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AID VOLATILITY AND POVERTY TRAPS

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## Abstract

This paper studies the impact of aid volatility in a two-period model where production may occur with either a traditional or a modern technology. Public spending is productive and “time to build” requires expenditure in both periods for the modern technology to be used. The possibility of a poverty trap induced by high aid volatility is first examined in a benchmark case where taxation is absent. The analysis is then extended to account for self insurance (taking the form of a first-period contingency fund) financed through taxation. An increase in aid volatility is shown to raise the optimal contingency fund. But if future aid also depends on the size of the contingency fund (as a result of a moral hazard effect on donors’ behavior), the optimal policy may entail no self insurance.

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“There is an incredible and increasing burden (on African countries) of aid with different conditions and aid that is not predictable... It is often very difficult for countries who need resources from outside to be able to plan ... if there is not enough predictability of the flows of aid.”

Rodrigo de Rato, IMF Managing Director, Cape Town (March 16, 2007).

## 1 Introduction

Various observers have advocated a large and sustained increase in foreign aid to facilitate the achievement of the Millennium Development Goals (MDGs) in low-income countries. The underlying argument is often that, given the limited ability of many of these countries to raise domestic resources through taxation, concessional external finance is essential to support a multi-year public investment program aimed at developing public capital in infrastructure, health, and education. In a recent report on Sub-Saharan Africa, for instance, the World Bank (2005*a*) called for a doubling of spending on infrastructure in the region (from 4.7 percent of GDP in recent years to more than 9 percent over the next decade), with much of this increase supported by net inflows of concessional resources.<sup>1</sup>

The unfortunate news, however, is that aid volatility tends to be quite high and may have in fact increased in recent years. Pallage and Robe (2001), using data for 63 aid recipients for the period 1969-95, found that aid is approximately twice as volatile as real output. In the same vein, Bulir and Hamann (2003), using data covering 72 countries over the period 1975-97,

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<sup>1</sup>See also the report of the Commission for Africa (2005) and Sachs (2005) for a discussion of the importance of a “Big Push” in public investment for achieving the MDGs. Agénor (2006) provides a theoretical analysis that highlights the role of improved governance in the context of a Big Push.

found that aid flows are significantly more volatile than domestic fiscal revenues; in addition, the information content of aid commitments in predicting actual flows is either very small or statistically insignificant—a result subsequently corroborated by Celasun and Walliser (2008). They also found much larger prediction errors in program assistance than in project aid, and a stronger tendency to over-estimation.<sup>2</sup> In subsequent studies, Bulir and Hamann (2007), as well as Hudson and Mosley (2006), found corroborating evidence; the volatility of aid continues to be much larger than the volatility of domestic tax revenues, with coefficients of variation in the range of 40-60 percent of mean aid flows. Both studies also found that aid volatility has actually increased since the late 1990s, as do the IMF’s Independent Evaluation Office (2007) with respect to aid to Sub-Saharan Africa and Kharas (2007) for a larger group of aid recipients.

Of course, by their very nature, some types of aid should exhibit a high degree of volatility, because they are designed to deal with local economic and social crises. This is certainly the case for emergency aid.<sup>3</sup> The World Bank (2005*b*, p. 106) for instance found that emergency assistance is more than three times more volatile than overall Official Development Assistance (ODA) flows. To a lower extent, high volatility may also characterize program

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<sup>2</sup>Program aid (also referred to as budget or “untied” aid) generally takes the form of a cash disbursement and is perfectly fungible. By contrast, project aid (or “tied” aid) consists of transfers for investment projects agreed between the donor and the recipient country; whether it is fungible or not depends on whether, prior to the aid commitment, the recipient country intended to finance the project itself.

<sup>3</sup>Volatility in emergency aid, such as food, can have important macroeconomic implications because its timing and scale could have a stabilizing effect on the government budget. When, for instance, the domestic supply of food falls, government revenues may decline and spending may rise; monetization of food aid in this case can stabilize flows to the budget, in addition to allowing some degree of consumption smoothing. However, based on past aid surges, Bulir and Haman (2007) found no evidence that these effects were significant or large.

assistance, given that it may depend (through conditionality) on short-run macroeconomic performance and disbursement triggers. By contrast, project aid should be relatively stable, given that it is designed to promote (directly or indirectly) investment in physical and human capital.<sup>4</sup> According to estimates by the World Bank (2006, p. 93), physical infrastructure accounted for 32.2 percent of ODA to low-income countries during the period 1990-92 and 40 percent during 1995-97, whereas education and health amounted to 8.1 percent and 10.9 percent for the same periods. As a proportion of domestic investment, project aid has also increased dramatically since the 1960s for many poor countries. Thus, in addition to complicating short-run macroeconomic management, volatility in that category of aid could be very detrimental to long-term economic and social development in these countries.

