Roads out of poverty? Assessing the links between aid, public investment, growth, and poverty reduction [☆]

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Abstract

This paper presents a dynamic macroeconomic model that captures key linkages between foreign aid, public investment, growth, and poverty. Public capital is disaggregated into education, core infrastructure, and health. Dutch disease effects associated with aid are accounted for by endogenizing changes in the relative price of domestic goods. The impact of shocks on poverty is assessed through partial elasticities and household survey data. The model is calibrated for Ethiopia and changes in the level of nonfood aid are simulated. The amount by which (nonfood) aid should increase to reach the poverty targets of the Millennium Development Goals is also calculated, under alternative assumptions about the degree of efficiency of public investment.
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1. Introduction

The macroeconomic effects of foreign aid and public investment have been the subject of renewed attention in recent years. Studies have focused, in particular, on the impact of external assistance on domestic savings, the government budget and fiscal policy, the real exchange rate, private investment, growth and poverty, and incentives for reform in the recipient country. Fiscal response models for instance have been used to examine the impact of aid on incentives to collect taxes and keep public expenditure under control (see for instance Franco-Rodriguez, 2000; McGillivray, 2000; McGillivray and Ouattara,

2003). Some of these studies showed that an increase in aid may lead to a decline in public savings through lower tax revenues, as governments reduce their tax collection effort.[1] Others found that shortfalls in aid-depending on its composition-tend on the contrary to translate into shortfalls in domestic revenue (Gupta et al., 2003), despite the fact that aid appears to be more volatile than domestic revenues (Bulir and Hamann, 2006).

Another line of research has examined the Dutch disease effects of foreign assistance. The argument, essentially, is that if aid is at least partially spent on nontraded goods, it may put upward pressure on domestic prices and lead to a real exchange rate appreciation. In turn, a real appreciation may induce a reallocation of labor toward the nontraded goods sector, thereby raising real wages in terms of the price of tradables. The resulting deterioration in competitiveness may lead to a decline in export performance and an adverse effect on growth.[2] It has also been argued, however, that if there is learning by doing (that is, endogenous productivity gains) and learning spillovers between production sectors, or if aid raises public investment in infrastructure, then the longer-run effect on the real exchange rate may be ambiguous (see Torvik, 2001; Adam and Bevan, 2003). Once dynamic considerations are taken into account, therefore, the Dutch "disease" does not have to be a terminal illness; longer-run, supply-side effects may outweigh over time adverse demand-side effects on relative prices.[3]

Yet another area of investigation has been the empirical link (based on reduced-form regressions) between aid and growth. In a contribution that has led to much subsequent controversy, Burnside and Dollar (2000) found that aid has no impact on the rate of economic growth in countries with poor macroeconomic policies. In an update of their initial study (Burnside and Dollar, 2004) they argued that the positive effect of aid on growth is conditional on having "good" institutions. However, a number of studies have questioned the robustness of the dependence of the aid-growth link on the policy regime.[4] More generally, Doucouliagos and Paldam (2005), using meta-analysis of a large set of regression results, found that the impact of aid on growth has often been statistically insignificant, and when positive and significant, relatively small.

In parallel, to the literature on the macroeconomic effects of aid, much research has focused on the role of public investment in the growth process. "Conventional" effects have emphasized the productivity, complementarity, and crowding-out effects of public investment (see Agénor, 2004b, Chapter 12). By contrast, more recent research has focused on the degree of efficiency (or lack thereof) of public capital and the existence and magnitude of congestion costs, which imply that the productivity gains associated with a greater stock of public capital may diminish over time because of excessive use.

Few studies, however, have attempted to consider jointly the links between foreign aid, public investment, and growth. Two exceptions are Chatterjee, Sakoulis and Turnovsky (2003) and Chatterjee and Turnovsky (2005) who analyzed the impact of aid tied to public investment in infrastructure on private capital formation and growth in an open economy. However, they did not examine the composition of aid and its links with public investment, or Dutch disease effects, which may alter the long-run impact of aid and public investment on growth.[5] Moreover, the models developed in these papers are parsimonious tools designed to address specific analytical issues, rather than guide practical policy decisions.

This paper fills an important gap in the literature by developing a medium-scale, quantitative macroeconomic model that captures the links between foreign aid, the

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[1] See also Gang and Khan (1990), Khan and Hoshino (1992), Otim (1996), Mavrotas (2002), Mavrotas and Ouattara (2003), and the review by McGillivray and Morrissey (2001). A major limitation of these models, however, is their partial equilibrium nature—the impact of aid on public savings is often studied in isolation from the wider macroeconomic effects of aid (both direct and indirect) on output, prices, and the real exchange rate. As shown by White (1993), feedback effects may change significantly the conclusions of these models.

[2] See Corden (1984) for a classic exposition, and van Wijnbergen (1986) for an early analysis related to Sub-Saharan Africa.

[3] Rajan and Subramanian (2005) appear to cast doubt on the view that aid may stimulate growth, because of an adverse Dutch disease effect. Their study suffers, however, from several methodological and conceptual problems. In particular, there is no distinction in estimation between fixed and floating exchange rate regimes. Under a flexible exchange rate regime, an aid-induced nominal appreciation will put downward pressure on the domestic price of imported inputs (a key feature of the production structure in developing countries) and thus domestic inflation, thereby mitigating the inflationary effect of aid through the demand side. More fundamentally, to the extent that aid leads to increases in productive spending (such as outlays on infrastructure), it will improve competitiveness in the longer run—even if the real exchange rate appreciates in the short run. Because the time profile of these effects may vary significantly across countries, panel data regressions provide misleading results on the dynamic effects of aid on the real exchange rate.

[4] See Guillaumont and Chauvet (2001), Dalgaard and Hansen (2001), Hansen and Tarp (2001), Chauvet and Guillaumont (2003), and Easterly, Levine, and Roodman (2003).

[5] They do not account, in particular, for the fact that aid, by leading to a real appreciation and a fall in exports, may increase the external debt-to-exports ratio and thus the risk premium that small open economies may face on world capital markets—thereby hampering growth. See Agénor and Yilmaz (2007) for a further discussion.

level and composition of public capital, growth, and poverty. Because the model is "structural" in nature, it allows one to decompose the various channels through which aid may affect growth. This is important for two reasons. First, as noted earlier, reduced-form regressions of the aid-growth link are largely inconclusive. A structural approach may help to explain the great variety of empirical results by relating them to specific behavioral assumptions and parameters—which are likely to vary across countries. For instance, in some countries aid inflows may have a large effect on the *flow* of public investment, but not on the *stock* of public capital, because of poor management. Cross-country regressions blur these differences—to such an extent that the "average" estimates can become meaningless. Second, from a policy perspective, it is crucial to identify the mechanisms through which various factors (including policy instruments) can alter the impact of aid on growth. For instance, reserve accumulation and/or exchange rate flexibility may help to limit the impact of aid inflows on the real exchange rate. Reduced-form regressions are not well-suited to capture these indirect effects. Similarly, simply linking infrastructure and growth through constant coefficients is not sufficient from a policy perspective; infrastructure may have potentially adverse effects on growth through crowding-out effects, or by raising the budget deficit (through its impact on maintenance spending). Moreover, infrastructure may be subject to (nonlinear) congestion effects, which may become "binding" once a certain threshold is reached. Partial equilibrium approaches cannot account for these effects.

The remainder of the paper is organized as follows. Section 2 describes the model. Section 3 presents parameter estimates and the calibration procedure for Ethiopia, and discusses trend-based projections for the period 2007–15. It also presents simulation results associated with an increase in nonfood aid. These results are then used to calculate nonfood aid levels consistent with achievement of a poverty target. Section 4 performs some sensitivity analysis. The last section offers some concluding remarks.

2. The model

The model presented in this paper focuses on the fiscal and supply-side effects of aid, as well as the stock and flow effects of public investment, while accounting at the same time for congestion costs associated with the excessive use of public services. It is designed to examine how increased aid and aid-funded levels of public investment, possibly coupled with changes in the composition of these outlays, can stimulate growth and

lead to sustained poverty reduction. At the heart of the model is a production function that accounts explicitly for the effect of public capital (in health and infrastructure) on output and the marginal productivity of private production inputs. Public capital in education also plays a role in the production process, because "raw" labor must be turned into educated labor to become productive.

The domestic (composite) good is an imperfect substitute for the foreign good and its price is determined through equilibrium between supply and demand. By accounting for changes in relative prices, the model allows us therefore to analyze potential Dutch disease effects associated with aid flows in both the short and the long run. In addition, the model captures explicitly the link between aid and public investment, and the possible adverse effects of large aid inflows on fiscal accounts (as emphasized in fiscal response models). Finally, although by its very nature the model is silent on distributional issues (there is only one aggregate household), the impact of policy shocks on poverty is assessed either by linking it to a household survey or by using partial elasticities relating consumption and poverty.[6]

We begin by discussing the production side and the determination of labor supply. We then examine components of aggregate demand (consumption, investment, and imports), the government budget constraint and the role of foreign aid, the balance of payments and the determination of the exchange rate, the equilibrium condition of the market for domestic goods, the savings-investment balance, and the link between the macro component and poverty.

