We first consider the permanent policy shift of a scale-up of public investment of 1% in the long run without the "big push" (left panel). In this case, the optimal share of education is high at 76%. When "big push" considerations are factored in (right panel), the optimal share comes down from 76% to 51%. As discussed in the previous subsection, the "big push" has two opposing effects on the comparative benefits of investment in roads versus schools. On the one hand, school investment catches up with investment in roads faster in terms of consumption, output, tax, and debt. On the other hand, short-run costs in terms of consumption are much higher. For the baseline calibration, the increase in short-run costs outweighs the acceleration benefits so that the optimal share of investment in schools goes down significantly. This result is pretty dramatic, considering the big advantage that schools have in terms of return in the baseline calibration.

In Figures 6 and 7 the corresponding equilibrium paths of macro variables are overlaid on the earlier two scenarios without and with a "big push", respectively. The paths of the variables for the optimal composition are sandwiched between those of the two scenarios. Without the "big push" these are closer to those for the scenario with all investment in schools, given the high optimal share of schools in this case. With the "big push", the paths of the macro variables are more clearly in-between the two extreme cases. All in all, the optimal composition of public investment into roads and schools improves welfare vis-a-vis all investment in schools by trading some of the future welfare gains with those in the present. It also reduces (to a small extent) the distortionary effects of higher taxation and risks to debt sustainability, the former being implicitly accounted for in the welfare comparison.

5.1 Key Determinants of the Optimal Investment Composition

In this section, we examine how the optimal composition of public investment responds to a number of determinants that are key from a policy perspective. We begin by addressing one practical dimension alluded to earlier: the uncertainty regarding the differential between returns to roads and schools. We then address important considerations from the fiscal and political-economy angles. First, given that investment in roads and schools may generate very divergent paths for government debt, we analyze the impact of the policymakers' degree of debt aversion on optimal investment composition. Second, we examine the role of political myopia. This turns out to be crucial given that investing in schools generates strikingly different profiles of gains in output, consumption, and ultimately welfare over the long run.

5.1.1 Return Differential

So far in our analysis we have assumed a differential of 15 percent in annual terms between the economic returns to schools and roads (namely the return is 25 percent for roads and 40 percent for schools). This baseline experiment was motivated by the conventional wisdom that in developing countries—where the lack of human capital may even be more severe than the lack of physical infrastructure—returns to schools may be very high in the long run. Notwithstanding this, the different macro-fiscal dynamics generated by investing in roads versus schools gave rise to important trade-offs, whereby it is optimal to devote a substantial share of the investment scale-up to roads, even if schools are given such an advantage in terms of macroeconomic return. These trade-offs become even more severe if the return differential between the two types of public investment becomes smaller.

Figures 8 and 9 report the paths of key macroeconomic variables assuming the same aggregate scale-up in public investment of one percent of initial GDP, under the extreme assumption of zero differential between the returns on schools and roads (namely assuming a return of 25 percent for both types of investment). From a qualitative perspective the story outlined in the previous section holds true also under this calibration: investing in schools give rise to a stronger increase in public debt (the differences being stronger without the "big push"), higher taxes to make debt stable, a more severe crowding-out of private consumption and investment in the short and medium run (more pronounced with a "big push"), and a more pronounced intertemporal substitution of labor. However, it also leads to a higher GDP in the long run. In particular, investing in schools yields a higher GDP in the long run, which offsets the lower GDP in the initial periods and helps ensure equality of the present value of benefits for two choices as required by the equal return assumption.

From a quantitative viewpoint, the long-run gains from investing in schools are intuitively smaller under the low return assumption and the paths of endogenous variables under the optimal composition is much closer to investing entirely in roads. In fact, lower returns to schools—by rendering the dynamic trade-offs between the two types of investment more stringent—make the welfare-optimal share of schools in the public investment scale-up smaller. Figure 10 depicts the optimal share of schools as a function of the return to schools, keeping the return to roads at 25 percent. When the return to schools drops from the baseline value of 40 percent to 25 percent, in the absence of a "big push", the optimal share of schools drops from around 76 percent to 12 percent; and from around 51 percent to about 25 percent with a "big push". If the return to schools declines below the 15-20 percent range—i.e. below that of roads—then schools' optimal share goes to zero.

The importance of analyzing the role of returns is twofold. On one hand, it clarifies that the results outlined in the previous section with a large return differential hold *a fortiori* when such a differential is narrower. On the other hand, it emphasizes that from the viewpoint of a benevolent welfare-optimizing social planner with infinite time horizon, investing a share of the public investment scale-up in schools strongly depends on the expected return relative to other investments and that a relatively high return differential is required for a non-trivial share of investment to be optimally allocated to schools.

5.1.2 Debt Aversion

Governments in developing countries may often face considerable challenges in accessing international financial markets. High risk premia often make this operation costly and sometimes, even if countries are willing to bear these costs, they find issuing government bonds infeasible. This situation—often dubbed as debt intolerance—may be the outcome of political instability, poor track record in meeting debt obligations, high macroeconomic volatility, and/or inability to mobilize tax revenues, which make buying debt instruments too risky in the eyes of foreign investors. Also for those countries with financial market access, the amount of external government debt they can accumulate, relative to the size of their economy, is typically well below the amount that can be accessed by advanced economies and some emerging markets. Moreover, resorting to domestic debt may not always be desirable because it absorbs internal resources and leads to crowding-out of non-governmental domestic demand. Therefore, the constraint on whether the government is able to borrow or not can be either imposed by the financial markets or maybe a choice of the policymakers. Given that the source of this constraint is of secondary importance for our analysis, we refer more generally to debt aversion, which in the model can be measured by parameter $\lambda_{\tau,1} \in (0, 1]$: a higher value of the parameter corresponds to a larger share of the fiscal gap being covered by tax increases as opposed to bond issuance; in the limit, when $\lambda_{\tau,1} = 1$, the government runs a balanced budget and no new debt is issued at all.

Figure 11 reports the optimal share of schools in the investment scale-up as a function of $\lambda_{\tau,1}$. The main results is that debt aversion makes it less optimal to invest in schools. Such a result is intuitive, since investing in schools results in a pronounced spike in government debt. Under baseline returns and in the absence of a "big push," the optimal share of schools goes from almost 90 percent, when the government resorts almost entirely to debt (and taxes are used minimally, just enough to prevent public debt from exploding), to under 70 percent when the government resorts entirely to taxes. In the presence of a "big push" the optimal share of schools is less sensitive to debt aversion because the differences between the debt paths generated by schools and roads are much smaller, as discussed above.