But here again the news are not good. In a study of disaggregated aid inflows to 66 low-income recipients over the period 1973-2002, Fielding and Mavrotas (2005) found that project aid (particularly in the more open economies) tends also to be quite volatile. Moreover, aid does not seem to operate as an “insurance mechanism” against adverse economic shocks; by and large, as documented by Pallage and Robe (2001) and Bulir and Hamann (2003, 2007), it tends to behave procyclically, thereby exacerbating the impact of these shocks. If the reasons for aid volatility are beyond the control of recipient countries, understanding its implications and designing ways to cope with it become primary policy concerns.

A key implication of lack of predictability in aid disbursements (particularly of project aid) is that it makes it difficult for recipient governments

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<sup>4</sup>If donor countries provide aid for financing large and “lumpy” projects, some degree of aid volatility should naturally be expected. Our contention, however, is that the recent increase in volatility of aid flows has been associated with an across-the-board increase in uncertainty associated with the availability of foreign assistance.

to formulate medium-term spending plans to spur growth and achieve the MDGs. If aid finances a large fraction of infrastructure investment, as is often the case in low-income countries, and if creating public capital requires time (as a result of a “time to build” assumption, for instance), an aid shortfall could bring the process to a halt if no alternative sources of financing are available. In addition, in response to high volatility, countries may opt to reduce the desired level of investment, which, *ceteris paribus*, means lower funding requirements; donors, seeing lower requirements, may misinterpret it as a signal of absorption problems, and effectively reduce aid commitments—making the initial concerns about lower assistance self-fulfilling and possibly contributing to the perpetuation of a stagnation equilibrium, or more broadly speaking a poverty trap. Aid volatility may therefore have permanent costs in terms of lost output and exert potentially large effects on growth and welfare.

Despite the importance of these potential effects, there has been relatively limited research on the consequences of aid volatility.<sup>5</sup> Among available empirical studies, Lensink and Morrissey (2000), Markandya, Ponczek, and Yi (2006), and Neanidis and Varvarigos (2007) have all found that aid volatility (particularly with respect to program aid) has a significant negative impact on growth. This effect appears to be robust across country groups, regression specifications, and estimation techniques. More directly relevant to the issue addressed in this paper, Hudson and Mosley (2008) found that aid volatility tends to reduce both government expenditure and aggregate investment—

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<sup>5</sup>Much recent research has focused on the general issue of volatility and growth; see, for instance, Turnovsky and Chattopadhyay (2003), Aghion et al. (2005), Blackburn and Pelloni (2004), Hnatkovska and Loayza (2005), Chong and Gradstein (2006), Geert, Harvey, and Lundblad (2006), Kose, Prasad, and Terrones (2005), Norrbin and Yigit (2005), and Imbs (2007), for some recent contributions. However, none of these studies addresses the more specific issues related to the volatility of aid.

particularly so when considering sudden declines or shortfalls in aid. At the analytical level, most of the research has focused on the impact of the *level* of aid and its implications for growth. Chatterjee, Sakoulis, and Turnovsky (2003), and Chatterjee and Turnovsky (2005, 2007), for instance, analyze the impact of aid tied to public investment in infrastructure on private capital formation and growth, and so do Agénor and Yilmaz (2008) in a model with endogenous relative prices. Studies that examine specifically the volatility of aid, such as Arellano, Bulir, Lane, and Lipschitz (2009), and Pallage, Robe, and Bérubé (2006), tend to focus on the implications of such volatility for consumption smoothing. In doing so, however, they tend to neglect longer-term, supply-side effects, namely, the fact that aid volatility may affect governments' ability to finance public investment programs and spur private capital accumulation and production—fluctuations in which may in turn generate large movements in consumption and sizable welfare effects.