2.1. The supply side

The economy that we consider produces a single homogeneous good that is imperfectly substitutable to an imported good. Domestic production requires land, in quantity LAND, educated labor, LE, private capital, KP, and public capital in health and core infrastructure, KGhea and KGinf, respectively:

$$Y = Y(\text{LAND}, \text{LE}, \text{KP}, \text{KGhea}, \text{KGinf}),$$

where *Y* is production of domestic goods. The area of land allocated to production is a fixed input, and for simplicity we normalize it to unity. The introduction of public capital

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[6] The lack of emphasis on distributional issues is very much by design. The implicit view is that the ability of many low-income countries to engage in income or asset redistribution is limited for a variety of reasons (including the low level of income to begin with), and that poverty reduction in many of them will require a sustained increase in growth rates.

in core infrastructure (namely, roads, energy, water and sanitation, and telecommunications) in the production function is based on the view that the flow of services that it produces raises the productivity of private inputs. Similarly, we assume that the flow of services produced by the stock of public capital in health raises directly the productivity of labor in the production process.

In order to account explicitly for differences in the degree of substitutability among the above set of inputs, we adopt a nested CES production structure. At the lowest level, the supply of educated labor, LE, and the stock of public capital in health, KGhea, are used to produce the composite input T, which we refer to below as "effective" labor:

$$T = AT \cdot [\beta T \cdot \text{LE}^{-\rho T} + (1 - \beta T) \times (\text{KGhea}_{-1}/\text{POP}_{-1}{}^{\theta H})^{-\rho T}]^{-1/\rho T}, \quad (1)$$

where $AT > 0$, $\beta T \in (0,1)$, POP is total population, and $\sigma T = 1/(1+\rho T)$ denotes the elasticity of substitution between LE and KGhea/POP$^{\theta H}$. The stock of public capital in education is divided by the size of the population to the power $\theta H \geq 0$ to account for congestion effects in the provision of health services. When $\theta H = 0$, these effects are absent. Thus, our specification is consistent with the evidence suggesting that good health enhances workers' productivity, as documented for instance by Strauss and Thomas (1998). The introduction of public capital in health is also consistent with the empirical evidence provided by Bloom et al. (2001), among others, according to which health has a positive effect on growth by improving the quality of human capital.[7]

Population grows at the constant exogenous rate, n:

$$\text{POP} = (1 + n)\text{POP}_{-1}. \quad (2)$$

At the second level, effective labor is used, together with private capital, KP, to produce the composite input J:

$$J = AJ \cdot [\beta J \cdot T^{-\rho J} + (1 - \beta J)\text{KP}^{-\rho J}]^{-1/\rho J}, \quad (3)$$

where $AJ > 0$, $\beta J \in (0,1)$, and $\sigma J = 1/(1+\rho J)$ is the elasticity of substitution between T and KP.

At the third level, the composite input J and public capital in core infrastructure, KGinf, are combined to produce output of domestic goods:

$$Y = AY \cdot [\beta Y \cdot J^{-\rho Y} + (1 - \beta Y) \times (\text{QUAL} \cdot \text{KGinf}_{-1}/Y_{-1}{}^{\theta I})^{-\rho Y}]^{-1/\rho Y}, \quad (4)$$

where $AY > 0$, $\beta Y \in (0,1)$, $\theta I \geq 0$ and QUAL denotes an index of the quality of infrastructure, which is taken as given. The lagged value of output, Y_{-1}, is introduced to capture congestion effects on public infrastructure capital. Such effects are absent when $\theta I = 0$. Thus, the positive impact that public infrastructure can exert on the marginal productivity of the composite input J can be highly mitigated if congestion effects are large or the quality of public capital is poor. A high degree of complementarity between the "quality-adjusted" stock of public capital in infrastructure and private inputs in the production process is obtained by imposing a low value for the elasticity of substitution $\sigma Y = 1/(1+\rho Y)$.

Educated labor is produced from "raw" labor, LR, which grows at the same rate as total population, n:

$$\text{LR} = (1 + n)\text{LR}_{-1}. \quad (5)$$

The transformation of raw labor into educated labor requires an accumulation of skills that takes place through a publicly-funded education system, which is free of charge. In line with the micro evidence reviewed by Agénor and Moreno-Dodson (2007), we specify a three-level nested CES structure to highlight the role of health and infrastructure on education. At the first level, the stock of public capital in core infrastructure, KGinf, and the stock of public capital in health, KGhea, are combined to produce a composite public capital good, KHI, which is defined as:

$$\text{KHI} = \text{AKHI} \cdot [\beta\text{KHI} \cdot \text{KGhea}^{-\rho\text{KHI}} + (1 - \beta\text{KHI})\text{KGinf}^{-\rho\text{KHI}}]^{-1/\rho\text{KHI}}, \quad (6)$$

where $\text{AKHI} > 0$, $\beta\text{KHI} \in (0,1)$, and $\sigma\text{KHI} = 1/(1+\rho\text{KHI})$ is the elasticity of substitution between public capital in core infrastructure and health.

At the second level, the stock of public capital in education, KGedu, and the stock of composite public capital, KHI, produce a composite public education input, KEI, which is defined as:

$$\text{KEI} = \text{AKEI} \cdot [\beta\text{KEI} \cdot \text{KGedu}^{-\rho\text{KEI}} + (1 - \beta\text{KEI})\text{KHI}^{-\rho\text{KEI}}]^{-1/\rho\text{KEI}}, \quad (7)$$

where $\text{AKEI} > 0$, $\beta\text{KEI} \in (0,1)$, and $\sigma\text{KEI} = 1/(1+\rho\text{KEI})$ is the elasticity of substitution between KGedu and KHI.

At the third level, the production function for newly-educated workers, LE$_N$, depends on the quantity of raw labor in the economy, LR, as well as the stock of

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[7] See Agénor and Moreno-Dodson (2007) for a review of the evidence on health and growth.

composite public capital in education, KEI, both lagged by one period:

$$\mathrm{LE}_N = AE \cdot [\beta E \cdot (\mathrm{LR}_{-1})^{-\rho E} + (1 - \beta E)$$
$$\{\mathrm{KEI}_{-1}/(\mathrm{LR}_{-1})^{\theta E}\}^{-\rho E}]^{-1/\rho E}, \qquad (8)$$

where $AE > 0$, $\beta E \in (0,1)$, $\theta E \geq 0$, and $\sigma E = 1/(1 + \rho E) \geq 0$. The stock of composite public capital in education is divided by the term $(\mathrm{LR}_{-1})^{\theta E}$ in order to capture congestion effects in the education system due to overcrowded classrooms (see Agénor, 2005b, in press, for a formal analysis). The higher the quantity of raw labor that needs to be transformed into educated labor, the lower the contribution of the composite public education input to the production of educated labor. If $\theta E = 0$, there are no congestion effects, and a higher quantity of raw labor only has a positive effect on the flow supply of educated labor.

Given the flow equation above, the quantity of educated labor available in the economy, LE, is, at any given moment in time,

$$\mathrm{LE} = (1 - \delta E)\mathrm{LE}_{-1} + \mathrm{LE}_N, \qquad (9)$$

where $\delta E \in (0,1)$ is the rate of attrition of the stock of educated labor.

The allocation of domestic output between exports, X, and domestic sales, DOM, is assumed to follow a constant elasticity of transformation (CET) function, given by

$$Y = \mathrm{ADE} \cdot [\beta \mathrm{DE} \cdot X^{\rho \mathrm{DE}} + (1 - \beta \mathrm{DE})\mathrm{DOM}^{\rho \mathrm{DE}}]^{1/\rho \mathrm{DE}}, \qquad (10)$$

where $\mathrm{ADE} > 0$, $\beta \mathrm{DE} \in (0,1)$, and $\sigma \mathrm{DE} = 1/(\rho \mathrm{DE} - 1)$, with $1 < \sigma \mathrm{DE} < \infty$ measuring the elasticity of transformation between exports and domestic sales. Standard efficiency conditions require the allocation of output between exports and domestic sales to satisfy

$$X/\mathrm{DOM} = \{(\mathrm{PX}/\mathrm{PD}) \cdot [(1 - \beta \mathrm{DE})/\beta \mathrm{DE}]\}^{\sigma \mathrm{DE}}, \quad (11)$$

where PD denotes the price of the domestic good (whose determination is discussed below), and PX the domestic-currency price of exports, given by

$$\mathrm{PX} = \mathrm{ER} \cdot \mathrm{PX}^*, \qquad (12)$$

where ER is the nominal exchange rate and PX* the world price of exports (assumed exogenous). Given the production function defined earlier, the allocation function between exports and domestic sales can be used to determine X, and the identity

$$\mathrm{PY} \cdot Y = \mathrm{PD} \cdot \mathrm{DOM} + \mathrm{PX} \cdot X, \qquad (13)$$

can be used to determine either PY or DOM.