Analyzing debt aversion/intolerance in this context is important because it emphasizes one of the challenges that poor economies face in investing in schools (versus roads): economic returns on schools take longer to materialize and require more financial resources in the initial phases of the investment program. Absent access to external financing, higher distortionary taxation—*ceteris paribus*—makes it optimal to devote a smaller fraction of the investment scale-up to schools. This also underscores the role of international cooperation. By mitigating this financial friction via concessional financing and grants, multilateral organizations can have an important role in helping governments achieve higher social spending targets.

5.1.3 Political Myopia

It is well known that the decisions of political incumbents are quite often not aligned with the interests of the general population. For example, the literature on political economy studies how selfish political leaders distort the provision of public goods to enhance their chances of getting re-elected (see Aidt and Dutta, 2007; Bonfiglioli and Gancia, 2013).

We introduce these political considerations into the model to shed light on how such practical realities may affect the optimal composition of the public investment scale-up in roads and schools. The adverse impact of political leaders' selfish desire for getting re-elected is modeled as their myopia in evaluating the benefits of various policies. Specifically, the incumbents disregard the benefits of policies that arise after a certain time horizon. A fully selfless (or altruistic) planner has an infinite time horizon. The greater the selfishness, the higher the political myopia and therefore the shorter the time horizon. The ranking of policies is still based on agents' discounted utility, yet summed over limited time horizons to capture leaders' myopia.

In Figure 12, we plot the welfare-maximizing share of schools in the public investment scale-up as a function of the social planner's time horizon, both for the case with no "big push" (left panel) and for the case with "big push" (right panel). In the former case, a planner with a horizon of less than 30 years would not invest at all in schools. A time horizon of 60-70 years is needed to take a myopic leader's desired share close to that of a completely altruistic social planner with infinite horizon. In the latter case, the threshold for no investment in schools falls to 20 years and it takes 45-55 years to get to a share comparable to that under an altruistic social planner.

The cost of myopia of political leaders falls with a "big push" as it brings forward in time the benefits of investing in schools. Therefore, from a policy perspective, the adverse effects of a leader's myopia can be mitigated by incorporating a "big push" in their infrastructure scale-up. Political myopia is an important consideration for low-income developing countries since it helps justify the preference for quicker gains obtained with investing in roads. The argument for investing in schools would require a far-reaching vision that would go beyond one generation.

6 Conclusions

There is a large literature on the macroeconomic effects of public investment, yet most of this literature abstracts from its composition. We investigate this policy choice from the perspective of roads versus schools to address the following questions: (1) Why is spending on schools not higher in developing economies? and (2) What are the determinants of the composition of public infrastructure investment?

We show that some governments' apparent failure to invest more in schools could be rationalized in a model with a detailed specification of fiscal policy that includes distortionary taxation and exhibits debt aversion. In our baseline case, even with a large (15 percent) return differential in favor of schools, the government chooses to limit the fraction of the investment increase dedicated to schools to about three fourths. The different pace with which roads and schools contribute to economic growth is central to this optimal allocation decision. The combined dynamics of front-loaded fiscal costs of investments and slow pace of accrual of growth benefits from investing in schools—albeit larger in the long run—does not square well with a macro-fiscal regime with distortionary taxation and debt intolerance, with political myopia adding further fuel to the fire.

A "big push" in public investments can mitigate concerns arising from myopia of policy makers, but it comes at the cost of exacerbating the threat to fiscal and debt sustainability. In fact, assuming a typical "big push" decreases the fraction of the investment scale-up dedicated to schools to about one half. Multilateral agencies could alleviate these concerns and incentivize policymakers in developing countries to undertake long-term investment in schools by providing tied concessional financing and grants. While tying aid to investment in schools would address the issue of myopia, concessional terms would mitigate concerns of debt intolerance.

The incentives to alleviate these concerns would become even stronger if another major component of social infrastructure, namely, health were also taken into consideration. While the exact dynamic response to investment in health infrastructure (hospitals) would differ, similar trade-offs would operate vis-a-vis investment in roads. We leave the task of carrying out this analysis for future research.

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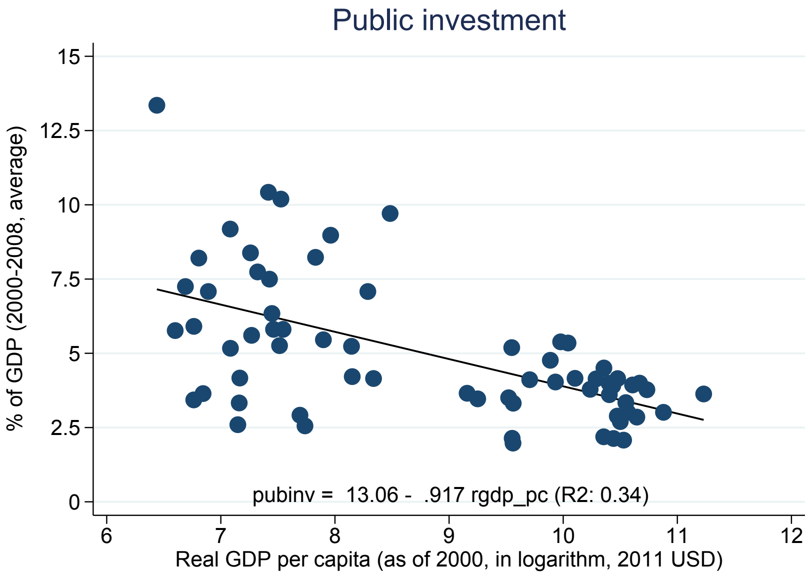
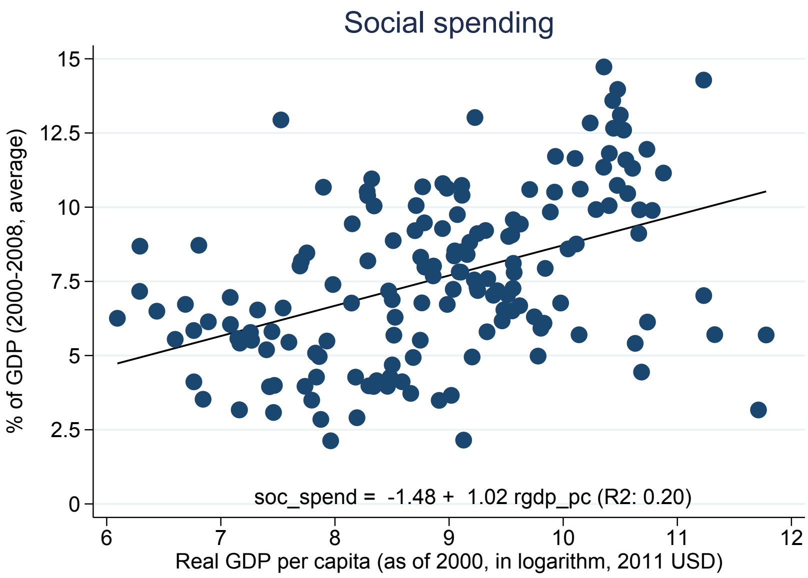
Table 1: Calibration