This paper takes a step forward by studying the impact of aid volatility on production and welfare. We do so in a two-period model where risk-neutral agents must choose between a traditional and modern technologies. In addition, a “time to build” assumption requires public expenditure in both periods for the modern technology to be adopted. Although aid disbursements are known with certainty in the first period, they are uncertain in the second. Section II considers the benchmark case where domestic taxation is absent and shows how a poverty (or low output) trap induced by high aid volatility can emerge. Section III extends the analysis to account for the possibility of self insurance, through a first-period contingency fund. Reserve accumulation has indeed been advocated by various observers (including the International Monetary Fund (2007)) as a way to mitigate adverse effects of sharp fluctuations in foreign assistance on government spending programs.

We show, however, that if future aid is dependent on the size of the contingency fund (as a result of a moral hazard effect), the optimal policy may entail no self insurance. The final section offers some concluding remarks.

## 2 The Basic Framework

We consider a two-period economy with population constant at  $\bar{L}$  and risk-neutral agents. Each agent supplies up to one unit of labor. Production of a single good can take place under two alternative technologies: a “traditional” technology, which involves only labor, and a more productive “modern” technology, which requires not only labor but also government services (infrastructure, for short) provided in both periods. There is no private physical capital and there is no opportunity to borrow on international financial markets.

The representative agent’s discounted present value utility is given by

$$U = C_1 - \nu L_1 + \frac{C_2 - \nu L_2}{1 + \beta}, \quad (1)$$

where  $C_h$  is consumption,  $L_h$  labor supply (both in period  $h = 1, 2$ ),  $\nu \in (0, 1)$ , and  $\beta > 0$  is a subjective discount rate. For simplicity, the instantaneous utility function is taken to be linear in both arguments.

In the first period, the economy uses the traditional technology only; in the second, whether the traditional or the modern technology is used depends on expected profits. Because of the low level of income, we assume initially that the government cannot raise resources domestically; therefore spending in both periods is financed solely by foreign aid.

For simplicity, the traditional production technology is assumed to be Ricardian. Let  $Y_1$  denote output in period 1; thus

$$Y_1 = \bar{L}, \quad (2)$$

where, for simplicity, the marginal product of labor is set equal to unity.

Output in period 2 can be produced with either the modern or the traditional technology. The modern technology requires a labor commitment in quantity  $L_2$ —perhaps because time is needed to relocate workers from the traditional to the modern sector—and a combination of public infrastructure services in both periods. The production function is given by

$$Y_2 = b \frac{L_2^\gamma (G_1^\alpha G_2^{1-\alpha})^{1-\gamma}}{\gamma}, \quad (3)$$

where  $G_1$  ( $G_2$ ) denotes government spending in period 1 (2),  $b > 0$  measures the total productivity of the modern technology, and  $\alpha, \gamma \in (0, 1)$ . The use of the modern technology also involves a “startup cost” of  $\kappa_1$ , which is incurred in period 1.<sup>6</sup>

If, instead, the traditional technology is used in period 2, production is given by

$$Y_2 = \bar{L} - L_2, \quad (4)$$

given that the labor commitment  $L_2$  is made in period 1.

For the time being, we assume that aid, given by  $A_i$ ,  $i = 1, 2$ , finances government spending in both periods. In period 1, there is no uncertainty; however, second-period aid is uncertain. Specifically, we assume that

$$A_1 = G_1, \quad (5)$$

$$A_2 = G_2 = (1 + \varepsilon)\bar{A}, \quad (6)$$

where  $\bar{A} > 0$  and  $\varepsilon$  is a random variable with zero mean, so that  $E(\varepsilon) = 0$ , and variance  $\sigma_\varepsilon^2$ . In what follows, we will assume that  $\varepsilon$  follows a symmetric distribution over the interval  $(-\bar{\varepsilon}, +\bar{\varepsilon})$ ,  $\bar{\varepsilon} \leq 1$ , and density function  $f(\varepsilon)$ .

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<sup>6</sup>Our analysis is not altered if  $\kappa_1 = 0$ .