We also assume that wages are flexible, so that there is no open unemployment of educated labor. This is consistent with much of the evidence for the low-income countries in Sub-Saharan Africa, for which the model is designed (see, for instance, Dabalen, 2000; Agénor, 2006).

2.2. Household income, consumption and investment

To allocate domestic demand between domestic and imported goods, we use the standard Armington assumption. Excluding food aid, total demand for goods sold on the domestic market (which consist of both imports and domestically-produced goods), Qd, is defined as the sum of private and public spending on consumption and investment:

$$\mathrm{Qd} = (\mathrm{CP} + \mathrm{CG}) + (\mathrm{IP} + \mathrm{IG}), \qquad (14)$$

where CG and IG denote real government spending on consumption and investment, and IP and CP real private spending on investment and consumption, respectively.[8]

Total demand for goods sold domestically is allocated between demand for domestically-produced goods, DOM, and demand for imported goods, M, using a CES function with an elasticity of substitution of σ_{DM}:

$$M/\mathrm{DOM} = \{(\mathrm{PD}/\mathrm{PM}) \cdot [(1 - \beta \mathrm{DM})/\beta \mathrm{DM}]\}^{\sigma \mathrm{DM}}, \qquad (15)$$

where PM is defined as the product of the nominal exchange rate and the world price of imports, PM* (assumed exogenous), inclusive of the tariff rate, $\mathrm{tm} \in (0,1)$:

$$\mathrm{PM} = (1 + \mathrm{tm}) \cdot \mathrm{ER} \cdot \mathrm{PM}^*, \qquad (16)$$

Private investment (as a share of GDP) depends positively on the rate of growth in domestic output (to capture either an accelerator effect or the assumption that the rate of return on physical capital is positively correlated with the rate of growth), private foreign capital flows (measured as a ratio of GDP), ER·FP/NGDP, and the stock of public capital in core infrastructure relative to GDP, to capture the complementarity effect alluded to above. It also depends negatively on the economy's ratio of foreign debt over

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[8] In solving the model, Eq. (14) is used to determine residually private consumption.

GDP, $ER \cdot FdebtTot/NGDP$, to capture a possible debt overhang effect:[9]

$$PQ \cdot IP/NGDP = ip[\Delta Ys/Ys_{-1}, ER \cdot FP/NGDP,$$
$$ER \cdot FdebtTot/NGDP,$$
$$KGinf \cdot PQ/NGDP], \qquad (17)$$

where NGDP is nominal GDP and PQ is the composite price of goods sold domestically.

The stock of private capital evolves over time according to

$$KP = IP_{-1} + (1 - \delta P)KP_{-1}, \qquad (18)$$

where $\delta P \in (0,1)$ is a constant rate of depreciation.

2.3. Government budget and foreign aid

The government collects taxes (on income, imports, and domestic sales), and spends on goods and services (including for maintenance purposes). It also services its domestic and foreign debt, and invests in education, health, and core infrastructure. It receives foreign assistance, which takes two forms: food aid and nonfood aid. Both components are treated as a source of revenue for the government, but in addition food aid is assumed sold on local markets at face value. The deficit is financed through domestic and foreign borrowing.

Formally, the government budget balance, GBAL, is given by

$$GBAL = TAX + AID - PQ \cdot (CG + IG)$$
$$- RG^* \cdot ER \cdot FdebtG_{-1}$$
$$- RD \cdot DdebtG_{-1}, \qquad (19)$$

where FdebtG is the stock of foreign public debt, RG* the interest rate on that debt, DdebtG the stock of domestic public debt, RD the interest rate on that debt, and TAX total tax revenue. Both RG* and RD are assumed exogenous. AID is total aid measured in domestic-currency terms, and is given by

$$AID = ER \cdot (FAID\$ + NFAID\$), \qquad (20)$$

where FAID\$ is food aid and NFAID\$ nonfood aid, respectively, both measured in foreign-currency terms.

Assuming that the foreign-currency price of food aid is normalized to unity, FAID\$ can also be interpreted as a quantity variable.

The stock of domestic debt is defined as

$$DdebtG = DB + DdebtG_{-1}, \qquad (21)$$

where DB is the flow of domestic borrowing (from households), which is assumed fixed as a share of output.

In line with the fiscal response models referred to in the introduction, we assume that total tax revenues depend on domestic sales excluding food aid, Qs, and that the effective tax rate, TXR, depends on the ratio of total government expenditure, GTOT, to GDP, and the aid-to-GDP ratio, to capture a possible adverse effect of foreign assistance on fiscal effort:

$$TAX = TXR(TXR_{-1}, (GTOT/NGDP)_{-1}, AID/NGDP)$$
$$\times PQ \cdot Qs + tm \cdot ER \cdot PM^* \cdot M. \qquad (22)$$

From Eq. (19), total government spending is defined as

$$GTOT = PQ \cdot (CG + IG) + RG^* \cdot ER \cdot FdebtG_{-1}$$
$$+ RD \cdot DdebtG_{-1}, \qquad (23)$$

and nominal GDP (at market prices) is

$$NGDP = PY \cdot Y + tm \cdot ER \cdot PM^* \cdot M$$
$$+ \Psi \cdot TXR \cdot PQ \cdot Qd, \qquad (24)$$

where Ψ represents the share of indirect taxes in total domestic taxes.

Current noninterest expenditure, net of maintenance outlays, is a positive function of the lagged value of the total tax-to-GDP ratio (a measure of the domestic capacity to raise resources to finance current outlays and capital formation) and on its value in the previous period, to account for persistence effects associated with spending items such as salaries and transfers. Thus,

$$CG = NGDP \cdot cg[(TAX/NGDP)_{-1},$$
$$(PQ \cdot CG/NGDP)_{-1}]/PQ + \delta h \cdot \Sigma_h KGh_{-1}, \quad (25)$$

where $\delta h \cdot \Sigma_h KGh_{-1}$ measures maintenance expenditures, and $\delta h \in (0,1)$ denotes the constant rate of depreciation of capital ($h = $ edu, hea, inf).

Total public investment, as a share of domestic output, depends positively on the lagged value of the tax-to-GDP ratio and nonfood aid as a share of domestic output, and negatively on the ratio of foreign debt service

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[9] Pattillo, Poirson, and Ricci (2004) found a negative relationship between external debt and private capital formation in developing countries; see Agénor (2004b, Chapter 2) for a review of the evidence.

to domestic output, in line with the empirical results of Clements et al. (2003):[10],[11]

$$PQ \cdot IG/NGDP = ig[(TAX/NGDP)_{-1}, ER \cdot NFAID\$/NGDP,$$
$$(ER \cdot NFAID\$/NGDP)^2,$$
$$RG^* \cdot ER \cdot FdebtG_{-1}/NGDP]. \qquad (26)$$

This specification implies in particular that debt relief (a reduction in FdebtG) can lead to higher growth by increasing public investment. Moreover, we introduce a nonlinearity in the relationship between nonfood aid and public investment, by adding the squared value of the ratio of the former variable to output in the equation. To the extent that the coefficient of the linear term is positive and that of the quadratic term is negative, this specification would allow us to capture limits on the government's absorptive capacity: nonfood foreign assistance would be positively related to public capital outlays only up to a certain level of aid, and would be negatively related thereafter. In such conditions, aid would entail diminishing returns, as suggested for instance by the empirical results of Lensink and White (2001).

Public investment is allocated to health, education, and core infrastructure:

$$IG = IGedu + IGhea + IGinf, \qquad (27)$$

where each component is determined as a fixed fraction of total investment:

$$IGh = \kappa h \cdot IG, \qquad (28)$$

with h=edu, hea, inf, and $\Sigma \kappa h = 1$. The coefficients $\kappa h \in (0,1)$ are thus policy parameters that capture the allocation of investment outlays.

Stocks of public capital in education, health, and infrastructure are given by

$$KGh = \varphi h \cdot IGh_{-1} + (1 - \delta h)KGh_{-1}, \qquad (29)$$
$$h = edu, \ hea, \ inf,$$

where $\varphi h \in (0,1)$ is a parameter that measures the efficiency of public investment. The case of "full efficiency" corresponds to $\varphi h = 1$. However, as noted by Pritchett (2000), in developing countries up to half of all resources invested in investment projects do not have a positive impact on the public capital stock. Similarly, Arestoff and Hurlin (2005) found values of φ ranging from 0.4 to 0.6. In the aid experiment reported below, we assume first a uniform value of $\varphi h = 0.5$, and perform subsequently some sensitivity analysis.