Parameter	Value	Definition
κ	0.3400	Intertemporal elasticity of substitution of consumption
n_o	0.3600	Initial proportion of time used for non-leisure activities
ζ	1.1648	Preference parameter for leisure
α	0.4750	Capital's share in value added
R_z^i	0.2500	Initial return on infrastructure
ψ	0.1123	Elasticity of output with respect to infrastructure
ω	0.0800	Speed of transition of human capital from schools to the labor force
R_z^e	0.4000	Initial return on schools
ϕ	0.5467	Elasticity of human capital accumulation with respect to schools
ν	0.5838	Elasticity of human capital accumulation with respect to private effort
χ	0.6911	Elasticity of effective units of labor with respect to human capital
δ_k, δ_e	0.0500	Depreciation rate of private economic and human capital
δ_z^i, δ_z^e	0.0500	Depreciation rate of public infrastructure and schools
g	0.015	Trend growth rate
r^d	0.1000	Initial real interest rate on domestic debt
r^k	0.1500	Initial gross return on capital
r^f	0.0400	Risk-free real world interest rate
r^x	0.0600	Initial real interest rate on public external borrowing
υ_g	0.0200	Public debt risk premium
η_g	0.0000	Public debt risk premium sensitivity parameter
b_o^d/y_o	0.2000	Initial public domestic debt to GDP ratio
b_o^x/y_o	0.0000	Initial public external debt to GDP ratio
$\mathcal{G}_o/y_o$	0.0400	Initial grants and other revenues to GDP ratio
g_o^i/y_o	0.0200	Initial capital investment in infrastructure to GDP ratio
g_o^e/y_o	0.0060	Initial capital investment in schools to GDP ratio
m_o^i/y_o	0.0200	Initial current expenditure on infrastructure to GDP ratio
m_o^e/y_o	0.0140	Initial current expenditure on schools to GDP ratio
γ_z^i	0.0650	Current expenditure on infrastructure as fraction of infrastructure stock
γ_z^e	0.1517	Current expenditure on schools as fraction of school stock
s^i	0.7692	Fraction of government capital expenditure going to infrastructure
τ_o	0.1500	Initial consumption VAT rate
$\mathcal{T}_o$	7.9376	Initial transfers to GDP ratio
λ	0.0000	Share of fiscal adjustment borne by transfers
$\rho_\tau, \rho_\mathcal{T}$	0.9900	Speed of adjustment of reference values for tax and transfers
$\lambda_{\tau,1}, \lambda_{\mathcal{T},1}$	0.2500	Fiscal policy reaction parameters for policy instruments
$\lambda_{\tau,2}, \lambda_{\mathcal{T},2}$	0.0200	Fiscal policy reaction parameters for debt