Assuming a constant wage normalized to unity, the optimal labor commitment is the solution of the following maximization problem:

$$\max_{L_2} E \left\{ b \frac{L_2^\gamma (A_1^\alpha G_2^{1-\alpha})^{1-\gamma}}{\gamma} - (1 + \beta)\kappa_1 - L_2 \right\},$$

where  $E$  is the expectations operator and  $(1 + \beta)\kappa_1$  measures the value of the startup cost from the perspective of period 2. The solution of this problem for the individual agent yields<sup>7</sup>

$$L_2^* = b^{1/(1-\gamma)} A_1^\alpha \{E[G_2^{(1-\alpha)(1-\gamma)}]\}^{1/(1-\gamma)} \leq 1. \quad (7)$$

Using this result, expected private profits (measured from the perspective of the first period) associated with the adoption of the modern technology are thus given by

$$\Pi = \frac{b^{1/(1-\gamma)}(\gamma^{-1} - 1)A_1^\alpha [E(G_2^\Omega)]^{1/(1-\gamma)}}{1 + \beta} - \kappa_1, \quad (8)$$

where  $\Omega \equiv (1 - \alpha)(1 - \gamma) < 1$ .

Because of homogeneity, all agents  $\bar{L}$  adopt the modern technology, if it profitable to do so. Using (8), and abstracting from any cost associated with aid, the expected social surplus of the recipient country is thus given by

$$V = \bar{L} \left\{ \frac{b^{1/(1-\gamma)}(\gamma^{-1} - 1)A_1^\alpha [E(G_2^\Omega)]^{1/(1-\gamma)}}{1 + \beta} - \kappa_1 \right\} - \bar{A}. \quad (9)$$

If the term in brackets is positive, a large enough value of  $\bar{L}$  will ensure that  $V > 0$ , implying that the modern technology is welfare enhancing. In turn, for the term in brackets to be positive, the productivity of the modern

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<sup>7</sup>We assume that  $b$  and  $A_1$  are such that this inequality holds. Recall that each agent supplies up to one unit of labor. Equation (7) implies an internal solution, where both technologies are used in period 2. If  $L_2^* > 1$ , we will observe a corner solution, where all workers are committed to the modern sector and the second-period wage exceeds unity. Our analysis can be extended to apply to this case.

technology, as measured by  $b$ , must be high enough, in comparison to the startup cost  $\kappa_1$ , and the discount rate  $\beta$  cannot be too high.

The impact of volatility on the social surplus operates through  $E(G_2^\Omega)$ . The concavity of  $G_2^\Omega$ —which results from the diminishing marginal productivity of public infrastructure in private production, that is,  $\gamma < 1$ —implies that volatile aid reduces expected private profits as well as the social surplus. This is a reflection of Jensen’s inequality, embodied in the strict concavity of  $G_2^\Omega$ , as a function of  $G_2$ .<sup>8</sup> In effect, the economy would be better off getting the amount of aid  $\bar{A}$  with certainty than getting the same amount on average, but with a non-zero variance.

By implication, if  $b$  is sufficiently low and the degree of aid volatility high enough, private agents may not find it profitable to adopt the modern technology; the economy may be stuck therefore in a stagnation equilibrium, or more broadly speaking a poverty trap (which we define as a state of “low” output, that is, output produced by the traditional technology), with possibly large welfare losses. This result can be summarized in the following proposition:

**Proposition 1.** *High aid volatility, by reducing expected private profits associated with the modern technology and the social surplus, may lead to a poverty (or low output) trap.*

Thus, in this model, a necessary condition for a stagnating equilibrium

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<sup>8</sup>More specifically, Jensen’s inequality implies here that  $E(G_2^\Omega) < (EG_2)^\Omega$ , that is, using (6),  $E([(1 + \varepsilon)\bar{A}]^\Omega) < \bar{A}^\Omega$ . Given diminishing returns, an increase in uncertainty (higher volatility of  $\varepsilon$ ) leads to a worse outcome than  $\bar{\varepsilon} = 0$ . For small support  $\bar{\varepsilon}$ , a second-order Taylor approximation implies that higher aid volatility reduces expected profits. More generally, the concavity of expected profits implies that for a symmetric distribution of aid shocks, higher volatility induced by a multiplicative increase in the distribution reduces the expected surplus associated with the modern technology. That is, magnifying the aid shock,  $\varepsilon$ , by a factor  $q$  to  $q\varepsilon$ , where  $q > 1$ , increasing thereby the standard deviation of the aid shock by a factor of  $q$ , can be shown to reduce the expected surplus.

to emerge (that is,  $V < 0$ ) is for adoption of the modern technology to be feasible (or desirable) when aid is at its expected value  $\bar{A}$ —as can be inferred from (9)—but not feasible when *actual* aid flows are too volatile.