Using Eqs. (19) and (23), the government budget balance, GBAL, can be rewritten as

$$GBAL = TAX + AID - GTOT. \qquad (30)$$

The government budget deficit, −GBAL, can be financed by either domestic borrowing, DB, or foreign financing, FG:

$$-GBAL = DB + FG \cdot ER. \qquad (31)$$

This equation can be used to determine either DB or FG. If, for instance, the deficit is financed by (concessional) borrowing from abroad (as assumed in the application to Ethiopia that we discuss later on), and DB is predetermined, then

$$FG = (-GBAL - DB)/ER. \qquad (32)$$

2.4. Balance of payments and the exchange rate

The balance of payments accounts for trade flows, interest payments, foreign borrowing, and aid. Measured in foreign-currency terms, it is given by

$$PX^* \cdot X - PM^* \cdot M - RG^* \cdot FdebtG_{-1} - RP^*$$
$$\times FdebtP_{-1} + UTR\$ + (FAID\$ + NFAID\$)$$
$$+ FG + FP - \Delta NFA = 0, \qquad (33)$$

where FP denotes private capital inflows, ΔNFA the change in net foreign assets of the central bank (measured in foreign-currency terms), RP* the interest rate on private foreign borrowing, and $UTR the foreign-currency value of private unrequited transfers (all, except NFA, assumed exogenous). The foreign-currency value of the stock of private foreign debt, FdebtP, is thus defined as

$$FdebtP = FP + FdebtP_{-1}, \qquad (34)$$

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[10] The link between nonfood aid and public investment captured here is consistent with the empirical results of Gomanee, Girma, and Morrissey (2002), who found evidence of a positive effect of aid on investment in Sub-Saharan Africa.

[11] Clements et al. (2003) found that the adverse effect of external debt service on public investment is nonlinear, and that urbanization and trade openness have a positive effect on the ratio of public investment to GDP in low-income countries. These additional variables could easily be added to the model, but we refrained from doing so given that none of them proved significant in the regression results for Ethiopia reported below. Note also that Mahdavi (2004) found an adverse effect of the level of foreign debt itself on capital expenditure in Sub-Saharan Africa.

whereas the foreign-currency value of the stock of external public debt is given by

$$FdebtG = FG + FdebtG_{-1}.$$ (35)

Total external debt, FdebtTot, is thus defined as

$$FdebtTot = FdebtP + FdebtG.$$ (36)

Given our intention to calibrate the model later on to Ethiopia, a country that has been operating a flexible exchange rate regime, we assume that the balance of payments clears through adjustment in the nominal exchange rate, ER. In addition, we assume that (in line with the current practice of many central banks) official reserves are kept as a constant multiple ϕ_{RM} of current imports:

$$NFA = \phi_{RM}PM^* \cdot M.$$ (37)

2.5. Market equilibrium and domestic prices

Excluding food aid, the supply of goods to the domestic market is determined through a CES combination of imports and domestic sales of the domestically-produced good, DOM:

$$Qs = ADM[\beta DM \cdot DOM^{-\rho DM} + (1 - \beta DM)M^{-\rho DM}]^{-1/\rho DM},$$ (38)

where $ADM > 0$, $\beta DM \in (0,1)$, and $\sigma DM = 1/(1+\rho DM)$ is the elasticity of substitution between the domestic and imported goods.

The price of the composite good is a CES aggregation of the price of the domestically-produced good and the price of imports:

$$PQ = [\beta DM \cdot PD^{1-\sigma DM} + (1 - \beta DM) \times PM^{1-\sigma DM}]^{1/(1-\sigma DM)}.$$ (39)

Market equilibrium requires equality between the total supply of goods on the domestic market (which includes not only the supply of the composite good, Qs, but also food aid, sold by the government at the price at which it receives it) be equal to total aggregate demand for these goods (which consists of demand for the composite good and demand for food aid). We assume that the demand for food aid is perfectly elastic at the government-imposed price, which implies that the actual quantity of food aid transacted in the market is supply-determined. The equilibrium condition between aggregate supply and aggregate demand therefore boils down to equality between the supply and demand for the composite good:[12]

$$Qs = Qd.$$ (40)

The identity

$$PQ \cdot Qd = PD \cdot DOM + PM \cdot M,$$ (41)

can therefore be used to determine the price of domestic goods, PD, whereas Eq. (15) can be used to determine either the quantity of domestically-produced goods, DOM, or imports, M.

The price of the domestic good, PD, adjusts gradually to its desired value, which is defined as a constant markup over the weighted average of the nominal wage earned in private production, W_{LE}, and the domestic price of imports. Normalizing the markup rate to unity yields

$$PD = \lambda_{PD}[\alpha_{PD} \cdot W_{LE} + (1 - \alpha_{PD}) \cdot PM] + (1 - \lambda_{PD})PD_{-1},$$ (42)

where $\lambda_{PD} \in (0,1)$ is the speed of adjustment and $\alpha_{PD} \in (0,1)$ is the share of labor costs in production, and W_{LE} is measured by the marginal product of educated labor derived from Eq. (1). Given the aggregate nature of the model and its dynamic structure, the assumptions of markup pricing and gradual adjustment are more attractive than the assumption of full price flexibility.

2.6. Poverty analysis

To link the core macro structure presented above to poverty, and to assess the effects of policy shocks on the poor, an attractive methodology from an operational standpoint is the procedure proposed by Agénor et al. (2003), and further developed by Agénor et al. (2004), in the context of the Integrated Macroeconomic Model for Poverty Analysis. Assuming that the focus is on income as a measure of poverty, applying this procedure would entail following five steps in the present case:

1. From an existing household survey, extract the value of income (in current monetary units) for each

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[12] Implicit in our specification is the assumption that total supply of goods is additive, that is, given by $PQ \cdot Qs + ER \cdot FAID\$$. Thus, food aid displaces the supply of composite goods, consisting of domestic and imported goods, on a one-to-one basis. An alternative specification would be to use a second-level CES function with either Qs and $ER \cdot FAID\$/PQ$, or M and $ER \cdot FAID\$/PQ$. In the latter case, food aid would displace private imports, rather than domestic production.

household, and given the poverty line, calculate the initial poverty rate.
2. Following a policy or exogenous shock, generate the growth rate in per capita income of the representative household in the macro model, up to the end of the simulation horizon (say, period $t+N$).
3. Apply this growth rate to the income data for each household in the survey. This gives new income levels for each household, for periods $t+1,..., t+N$.
4. Update the poverty line in the survey for periods $t+1,... t+N$ by using the growth rate of the composite price index generated by the macro model. This assumes implicitly that the poverty line is constant in real terms.
5. Using the new data on nominal income per household and the poverty line, calculate "post-shock" poverty indicators. Compare with initial indicators to assess the poverty effect of the shock.

In this approach, distribution among the households contained in the survey is assumed not to change following any shock. Growth (in income) is thus implicitly assumed to be distribution neutral. The caveat, of course, is that to the extent that distribution changes, growth may not benefit automatically the poor (see Dagdeviren et al., 2002).

An alternative approach is to relate directly the poverty rate, estimated for some base period, to the growth rate of income per capita derived from the model, using an estimated partial elasticity. This approach is attractive for countries where a representative and reliable household survey is not available and only a point estimate of poverty can be gleaned from the data. Another advantage of this procedure is that changes in income distribution can be captured indirectly; by varying the partial growth elasticity within a "plausible" range around (minus) unity, nonneutral changes in growth rates can be accounted for.

3. An application to Ethiopia

The model can be used to perform a variety of policy simulations that are of crucial importance for many low-income countries involved in building growth and poverty reduction strategies supported by increased foreign assistance or debt relief. For instance, by how much would private investment and growth per capita increase if the overall level of public investment rises by a given percentage of GDP, and if at the same time the share of spending allocated to core infrastructure increases? Or, by how much should foreign aid increase, in order to double the growth rate of income per capita, or for poverty to fall

to the levels envisaged under the United Nations' Millennium Development Goals (MDGs) at the horizon 2015, that is, by 50% relative to 1990? To illustrate the functioning and properties of the model, we partly estimate it and partly calibrate it for Ethiopia.[13]

We begin by reporting econometric estimates of some of the behavioral equations of the model and describe some features of the calibration procedure, as well as the household survey that we use. We then discuss the assumptions underlying trend-based projections for the period 2007–15, as a prelude to the policy experiment that we want to focus on.

3.1. Parameter estimates and calibration

To apply the model to Ethiopia, we calibrated some parameters and estimated some of the behavioral equations described earlier. Specifically, using annual time series, we estimated the three "fiscal" regressions—those linking the effective tax rate to the aid–GDP ratio and the government spending–GDP ratio; government consumption expenditure to the tax revenue–GDP ratio and government expenditure–GDP ratio; and public investment to the tax revenue–GDP ratio and the nonfood aid–GDP ratio (see Eqs. (22), (25), and (26)).[14] Estimation was performed with ordinary least squares in all cases. This is unlikely to create significant endogeneity bias, because all the domestic explanatory variables are lagged; in addition, we treat the aid-to-GDP ratio as predetermined not only because it depends to a significant extent on donors' preferences (with feedback effects from past domestic variables unlikely to be systematic) but also because a key objective of the model is to simulate the impact of an exogenous change in aid.