Figure 1: Stylized Facts on Public Investment and Social Spending

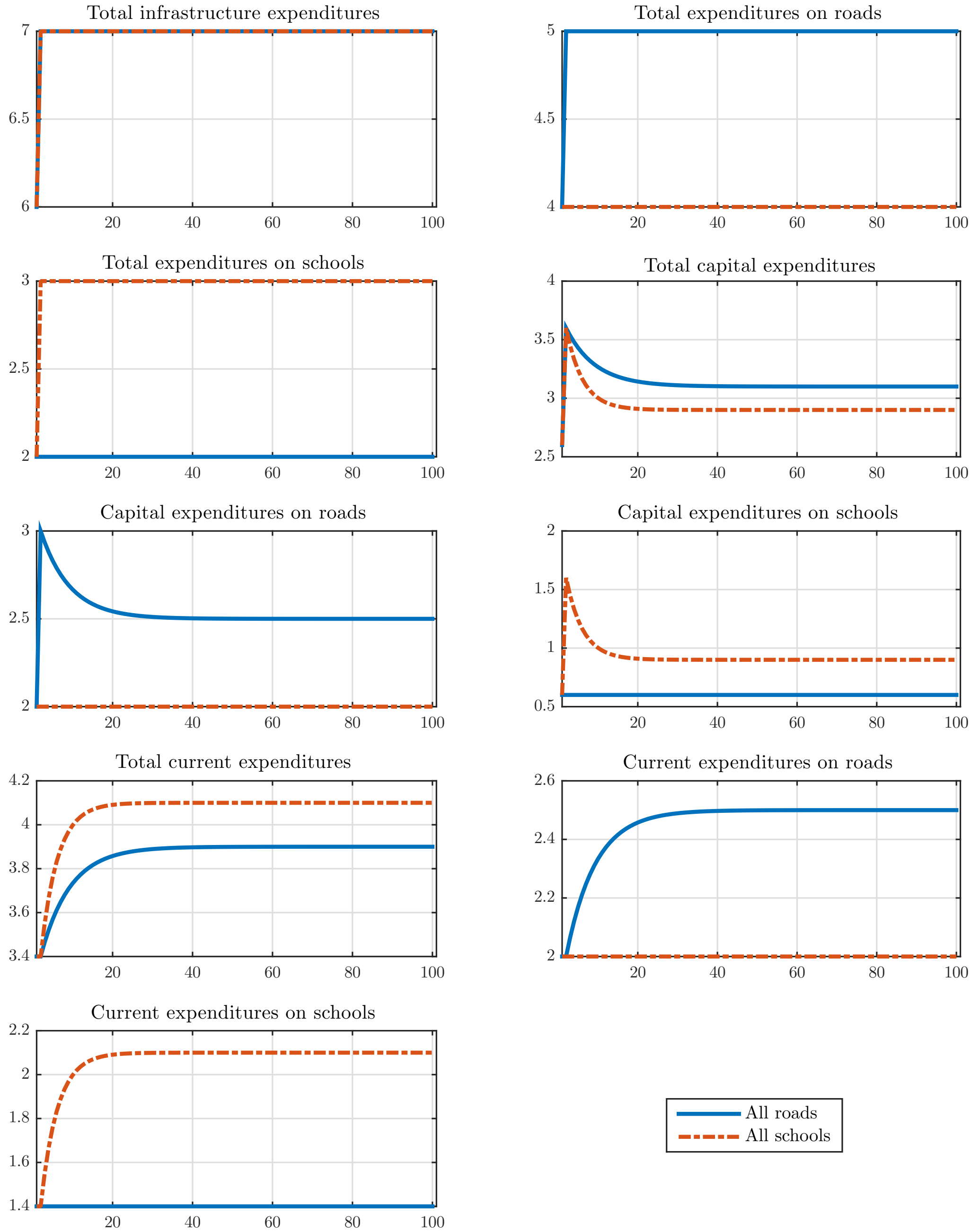


Source: IMF's Fiscal Affairs Department.



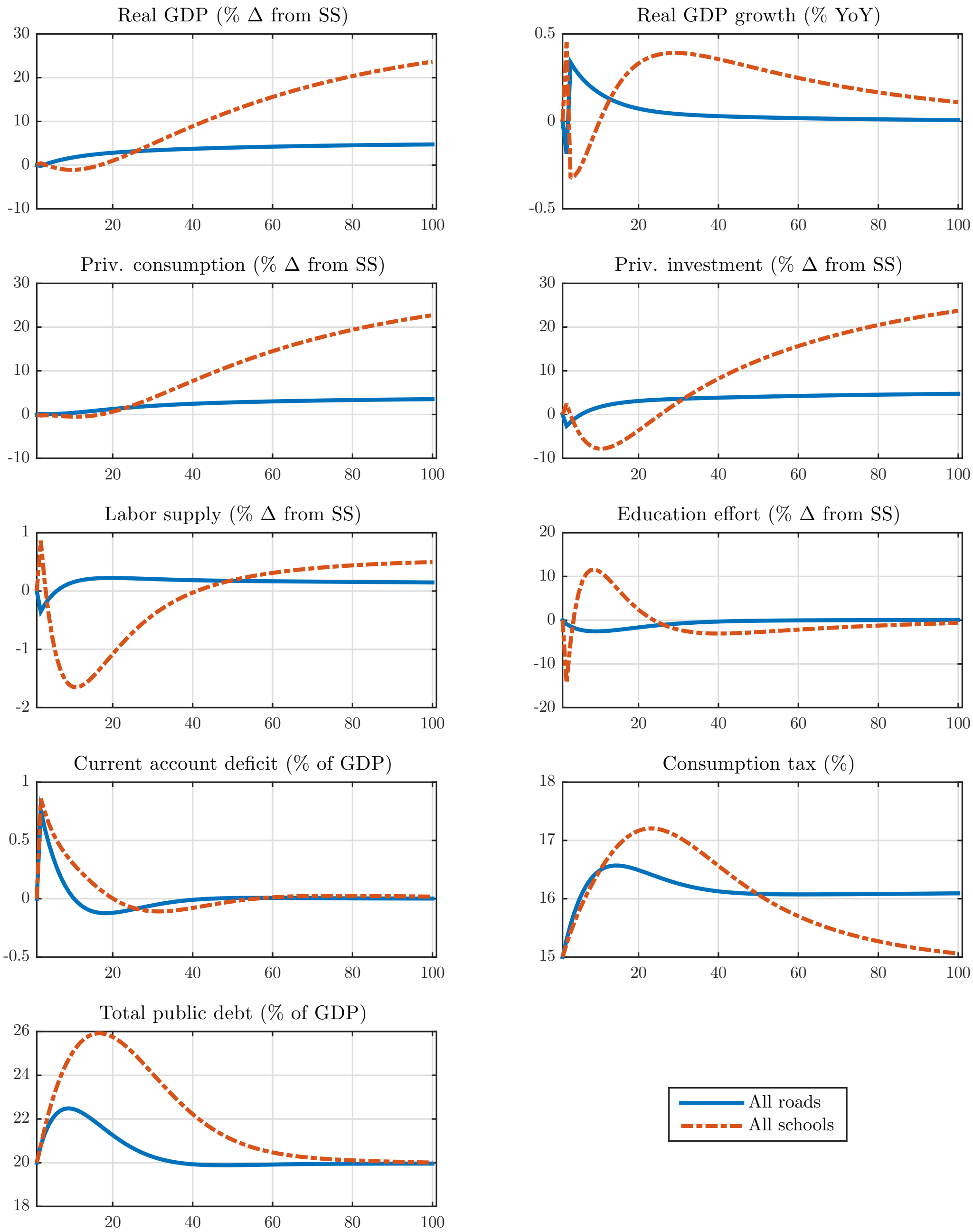
Source: World Bank's World Development Indicators and IMF's Fiscal Affairs Department.
Notes: Social spending is the sum of government spending on education and health (includes both current and capital expenditures).