Figure 1 illustrates the welfare cost of aid volatility, reporting a simulation of an economy where the aid shock follows a uniform distribution in the interval  $(-\bar{\varepsilon}, +\bar{\varepsilon})$ . We plot the expected surplus, (9), for varying levels of  $\bar{\varepsilon} \in (0, 1)$ . Panel A corresponds to the case where the productivity is relatively high, hence public investment is highly productive. In the absence of aid volatility, public investment yields a surplus that exceeds the public investment second period cost by about 55 percent. The optimal share of labor employed in the nontraditional sector is about 0.2. Volatility reduces the surplus of the non-traditional sector to about 40 percent for  $\bar{\varepsilon} = 1$ .

Panel B corresponds to the case where the productivity of the non traditional sector is low. For zero volatility, the non-tradition sector yields a surplus that exceeds the second public investment by about 9 percent. High enough volatility would terminate the non-traditional sector, eliminating thereby any surplus (recall that the surplus is zero in the traditional sector). The optimal share of labor employed in the non-traditional sector is about 0.15, dropping to zero for high enough volatility. Thus, small changes in productivity have sizable effects on the expected surplus.

### 3 Self Insurance and Moral Hazard

We now consider the case where the government self insures by building a contingency fund in the first period, in order to alleviate the risk of an aid shortfall in the second period. For simplicity, we will assume in what follows that  $A_1$  (which is given) is normalized to unity.

The first step is to calculate the optimal value of spending in the second period for the case, where the realized level of aid is large enough to ensure that the aid constraint does not bind. This is determined so as to maximize the difference between output produced with the modern technology and the “best” alternative use of the aid inflow, that is, consumption:

$$\max_{G_2} E \left\{ \bar{L}b \frac{(L_2^*)^\gamma G_2^\Omega}{\gamma} - G_2 \right\},$$

where  $L_2^*$  is given by (7). The term in brackets represents the difference between the benefit from spending aid for productive purposes if it induces agents to adopt the modern technology, compared to the benefit derived from simply consuming those resources. Solving this problem yields

$$G_2^* = \left\{ \left( \frac{\bar{L}b^{1/(1-\gamma)\Omega}}{\gamma} \right) [E(G_2^\Omega)]^{\gamma/(1-\gamma)} \right\}^{1/(1-\Omega)}. \quad (10)$$

The second step is to determine the resources available to the government in the first and second periods. In the first period, as noted earlier, production uses the traditional technology. Because agents supply one unit of labor and the productivity of labor is unity, total income is also unity. With  $\tau_1$  denoting the period-1 tax rate, tax revenues are in principle given by  $\bar{L}\tau_1$ . However, suppose also that collecting taxes is subject to costs, which reduce proceeds (in a nonlinear fashion) by  $-\bar{L}\lambda\tau_1^2/2$ . Total resources (or liquidity) that the government can have access to in the second period to finance spending, taking into account both domestic resources and (volatile) aid, is given by<sup>9</sup>

$$\Gamma(\tau_1, \varepsilon) = \bar{L} \left( \tau_1 - \frac{\lambda\tau_1^2}{2} \right) (1 + \beta) + (1 + \varepsilon)\bar{A}. \quad (11)$$

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<sup>9</sup>We assume that due to administrative lags in the collection of taxes, only first-period taxes and realized second-period aid (rather than  $A_1$ ) can be used to fund second-period public investment. The main results of our paper do not depend on this assumption.

Given that the unconstrained, optimal second-period spending is determined by (10), there are two cases to consider, depending on the value of the aid shock:

$$G_2 = \begin{cases} \Gamma(\tau_1, \varepsilon) & \text{if } \varepsilon < \varepsilon_C \\ G_2^* & \text{if } \varepsilon > \varepsilon_C \end{cases},$$

where the critical value of the shock,  $\varepsilon_C$ , is obtained from  $\Gamma(\tau_1, \varepsilon_C) = G_2^*$ . It follows that the threshold state,  $\varepsilon_C$ , depends negatively on the tax rate and positively on the parameter  $\lambda$ , which characterizes tax collection costs:

$$\varepsilon_C = \varepsilon_C(\tau_1; \lambda),$$

with  $\partial\varepsilon_C/\partial\tau_1 < 0$  and  $\partial\varepsilon_C/\partial\lambda > 0$ .