The results are summarized in Tables 1 and 2. The regression with the effective tax rate as the dependent variable indicates that the aid-to-GDP ratio did not have a statistically significant adverse effect on tax effort; however, the estimated coefficient, −0.12, had the right (negative) sign, and we kept it in the specification. By contrast, the coefficient of the lagged value of the effective tax ratio is highly significant and relatively large.

The results also show that the tax revenue–GDP ratio and the ratio of nonfood aid to GDP have a positive

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[13] The detailed version of this article contains a review of trends in growth and poverty, foreign aid and its composition, and public investment in the country. See also Bigsten et al. (2003) and Demeke et al. (2003).
[14] We initially tested for a positive effect of aid on government consumption but the results did not yield a coefficient with the right sign.

Table 1
Calibrated and imposed parameters

Parameter	Definition	Value
α_{PD}	Share of wages in domestic price-setting equation	0.600
λ_{PD}	Partial adjustment parameter in domestic price equation	0.300
θE	Parameter capturing congestion effects in the education system	0.300
θH	Parameter capturing congestion effects in the provision of health services	0.100
θI	Parameter capturing congestion effects on infrastructure capital	0.200
δE	Rate of depreciation of stock of educated labor	0.000
δh	Rate of depreciation of public capital, h=edu, hea, inf	0.025
ϕ_{RM}	Multiplier of current imports in official reserves equation	0.760
δP	Rate of depreciation of private capital	0.040
σDE	Elasticity of transformation between exports and domestic sales	0.300
σDM	Elasticity of transformation between imports and demand for domestically-produced goods	0.300
σE	Elasticity of substitution between LR_{-1} and $KEI_{-1}/(LR_{-1})^{\theta E}$	0.400
σJ	Elasticity of substitution between T and KP	0.300
σKEI	Elasticity of substitution between KGedu and KHI	0.300
σKHI	Elasticity of substitution between KGhea and KGinf	0.300
σT	Elasticity of substitution between LE and $KGhea_{-1}/POP_{-1}{}^{\theta H}$	0.300
σY	Elasticity of substitution between J and $KGinf_{-1}/Ys_{-1}{}^{\theta I}$	0.500

effect on the public investment–GDP ratio, with coefficients less than unity. We initially tested for a nonlinear effect of nonfood aid, in line with the specification in Eq. (22). However, the coefficient associated with the squared term was found to be insignificant. We also found no evidence of an adverse effect of debt service on public capital formation. Both variables were therefore dropped from the final results. Of course, the fact that the quadratic term in nonfood aid was not significant does not imply that absorption constraints do not exist, or do not matter, but rather that in the case of Ethiopia they are perhaps not well captured by the specification that we proposed.[15]

We also estimated a private investment equation, starting from the specification given above (see Eq. (17)). Preliminary regressions indicated that private foreign capital flows as a share of GDP were not

significant. We tested for the effect of the current and lagged values of the external debt–GDP ratio, using both linear and quadratic terms (to capture a possible nonlinear relationship, as indicated earlier), but both variables turned out to be either insignificant or to have an incorrect sign. They were therefore dropped from the final specification. The two variables left in the regression are the rate of growth of real output and the ratio of the public capital stock in infrastructure to GDP. Although in both cases the coefficients are relatively small, the data do provide supportive evidence of both an accelerator effect and a complementarity effect of public capital in infrastructure on private capital formation, as discussed earlier.

All other parameters were determined either by using shares for the base period, by dwelling on the literature on Ethiopia (e.g., Gelan, 2002) or, when country-specific data were not available, by using plausible values for low-income developing countries in general (see Table 1). The elasticities of substitution on the production side were kept at relatively low values. For instance, the elasticity of substitution between T and KP, σJ, was set to 0.3; the elasticity of substitution between LE and $KGhea/POP^{\theta H}$, σT, was set to 0.3; and the elasticity of substitution

Table 2
Estimated behavioral equations (ordinary least squares)

Coefficients	Estimated value	Two-standard error confidence interval		Actual value used
Domestic tax rate				
$\log(TXR)=a_1+a_2\cdot\log(TXR)_{-1}+a_3\cdot\log(GTOT/NGDP)_{-1}+a_4\cdot\log(AID/NGDP)$				
a_2	0.750***	0.461	1.039	0.750
a_3	0.102	−0.443	0.648	0.102
a_4	−0.122	−0.336	0.093	−0.050
Government consumption				
$\log(PQ\cdot CG/NGDP)=b_1+b_2\cdot\log(PQ\cdot CG/NGDP)_{-1}+b_3\cdot\log(TAX/NGDP)_{-1}$				
b_2	0.489**	0.125	0.853	0.389
b_3	0.384*	−0.045	0.812	0.084
Public investment				
$\log(PQ\cdot IG/NGDP)=c_1+c_2\cdot\log(TAX/NGDP)_{-1}+c_3\cdot\log(ER\cdot NFAID\$/NGDP)$				
c_2	0.904***	0.283	1.524	0.604
c_3	0.247*	−0.001	0.495	0.247
Private investment				
$\log(PQ\cdot IP/NGDP)=d_1+d_2\cdot\Delta Ys/Ys_{-1}+d_3\cdot\log(KGinf\cdot PQ/NGDP)_{-1}$				
d_2	0.097**	0.008	0.187	0.097
d_3	0.086***	0.060	0.113	0.086

***, **, and * stand for 1%, 5%, and 10% significance level, respectively.
Note: for a definition of the variables involved, see Eqs. (22), (25), (26), and (17), respectively.

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[15] In solving the model, we found that some parameters (relating for instance the government consumption expenditure–GDP ratio to the tax revenue–GDP ratio) created instability. Given the short time series available, we chose to reduce the values of these parameters, within two standard errors of the point estimates. Table 2 shows these intervals and the actual values used.

between J and KGinf, σY, was set to 0.5. Measures of congestion effects were difficult to estimate, given the lack of information for developing countries in general. We used relatively low values to avoid putting undue weight on these parameters. Specifically, for the parameter capturing congestion effects in the education system, θE, we chose a value of 0.3; for the parameter determining the strength of congestion effects in the provision of health services, θH, we chose a value of 0.1; and for the parameter capturing congestion effects in infrastructure, θI, we chose a value of 0.2. Relatively small values (in the range of 2 to 4%) were also chosen for the depreciation rates of the various capital stocks, in line with available estimates. The elasticity of transformation in domestic production and the elasticity of substitution between domestic and imported goods were both set at 0.3. In addition, we assumed that the "desired" allocation of private expenditure between these goods (as described in Eq. (15)) occurs gradually, with an adjustment parameter that captures a low propensity to substitute between domestic and imported goods in the short run. The coefficient measuring the share of wages in the domestic price-setting equation, α_{PD}, was set at 0.6, which reflects the relatively large share of salaries in production costs, and the speed of adjustment at 0.3. Finally, it was assumed that net foreign assets are kept at 5 months of imports.

We calibrated the model for 2003. Data on national accounts, fiscal accounts, balance of payments (based on IMF estimates), and OECD data were combined to produce a consistent set of estimates.[16] Significant discrepancies appeared in the aid data between national sources, the OECD's DAC database, and the fiscal and balance-of-payments accounts; we chose to use the OECD data, which are the most comprehensive, and adjusted the other information accordingly while keeping intact major equilibrium relationships (namely, the fiscal balance and the current account of the balance of payments). Capital stock data (both public and private) were derived using the perpetual inventory method, using relatively small depreciation rates (as indicated earlier) and a uniform efficiency parameter equal to 0.5. In solving the model, we used the net output price PY as the numéraire, and therefore kept its value fixed in the aid experiment reported later.

To calculate the poverty effects of policy shocks, we first linked the model to a household survey, using the methodology outlined earlier. The data that we use are from the 1999/2000 *Household Income, Consumption, and Expenditure Survey* (HICES) conducted by the

Ethiopian Central Statistical Authority. The survey covers 17,332 households. We report only the headcount index (that is the relative number of poor), for simplicity. We also used the partial (consumption) growth elasticity approach mentioned earlier. Specifically, results for three different values for that elasticity are reported: −1.0 (which corresponds to the case where growth is distribution neutral), −0.5, and −1.8. The elasticity of −0.5 is close to the elasticity of the poverty headcount index with respect to the change in (mean) expenditure estimated by Christiansen et al. (2003, Table 4, p. 326) for Ethiopia, whereas the elasticity of −1.8 reflects the case where growth in consumption entails a more than proportional effect on poverty. We use an initial point estimate of the poverty rate of 44.2% in 2000 in all three cases.