Figure 2: A Permanent Increase In Public Infrastructure: Current and Capital Expenditures Associated to Investing All In Roads Versus All In schools



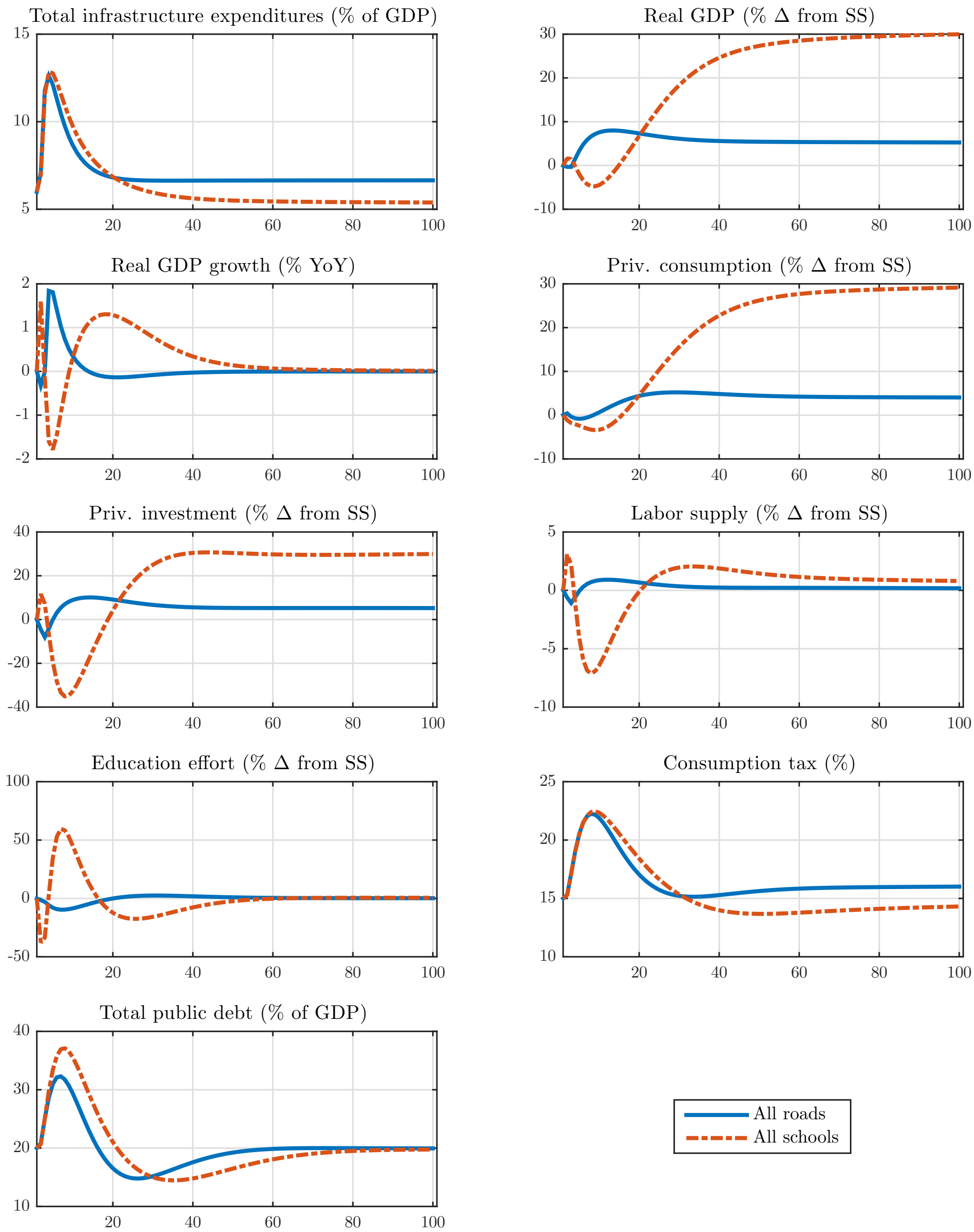
Notes: Aggregate shock size: 1% of initial steady-state GDP; x-axes in years; y-axes in percent of initial steady-state GDP).

Figure 3: A Permanent Increase In Public Infrastructure: Effects On Key Macroeconomic Variables Associated To Investing All In Roads Versus All In Schools



Notes: Aggregate shock size: 1% of initial steady-state GDP; x-axes in years; y-axes in percent deviations from initial steady state, unless otherwise indicated.

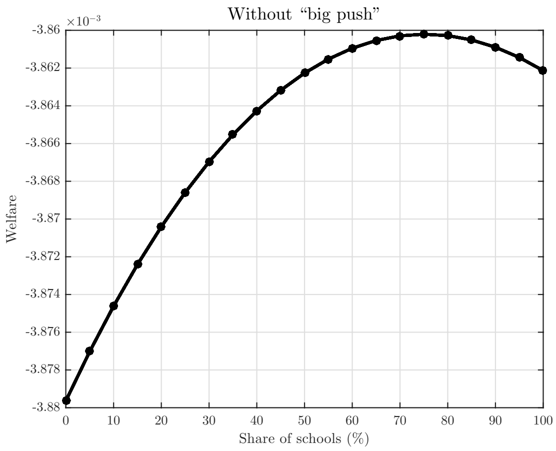
Figure 4: A Permanent Increase In Public Infrastructure With A “Big Push” In The Short Run: Effects On Key Macroeconomic Variables Associated To Investing All In Roads Versus All In Schools



Notes: Long-Run Aggregate shock size: 1% of initial steady-state GDP, with a big push; x-axes in years; y-axes in percent deviations from initial steady state, unless otherwise indicated.

Figure 5: Share Of Schools In the Public Investment Scale-Up And Associated Welfare

(a) Without "Big Push"



(b) With "Big Push"