In the first case,  $\varepsilon < \varepsilon_C$ , spending is constrained by available resources and the optimal level cannot be achieved. In the second case,  $\varepsilon > \varepsilon_C$ , spending is unconstrained, because resources exceed the optimal value; if so, we assume that the “excess” resources, given by  $\Gamma(\tau_1, \varepsilon) - G_2^* = \bar{A}(\varepsilon - \varepsilon_C)$ , are consumed.

The expected social surplus may now be written as

$$\begin{aligned} V = & \bar{L}(1 - \tau_1) + \bar{L} \int_{-\bar{\varepsilon}}^{\varepsilon_C} b \frac{L_2^\gamma}{\gamma} \frac{\Gamma(\tau_1, \varepsilon)^\Omega}{1 + \beta} f(\varepsilon) d\varepsilon & (12) \\ & + \int_{\varepsilon_C}^{\bar{\varepsilon}} \left\{ \bar{L} b \frac{L_2^\gamma}{\gamma} \frac{G_2^{*\Omega}}{1 + \beta} + \frac{\bar{A}(\varepsilon - \varepsilon_C)}{1 + \beta} \right\} f(\varepsilon) d\varepsilon - \bar{L}\kappa_1 - 1 - \frac{L_2}{1 + \beta}. \end{aligned}$$

The optimal period-1 tax rate is therefore given by

$$\frac{dV}{d\tau_1} = -\bar{L} + \bar{L}(1 - \lambda\tau_1) \left\{ \int_{-\bar{\varepsilon}}^{\varepsilon_C} b \frac{L_2^\gamma}{\gamma} \frac{\Omega\Gamma(\tau_1, \varepsilon)^{\Omega-1}}{1 + \beta} f(\varepsilon) d\varepsilon + \int_{\varepsilon_C}^{\bar{\varepsilon}} f(\varepsilon) d\varepsilon \right\} = 0,$$

which can be rewritten as

$$-1 + (1 - \lambda\tau_1) \left\{ \int_{-\bar{\varepsilon}}^{\varepsilon_C} b \frac{L_2^\gamma}{\gamma} \frac{\Omega\Gamma(\tau_1, \varepsilon)^{\Omega-1}}{1 + \beta} f(\varepsilon) d\varepsilon + \int_{\varepsilon_C}^{\bar{\varepsilon}} f(\varepsilon) d\varepsilon \right\} = 0,$$

or equivalently<sup>10</sup>

$$\frac{1}{1 - \lambda\tau_1} = \int_{-\bar{\varepsilon}}^{\varepsilon_C} b \frac{L_2^\gamma \Omega\Gamma(\tau_1, \varepsilon)^{\Omega-1}}{\gamma} f(\varepsilon) d\varepsilon + \int_{\varepsilon_C}^{\bar{\varepsilon}} f(\varepsilon) d\varepsilon. \quad (13)$$

This condition can be interpreted as a public finance intertemporal arbitrage characterizing the optimal tax, which in turn determines the optimal resources held in the contingency fund, and second-period liquidity,  $\Gamma$ . The left-hand side of (13) is the gross cost of public funds; raising one unit of net public funds requires higher gross tax revenue of  $1/(1 - \lambda\tau_1)$ .<sup>11</sup> The right-hand side is the expected marginal benefit of liquidity, discounted to the first period. Specifically, a unit of net public funds increases second-period liquidity by  $d\Gamma/d\tau_1 = 1 + \beta$ . In states of low aid ( $\varepsilon < \varepsilon_C$ ), the extra liquidity would finance higher second-period infrastructure spending,  $dG_2/d\tau_1 = d\Gamma/d\tau_1$ , increasing second-period output by  $(dY_2/dG_2)(1 + \beta)$ . In terms of the first period, extra liquidity would lead to a welfare gain of  $dY_2/dG_2$ . If spending in the second period is unconstrained ( $\varepsilon > \varepsilon_C$ ), the extra liquidity will support higher second-period consumption, inducing a discounted welfare gain of 1 (that is,  $(1 + \beta)/(1 + \beta)$ ). The right-hand side of (13) is thus the discounted expected welfare gain derived from marginal second-period liquidity.