3.2. Trend-based projections

Before conducting policy experiments with the model, we first project how the Ethiopian economy would evolve if recent economic trends were to continue into the future. Given that the model uses 2003 as its base period, this requires making a series of assumptions for the policy and other exogenous variables, over the period 2004–2015. The assumptions underlying these projections remain, of course, somewhat arbitrary, but they are instructive to the extent that they serve to highlight the need for changes in the policy environment to stimulate growth and reduce poverty in the long term.

The stock of land is assumed constant and normalized to unity. The quality of core public infrastructure and the efficiency of public investment are assumed to remain constant throughout. Population and the supply of raw labor both grow at the constant rate of 2.7%. The shares of public investment in infrastructure, health and education are kept constant at their base period values (about 46%, for instance, for core infrastructure). Domestic borrowing (which is negative in the base year) is assumed to increase to 2% of GDP in 2004 and to remain constant in proportion of GDP in subsequent years. Given the overall fiscal balance, we assume that Ethiopia borrows externally at concessional terms to close its budget gap. The interest rate on foreign public debt is assumed to be constant at 0.075%, whereas interest rates on private foreign borrowing and on domestic public debt are taken to be fixed at the levels observed in 2002. Foreign aid (measured in domestic-currency terms) is kept constant in proportion of GDP at the base period level (about 11.6%). The allocation of foreign assistance between food and nonfood aid is done according to the constant shares observed in the base period, with food aid representing 37.5% of total aid.

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[16] A full description of the data is provided in an Appendix, available upon request.

Public foreign borrowing is determined residually to balance the government budget (given the assumption of a constant domestic borrowing–GDP ratio), whereas private capital inflows are kept constant at 2% of GDP. Private unrequited transfers (measured in foreign-currency terms) are also assumed to be constant at 8% of GDP. Prices of imports and exports are assumed to grow at a constant rate, which is set equal to zero in the first case, and to 2% per annum in the second. Finally, the ratio of official reserves to imports is kept constant at 5 months.

The trend-based projections are shown in Table 3 for the period 2007–15. Growth rates of both real GDP and consumption per capita are at first negative, turning positive in later years. Part of the reason is that domestic prices grow at relatively high rates in the early years, and population grows at a rapid pace. Private savings as a share of GDP decline slightly during the period, whereas private investment increases (from 7.6% of GDP in 2007 to 8.0% in 2015). This is the consequence, in part, of higher public investment in infrastructure. Public spending on goods and services remains relatively constant (at around 35% of GDP), with maintenance expenditure representing about 0.8% of GDP. As a result of a gradual increase in domestic tax revenue, the overall fiscal deficit declines slightly over time-and so does public foreign borrowing. Nevertheless, ratios of domestic and external debt to GDP tend to increase. The real exchange rate (defined as the ratio of import prices, measured in domestic-currency terms, to the composite price index) depreciates at first and appreciates slightly toward the end of the period. Nevertheless, because exports (as a share of GDP) tend to increase faster than imports, the current account balance improves over time. The share of educated labor in the population rises steadily over time (from 45.5% to 51.5%), as a result of public investment in education and core infrastructure.

The projections displayed in Table 3 reveal also that, given the previous assumptions about Ethiopia's policies and international environment, prospects for a sharp reduction in poverty by 2015 (as called for under the MDGs) are rather bleak.[17] With the survey data, poverty falls from 42.4% in 2007 to 38.4% in 2015. With a partial elasticity of −0.5 (which is close to the estimate provided by Christiansen et al. (2003) for Ethiopia, as noted earlier), the poverty rate drops very little, from about 45 to 44%. Even in the "best case" scenario (an elasticity of −1.8), poverty would drop by no more than 4 percentage points. Thus, whether a

significant and sustained reduction in poverty can be achieved in Ethiopia may depend crucially on the country's ability to improve its growth performance. We now examine to what extent foreign aid (through, in particular, its effect on public investment) may indeed contribute to improving the country's growth prospects.

3.3. The impact of foreign aid

We consider a permanent, 5-percentage point increase in nonfood aid-to GDP ratio from 2007 onward. Results of this experiment are shown in Table 4.

The direct effect of the increase in aid is on the budget. On the one hand, it lowers the fiscal deficit (because it adds to resources "above the line"), and on the other it increases it, because it raises overall public investment, as discussed in the previous section. The increase in public investment is initially of the order of 3.6% of GDP, but it rises over time (as a result of the increase in tax revenue) to 4%. The initial improvement in the fiscal accounts therefore persists over time. The increase in public investment in core infrastructure "crowds in" private investment and leads to a higher growth rate in output of about 1 percentage point in the long run. In turn, the increase in the private capital stock tends to raise the demand for educated labor, given the low degree of substitution between these factors in private production. Because the increase in public investment is allocated across all components of government capital formation (according to initial shares), the greater demand for educated labor is matched in part by an increase in supply, of about 0.8 percentage points by 2015.

Over time, the increase in the stock of public capital in health raises the efficiency of educated labor, whereas the increase in public capital in core infrastructure raises the marginal productivity of all other production factors (including "effective" labor) as well as production of educated labor. Productivity gains contribute also to higher domestic output growth. The increase in per capita income tends to lower poverty; as shown in Table 4, by 2015 the poverty rate drops by about 6.8 percentage points based on survey data and by 5.8 percentage points with a partial elasticity of −1.8. However, with a partial elasticity of −0.5, it falls by only 1.7 percentage points at the same horizon.

The inflow of aid leads immediately to a nominal appreciation, which persists throughout the simulation period. Because wages do not change by much on impact, and because of markup pricing, this puts downward pressure on domestic prices as well. Nevertheless,

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[17] Note that these calculations do not account for the possibility of asymmetric effects in the relationship between growth and poverty (see Agénor, 2004a, 2005a).

Table 3
Ethiopia: trend-based projections, 2007–15 (efficiency parameter=0.5)

	Years								
	2007	2008	2009	2010	2011	2012	2013	2014	2015
Real GDP per capita at market prices (% change)	−0.3	−0.2	0.0	0.2	0.5	0.7	0.9	1.2	1.4
Poverty rate (200=44.2%)									
Poverty headcount index (survey data)	42.4	42.6	42.7	42.5	42.1	41.5	40.7	39.5	38.4
Real income per capita growth elasticity of −0.5	44.8	44.8	44.8	44.7	44.6	44.5	44.3	44.0	43.7
Real income per capita growth elasticity of −1.0	45.3	45.4	45.4	45.3	45.0	44.7	44.3	43.8	43.2
Real income per capita growth elasticity of −1.8	46.0	46.2	46.2	46.0	45.6	45.0	44.3	43.4	42.3
External sector (% of GDP)									
Trade balance	−32.2	−32.3	−32.3	−32.3	−32.3	−32.3	−32.3	−32.4	−32.5
Current account	−6.8	−6.7	−6.5	−6.3	−6.1	−5.9	−5.7	−5.5	−5.4
Capital account	7.9	7.8	7.6	7.5	7.4	7.3	7.3	7.2	7.2
Change in net foreign assets	1.1	1.1	1.1	1.2	1.3	1.4	1.5	1.7	1.8
Government sector (% of GDP)									
Total revenue	42.5	43.1	43.5	43.9	44.2	44.4	44.6	44.8	44.49
Domestic taxes	18.6	19.1	19.4	19.7	19.9	20.0	20.1	20.2	20.3
Indirect taxes on imports	12.3	12.4	12.5	12.6	12.7	12.7	12.8	12.9	13.0
Foreign aid (grants)	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6
Food aid	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Nonfood aid	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3
Total expenditure	85.4	86.0	86.5	86.9	87.1	87.3	87.5	87.6	87.8
Spending on goods and services (total)	35.0	35.2	35.4	35.5	35.5	35.6	35.6	35.7	35.7
Maintenance spending	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Other spending on goods and services	34.2	34.4	34.5	34.6	34.7	34.7	34.8	34.8	34.9
Investment	13.6	13.8	13.9	14.0	14.1	14.2	14.3	14.3	14.4
Interest payments	1.8	1.8	1.9	1.9	1.9	2.0	2.0	2.0	2.0
Over all fiscal balance	−7.9	−7.7	−7.6	−7.5	−7.4	−7.3	−7.3	−7.2	−7.1
Foreign financing	5.9	5.7	5.6	5.5	5.4	5.3	5.3	5.2	5.1
Domestic borrowing	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Prices and exchange rates									
Composite good price (% change)	2.8	2.3	2.0	1.7	1.4	1.1	0.8	0.5	0.2
Nominal exchange rate (% change)	2.9	2.5	2.3	1.9	1.5	1.2	0.7	0.4	0.0
Real exchange rate (% change)	0.1	0.2	0.3	0.2	0.2	0.1	0.0	−0.2	−0.3
Memorandum items									
Educated labor (in % of population)	45.5	46.2	47.0	47.7	48.5	49.3	50.0	50.8	51.5
Private investment (% of GDP)	7.6	7.7	7.8	7.8	7.9	7.9	7.9	8.0	8.0
Public investments (% of total public expenditure)	15.9	16.0	16.1	16.2	16.2	16.3	16.3	16.3	16.4
Non food aid (% of total public invesment)	53.7	52.9	52.3	51.9	51.5	51.3	51.0	50.9	50.7
External debt (% of GDP)	120.8	125.8	130.5	134.7	138.2	141.1	143.4	145.1	146.1
Net foreign assets/imports per month	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0

because the nominal appreciation exceeds the fall in composite prices, the real exchange rate appreciates, by about 0.5 in percentage terms on impact. Consequently, real exports fall (by about 1.2 percentage points as a share of GDP by 2015), whereas imports increase (by about 2.9 percentage points at the same horizon). In turn, the increase in imports leads to reserve accumulation, given the constant ratio between these variables. Thus, both the accumulation of net foreign assets, and the reduction in foreign borrowing implied by the

reduction in the budget deficit (given our budget closure rule) combine to mitigate the effect of the aid inflow on the exchange rate—although this is not sufficient to prevent a deterioration in the trade balance. Given the size of the aid inflow, the current account improves, but the magnitude of this improvement becomes gradually less significant.