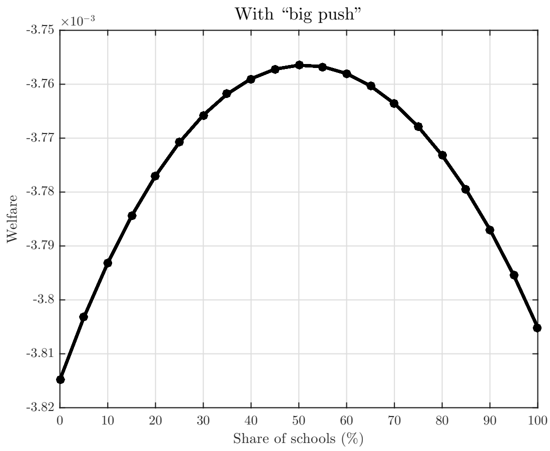
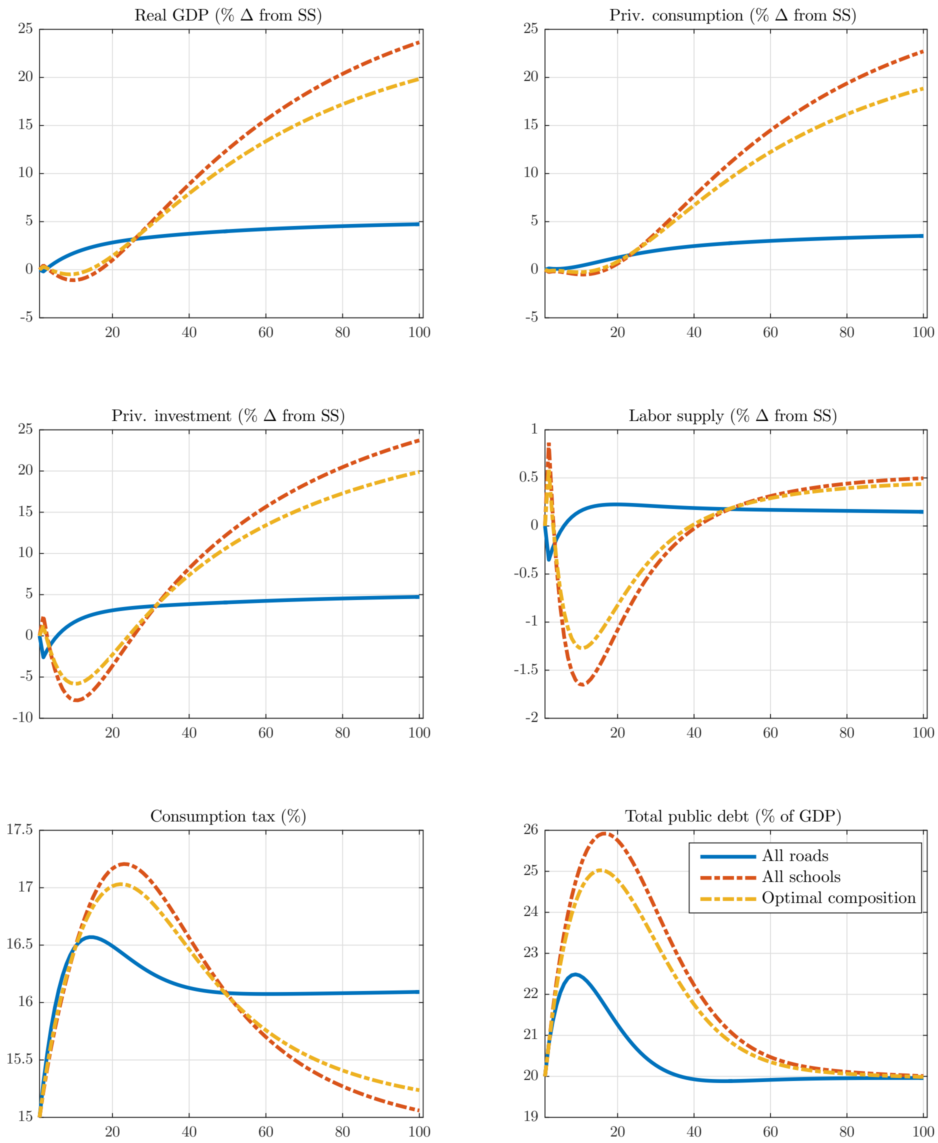
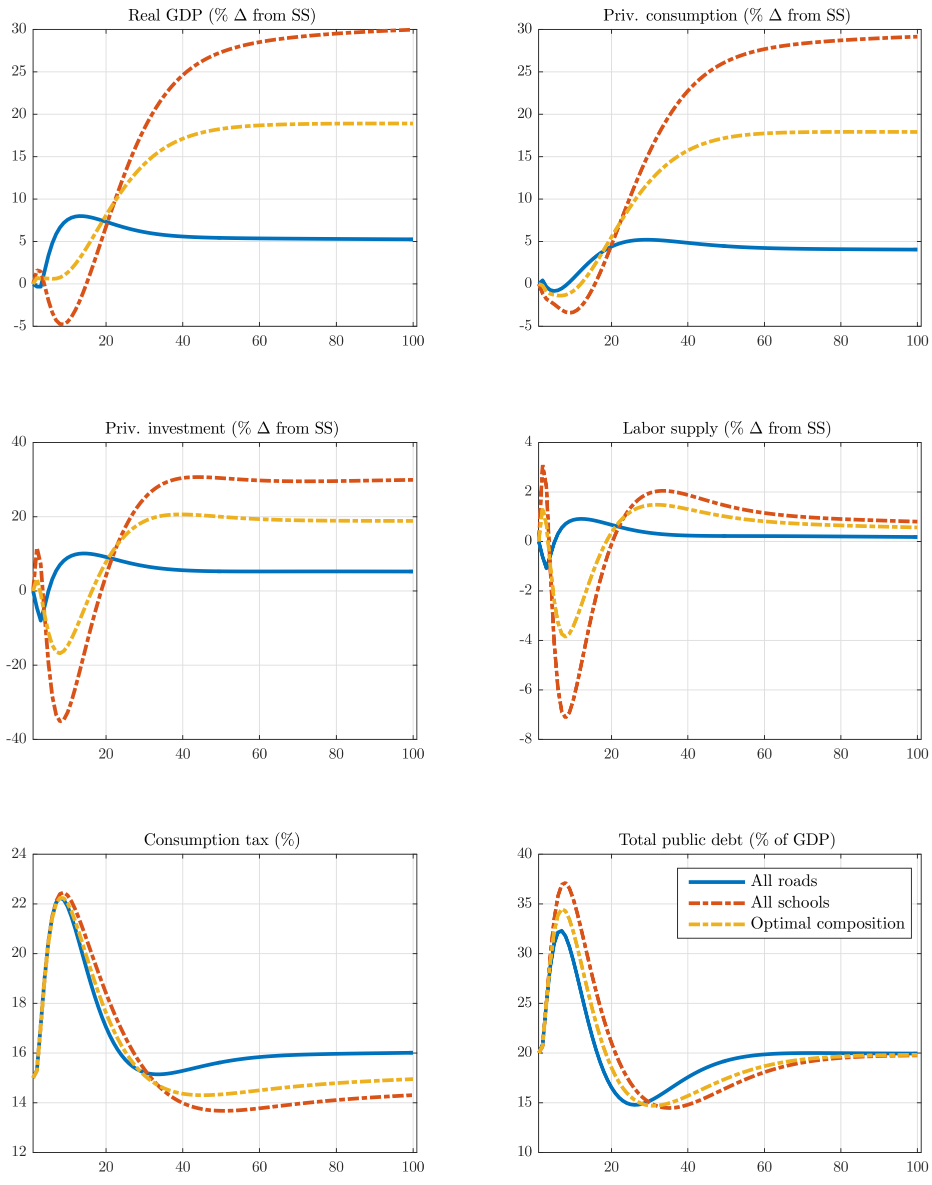


Figure 6: Effects Of The Optimal Composition Of The Public Investment Scale-Up On Key Macroeconomic Variables: Without The "Big Push"



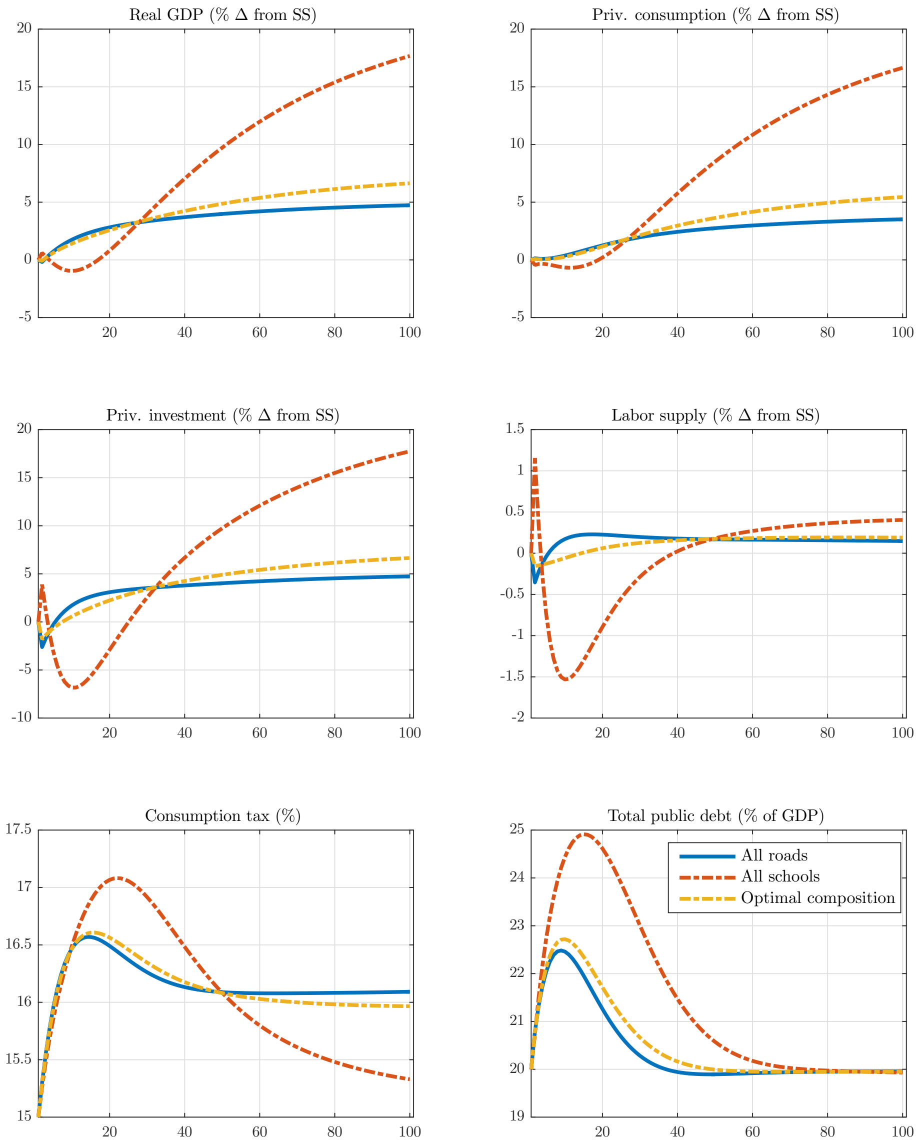
Notes: Aggregate shock size: 1% of initial steady-state GDP; x-axes in years; y-axes in percent deviations from initial steady state, unless otherwise indicated.

Figure 7: Effects Of The Optimal Composition Of The Public Investment Scale-Up On Key Macroeconomic Variables: With The "Big Push"



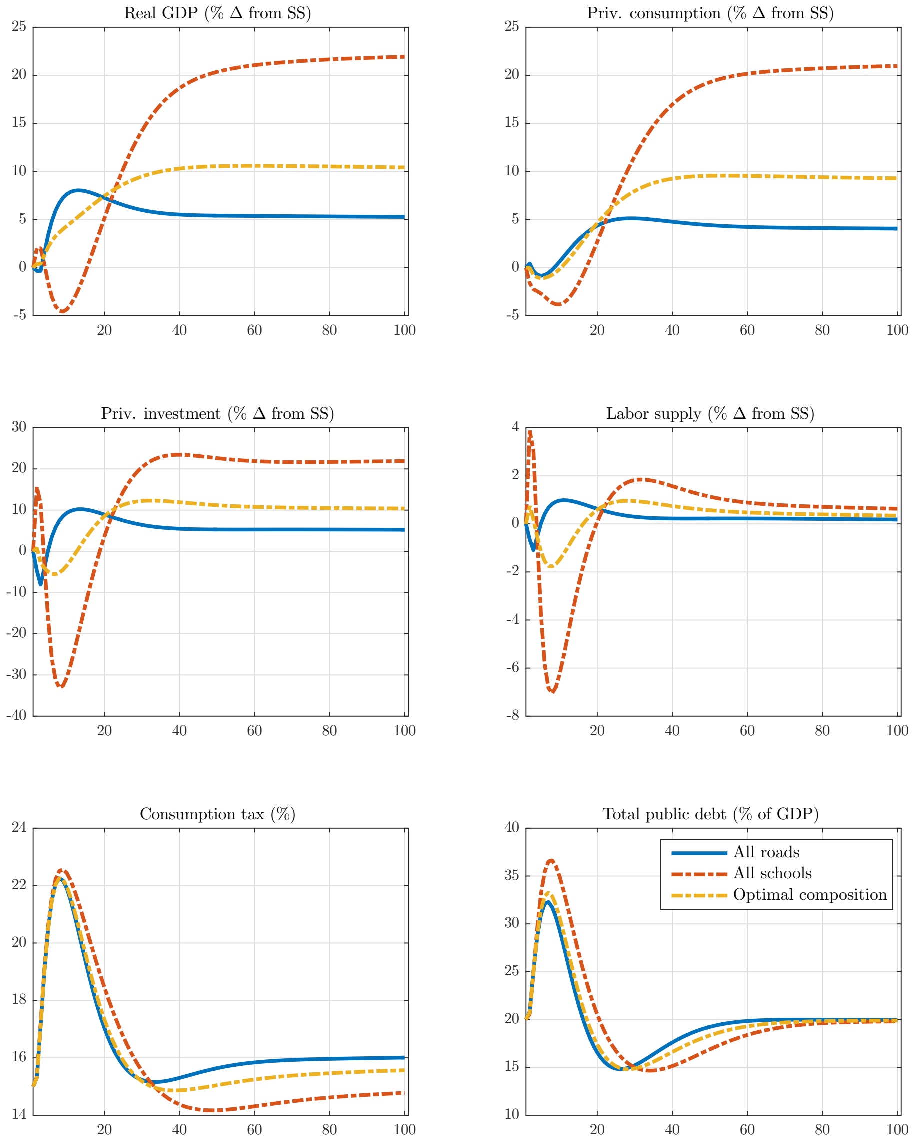
Notes: Long-Run Aggregate shock size: 1% of initial steady-state GDP, with a big push; x-axes in years; y-axes in percent deviations from initial steady state, unless otherwise indicated.