Over time, the initial appreciation tends to be reversed. Because the increase in nonfood aid raises public investment, and thus private capital formation, the potential

Table 4
Ethiopia: simulation results permanent increase of 5 percentage point in nonfood aid-to-GDP ratio (absolute deviations from baseline, efficiency parameter=0.5)

	Years								
	2007	2008	2009	2010	2011	2012	2013	2014	2015
Real GDP per capita at market prices (% change)	0.94	0.84	0.85	0.86	0.86	0.88	0.91	0.92	0.93
Poverty rate (2000=44.2%)									
Poverty headcount index (survey data)	−0.86	−1.68	−2.47	−3.24	−3.92	−4.68	−5.64	−6.14	−6.75
Real income per capita growth elasticity of −0.5	−0.21	−0.40	−0.59	−0.77	−0.96	−1.15	−1.34	−1.53	−1.72
Real income per capita growth elasticity of −1.0	−0.43	−0.80	−1.18	−1.56	−1.93	−2.29	−2.26	−3.01	−3.35
Real income per capita growth elasticity of −1.8	−0.78	−1.47	−2.15	−2.82	−3.46	−4.09	−4.69	−5.24	−5.75
External sector (% of GDP)									
Trade balance	−2.13	−3.05	−3.51	−3.76	−3.90	−3.99	−4.05	−4.09	−4.11
Current account	3.34	2.66	2.34	2.18	2.12	2.09	2.08	2.08	2.09
Capital account	−1.77	−1.75	−1.70	−1.67	−1.65	−1.64	−1.64	−1.64	−1.64
Change in foreign assets	1.57	0.91	0.64	0.52	0.47	0.45	0.44	0.44	0.44
Government sector (% of GDP)									
Total revenue	5.34	5.49	5.54	5.55	5.54	5.53	5.52	5.50	5.49
Domestic taxes	−0.04	−0.03	−0.04	−0.05	−0.07	−0.09	−0.10	−0.11	−0.12
Indirect taxes on imports	0.38	0.52	0.58	0.60	0.61	0.61	0.61	0.61	0.61
Foreign aid (Grants)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Food aid	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nonfood aid	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Total expenditure	3.58	3.79	3.91	3.96	3.98	3.98	3.96	3.95	3.94
Spending on goods and services (total)	0.00	0.03	0.06	0.07	0.08	0.08	0.08	0.08	0.08
Maintenance spending	−0.01	−0.01	−0.01	0.00	0.00	0.01	0.01	0.02	0.02
Other spending on goods and services	0.01	0.05	0.07	0.07	0.08	0.07	0.07	0.06	0.05
Investment	3.59	3.76	3.85	3.90	3.93	3.95	3.96	3.97	3.98
Interest payments	−0.02	−0.04	−0.07	−0.09	−0.11	−0.13	−0.15	−0.17	−0.19
Overall fiscal balance	1.76	1.74	1.70	1.66	1.65	1.64	1.63	1.63	1.64
Foreign financing	−1.76	−1.74	−1.70	−1.66	−1.65	−1.64	−1.63	−1.64	−16.4
Domestic borrowing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prices and exchange rates									
Composite good price (% change)	−0.47	−0.63	−0.55	−0.50	−0.46	−0.41	−0.37	−0.33	−0.30
Nominal exchange rate (% change)	−0.97	−1.21	−0.93	−0.79	−0.69	−0.58	−0.51	−0.46	−0.41
Real exchange rate (% change)	−0.51	−0.58	−0.38	−0.29	−0.22	−0.17	−0.14	−0.12	−0.11
Memorandum items									
Educated labor (in % of population)	0.00	0.00	0.03	0.10	0.19	0.31	0.46	0.63	0.82
Private investment (% of GDP)	−0.03	0.02	0.09	0.14	0.19	0.24	0.28	0.31	0.35
Public investment (% of total public expenditure)	3.40	3.52	3.57	3.59	3.61	3.61	3.62	3.63	3.63
Nonfood aid (% of total public investment)	17.90	17.17	16.79	16.59	16.47	16.40	16.34	16.30	16.27
External debt (% of GDP)	−3.32	−6.56	−9.49	−12.21	−14.77	−17.16	−19.40	−21.49	−23.43
Net foreign assets/imports per month	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

adverse effect of a rise in aggregate demand on prices is gradually offset by the positive supply-side effects associated with an expanding stock of public and private capital. The reason is that increases in both components of the economy's capital stock combine to raise the marginal product of educated labor. As a result, wages tend to increase, thereby mitigating the initial downward effect on prices induced by the nominal appreciation. This effect is reinforced by the fact that the increase in imports leads to

greater accumulation of foreign assets by the central bank (of about 0.5 percentage points of GDP in the medium term), which over time dampens the impact of aid inflows on the nominal exchange rate.

Thus, an important feature of this simulation is that although Dutch disease effects (a real appreciation and a deterioration of the trade balance) do materialize, they tend to be mitigated by the gradual supply-side effects and the macro policy environment. The inflow of aid

Table 5

Ethiopia simulation results permanent increase of 5 percentage point in nonfood aid-to-GDP ratio (absolute deviation from baseline, improving governance; efficiency parameter increase from 0.5 to 0.8)

	Years								
	2007	2008	2009	2010	2011	2012	2013	2014	2015
Real GDP per capita at market prices (% change)	0.94	0.87	0.91	0.99	1.04	1.09	1.15	1.19	1.24
Poverty rate (2000=44.2%)									
Poverty headcount index (survey data)	−0.86	−1.69	−2.55	−3.33	−4.15	−5.15	−6.12	−6.85	−7.68
Real income per capita growth elasticity of −0.5	−0.21	−0.40	−0.61	−0.82	−1.05	−1.28	−1.53	−1.77	−2.02
Real income per capita growth elasticity of −1.0	−0.43	−0.82	−1.22	−1.66	−2.10	−2.55	−3.01	−3.47	−3.92
Real income per capita growth elasticity of −1.8	−0.78	−1.49	−2.22	−2.99	−3.77	−4.54	−5.30	−6.03	−6.71
External Sector (% of GDP)									
Trade balance	−2.13	−3.05	−3.50	−3.76	−3.89	−3.98	−4.01	−4.07	−4.06
Current account	3.34	2.66	2.35	2.21	2.17	2.16	2.19	2.21	2.28
Capital account	−1.77	−1.75	−1.73	−1.71	−1.72	−1.72	−1.74	−1.75	−1.79
Change in foreign assets	1.57	0.90	0.63	0.49	0.45	0.44	0.45	0.46	0.50
Government sector (% of GDP)									
Total revenue	5.34	5.50	5.56	5.60	5.62	5.64	5.64	5.66	5.66
Domestic taxes	−0.04	−0.03	−0.04	−0.07	−0.09	−0.11	−0.14	−0.15	−0.17
Indirect taxes on imports	0.38	0.53	0.61	0.67	0.71	0.75	0.78	0.81	0.83
Foreign aid (Grants)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Food aid	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nonfood aid	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Total expenditure	3.58	3.79	3.91	3.97	4.00	4.00	4.00	4.00	3.99
Spending on goods and services (total)	0.00	0.03	0.06	0.08	0.08	0.09	0.09	0.09	0.10
Maintenance spending	−0.01	−0.01	0.02	0.06	0.10	0.13	0.16	0.19	0.22
Other spending on goods and services	0.01	0.04	0.04	0.01	−0.01	−0.04	−0.07	−0.10	−0.12
Investment	3.59	3.76	3.86	3.91	3.95	3.97	3.99	4.01	4.03
Interest payments	−0.02	−0.04	−0.07	−0.09	−0.12	−0.15	−0.17	−0.20	−0.23
Overall fiscal balance	1.76	1.75	1.72	1.71	1.71	1.71	1.74	1.75	1.78
Foreign financing	−1.76	−1.75	−1.72	−1.71	−1.71	−1.71	−1.74	−1.75	−1.78
Domestic borrowing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prices and exchange rates									
Composite good price (% change)	−0.47	−0.53	−0.26	−0.01	0.13	0.26	0.34	0.42	−0.45
Nominal exchange rate (% change)	−0.97	−1.00	−0.35	0.17	0.38	0.56	0.66	0.75	−0.76
Real exchange rate (% change)	−0.51	−0.46	−0.09	0.17	0.25	0.30	0.32	0.33	−0.31
Memorandum items									
Educated labor (in % of population)	0.00	0.02	0.13	0.36	0.68	1.08	1.57	2.13	2.75
Private investment (% of GDP)	0.02	0.21	0.48	0.74	0.97	1.18	1.37	1.54	1.69
Public investment (% of total public expenditure)	3.40	3.52	3.57	3.60	3.62	3.64	3.65	3.66	3.68
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Net foreign assets/imports per month	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

leads to a reduction in public foreign borrowing and "precautionary" reserve accumulation, both of which dampen over time the initial upward effect of the increase in foreign exchange supply on the nominal exchange rate. In effect, there is a substitution between debt and nondebt creating (public) capital inflows. Moreover, because of markup pricing, the initial nominal appreciation helps to put downward pressure on domestic prices.

Based on the results shown in Tables 3 and 4, we can calculate the level of nonfood aid necessary to induce a given reduction in poverty in Ethiopia between 2007 and 2015. This is a key policy issue not only for Ethiopia but also for other low-income countries where the current policy debate focuses on calculating how much financial support is needed to achieve internationally-agreed development goals for reducing poverty and improving key social indicators, (see Agénor et al.,

2006). Simple calculations show that, to reduce the proportion of poor by about 20 percentage points between 2007 and 2015 would require an increase in the nonfood aid to GDP ratio of about 10 percentage points using the household survey linkage, 11.5 points using a partial elasticity of −1.8, but about 39 points with an elasticity of −0.5. These estimates are, of course, only a rough order of magnitude, given that they do not account for nonlinearities. But there should be little doubt that increases in aid of these magnitudes are likely to create severe absorption problems.

4. Sensitivity analysis

The results outlined in the previous subsection are, of course, highly dependent on some of the parameters that we used to calibrate the model, as well as some of the equations that we specified. We now examine briefly how they would be altered by considering changes in the structure of the model and alternative values for some key parameters.

First, we have taken the markup rate in the domestic pricing-setting Eq. (42) to be constant. Alternatively, it could be assumed that the markup rate is endogenously related to excess demand, with private consumption being a function of disposable income. The implication is that the downward effect of the initial nominal appreciation induced by an increase in aid inflows on domestic prices would not be as strong as shown in Tables 4 and 5; in particular, the price of the domestic good could rise, if the markup rate is highly sensitive to excess demand. The magnitude of the initial real exchange appreciation would thus be larger than reported. However, this would not alter the longer-run supply-side effects described earlier. Alternatively, full price flexibility could be assumed; and again, domestic prices would unambiguously rise on impact, because of the increase in aggregate demand and the weak supply-side response in the short run. The appreciation of the real exchange rate would therefore be magnified. Again, however, beyond the short run the pattern identified earlier would remain the same.

Second, it could be assumed that the central bank sterilizes a greater portion of aid inflows, which would translate into more rapid accumulation of foreign reserves (assuming, for instance, that the initial level of reserves is well below target). This would reduce pressure toward appreciation on impact. However, given its nonmonetary nature (and the assumption that domestic interest rates are exogenous), the model is not well suited to capture the "second round" effects of more active sterilization, namely, the impact of changes

in net foreign assets on domestic liquidity and/or interest rates. Had we captured these effects, the benefits of greater reserve accumulation would be less than suggested-higher liquidity could increase pressure on domestic prices and lead to a more sustained real appreciation.

Among the parameters that were imposed or estimated, some of them play actually a limited role in the results. Regarding the congestion parameters, for instance, experiments show that they would have to take relatively large (and implausible) values for the marginal productivity effects associated with public capital to be eroded quickly. Similarly, as long as they are confined to a plausible range, changes in some of the elasticities related to production and consumption behavioral patterns would not have much effect on the qualitative (and possibly quantitative) nature of the results. By contrast, the fiscal parameters, namely the impact of aid on the tax rate, current government spending, and public investment, are crucial for the behavior of the model. The two-standard error confidence intervals reported in Table 2 are relatively large, and changes within that range could have a sizable impact on our simulation results. With a higher adverse impact of aid on the tax rate and current spending, for instance, and a lower positive effect on public investment, for instance, the supply-side effects would be much slower to materialize. By implication, Dutch disease effects would display more persistence—so much so that they could lead to an unsustainable external position.

Another key parameter in the model is the degree of efficiency of public investment. As noted earlier, the baseline projections and the aid simulation experiment were conducted under the assumption that the coefficient φh in Eq. (29) is uniformly equal to 0.5—a value that is consistent with the evidence for developing countries. Suppose instead that in the coming years Ethiopia implements institutional reforms aimed at improving governance and the management of public resources, while reducing corruption. Formally, this can be captured by assuming that the efficiency parameter rises from 0.5 to, say, 0.6 in 2007, 0.7 in 2008, and 0.8 in 2009, remaining constant at that value beyond that. Table 5 presents the simulation results associated again with a 5-percentage point increase in the aid–GDP ratio under these assumptions. The results show clearly that governance reforms can have a sizable impact by magnifying the effect of foreign aid. The increase in the growth rate in the medium term is more substantial, private investment rises more significantly, and poverty drops by a lot more. In addition, the initial

appreciation tends to be reversed much faster than in the previous case.

In these conditions, to reduce the proportion of poor by about 20 percentage points between 2007 and 2015 would require an increase in the nonfood aid to GDP ratio of about 9.3 points using the household survey linkage, 10.3 points using a partial elasticity of −1.8, but still about 35 points with an elasticity of −0.5. If the "true" partial elasticity is indeed that low, absorption problems will continue to make it impossible to achieve the MDG target through higher aid at a relatively short horizon. Nevertheless, these results illustrate the importance of combining increases in aid with reforms aimed at improving the management of public resources, to maximize their impact on growth and poverty reduction.[18]

5. Conclusions

The purpose of this paper was to develop a macroeconomic model that captures the links between foreign aid, the level and composition of public capital, growth, and poverty reduction in low-income countries, and illustrate its functioning with a concrete application. The first part described the model and the second presented an application to Ethiopia.

As noted earlier, the fiscal parameters, namely the impact of aid on the tax rate, current government spending, and public investment, are crucial for the behavior of the model. The two-standard error confidence intervals reports in Table 2 are relatively large, and changes within that range could have a sizable impact on our simulation results. With a higher adverse impact of aid on the tax rate and current spending, for instance, and a lower positive effect on public investment, for instance, the supply-side effects would be much slower to materialize. By implication, Dutch disease effects would display more persistence. Conversely, however, strong supply-side effects could make the Dutch disease a more transient phenomenon.

But although there is some significant degree of uncertainty regarding the appropriate values of some of the parameters that we use (and thus about the exact magnitudes that we have reported), there are several broad messages that can be drawn from the paper. First, our results are consistent with other recent studies (such as Nkusu, 2004), which emphasize the fact that in assessing the scope for Dutch disease effects associated

with foreign aid, the possibility of a (relatively) rapid supply response should not be discarded on a dogmatic basis. Second, our analysis draws attention to the fact that, under a flexible exchange rate regime, precautionary demand for reserves and substitution effects between aid and debt-creating capital flows may have a large impact on the behavior of the nominal exchange rate-and thus on the magnitude of the real appreciation associated with increases in foreign assistance. Third, our results illustrate the importance of combining increases in aid with reforms aimed at improving the management of public resources, to maximize their impact on growth and poverty reduction.

A final point relates to the differences between our model-based approach and the aid literature based on cross-country regressions. As noted earlier, in evaluating Dutch disease effects, it is critical, both conceptually and empirically, to distinguish between short-term (demand) effects and longer-term (supply-side) effects, taking into account the possible nonlinearities that may be associated with aid. From that perspective, dynamic nonlinear structural models have a clear advantage over the static, linear, single-equation, cross-country regressions that are typically estimated in the literature. Moreover, when it comes to providing advice on how to respond to aid inflows, developing country-specific, structural economic models is essential; relaying on "average behavior" summarized by cross-country regressions may lead to serious policy mistakes. Nevertheless, the high degree of uncertainty that model builders may face in estimating some key structural parameters suggests that cross-country regressions and structural models should be viewed as complementary, rather than substitute, methodologies.

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[18] These results are in line with those obtained for another low-income country, Niger, by Agénor et al. (2006).

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