Figure 8: Effects Of The Optimal Composition Of The Public Investment Scale-Up On Key Macroeconomic Variables: Without The "Big Push" Assuming The Same Returns in Roads and Schools



Notes: Aggregate shock size: 1% of initial steady-state GDP; x-axes in years; y-axes in percent deviations from initial steady state, unless otherwise indicated.

Figure 9: Effects Of The Optimal Composition Of The Public Investment Scale-Up On Key Macroeconomic Variables: With The "Big Push" Assuming The Same Returns in Roads and Schools



Notes: Long-Run Aggregate shock size: 1% of initial steady-state GDP, with a big push; x-axes in years; y-axes in percent deviations from initial steady state, unless otherwise indicated.

Figure 10: Optimal Share Of Schools In The Public Investment Scale-Up: The Effect of The Return To Schools

(a) Without "Big Push" (b) With "Big Push"

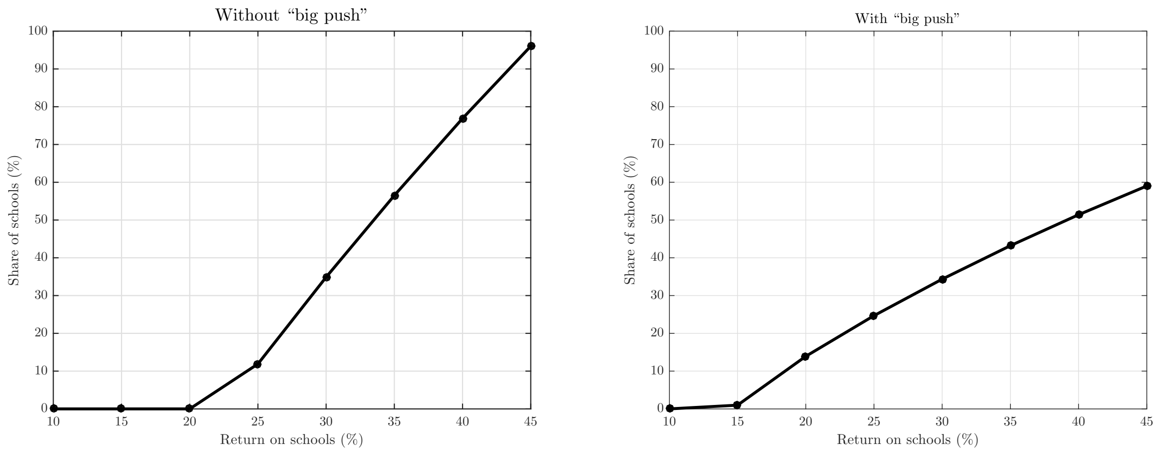


Figure 11: Optimal Share Of Schools In The Public Investment Scale-Up: The Effect of Debt Aversion

(a) Without "Big Push" (b) With "Big Push"

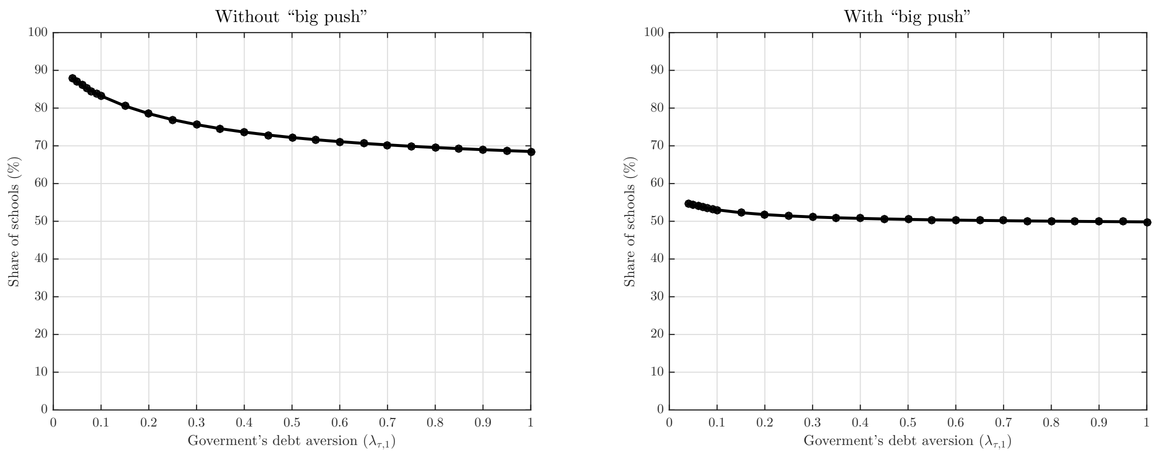


Figure 12: Optimal Share Of Schools In The Public Investment Scale-Up: The Effect of Government's Myopia

(a) Without "Big Push"

(b) With "Big Push"