These results are illustrated in Figure 2, which relates the marginal productivity of government spending ( $MPG$ ) to the realized aid shock. The bold curve shown in the figure depicts  $\max\{[\Delta Y_2/\Delta G_2]/(1 + \beta); 1\}$ . For  $\varepsilon < \varepsilon_C$ , it is the discounted marginal product of public infrastructure; for  $\varepsilon > \varepsilon_C$ , it is the discounted increase of second-period consumption financed by mar-

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<sup>10</sup>Note that in solving for the optimal tax rate we take  $G_2^*$  as given, as implied by the Envelope theorem; a change in  $G_2^*$  would lead to a change in  $\varepsilon_C$ , which in turn would have a negligible effect on the term on the right-hand side of equation (13).

<sup>11</sup>The wedge  $1/(1 - \lambda\tau_1) - 1 = \lambda\tau_1/(1 - \lambda\tau_1)$  measures the cost spent on collecting a unit of net tax revenue.

ginal liquidity,  $(1 + \beta)/(1 + \beta) = 1$ . The bold curve is also the discounted marginal benefit of first-period liquidity, that is, the right-hand side of (13). The optimal first-period tax rate equates this expected gain with the gross cost of public funds,  $1/(1 - \lambda\tau_1)$ . Hence, for a given  $\lambda$ , factors increasing the expected discounted gain of marginal liquidity (as represented by the bold curve in the figure) would increase optimal liquidity, thereby requiring a higher tax rate.<sup>12</sup>

Another implication of Figure 2 is that, in the limiting case of lump-sum taxes, the cost of self insurance approaches zero, and the optimal policy is full insurance—holding liquidity that would allow financing  $G_2^*$  even in the worst state of nature, that is,  $\varepsilon_C \rightarrow -\bar{\varepsilon}$  when collection costs tend to zero ( $\lambda \rightarrow 0$ ).<sup>13</sup>

From condition (13), the following proposition can be established regarding the impact of aid volatility, as measured by an increase in the standard error of the shock,  $\sigma_\varepsilon$ :

**Proposition 2.** *An increase in aid volatility raises the optimal tax rate,  $d\tau_1^*/d\sigma_\varepsilon > 0$ .*

The proof of this proposition is provided in the Appendix. It stems again from the application of Jensen’s inequality—in this case now due to the convexity of the marginal impact of the tax rate on the surplus with respect to  $\varepsilon$  (see the Appendix). It would hold therefore for any symmetric distribution with zero mean.

The impact of volatility on the optimal tax rate is illustrated in Figure

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<sup>12</sup>The sign of  $d\tau_1/d\lambda$  is, in general, ambiguous. In terms of Figure 2, the change in  $\lambda$  implies that there is no one-to-one connection between the induced changes in the expected value of the bold curve and the tax  $\tau_1$ . By implication, the impact of an increase in the tax collection cost on the critical threshold of the aid shock cannot be established *a priori*.

<sup>13</sup>Indeed, with lump-sum taxation, the gross cost of public finance is 1, hence the optimal policy should equate the expected bold curve to 1, implying that  $\varepsilon_C \rightarrow -\bar{\varepsilon}$  when  $\lambda \rightarrow 0$ .

3, plotting the marginal cost of public funds as a function of the tax rate (curve  $MCP$ ) and the *expected* marginal productivity of public spending in period 2 (curve  $E(MPG)$ ), drawn for  $\lambda > 0$  and for given aid volatility,  $\sigma_\varepsilon$ . The upward-sloping  $MCP$  corresponds to  $\lambda > 0$  (positive tax collection costs) and the flat  $MCP$  corresponds to  $\lambda = 0$  (lump-sum tax economy). More costly tax collection makes the  $MCP$  curve steeper, reducing thereby the optimal tax rate. The convexity of curve  $MPG$ , which is proved in the Appendix, implies that higher aid volatility shifts curve  $E(MPG)$  upward, increasing thereby the optimal tax rate (from  $\tau_1^*$  to  $\tau_1^{**}$ ), and the optimal precautionary reserves.

Holding volatility of the aid shock  $\varepsilon$  constant, another result emerges if there is a “moral hazard” effect associated with building precautionary resources through first-period taxation. Rather than modeling donor behavior explicitly, we address this issue by using a “reduced form” approach. Let  $R = \bar{L}(\tau_1 - \lambda\tau_1^2)$  denote the total contingency fund built in the first period. Suppose also that the expected value of aid in the second period,  $\bar{A}$ , is inversely related to the size of the fund, so that, assuming a linear form for simplicity,

$$\bar{A} = \bar{A}(R) = \bar{A}_0(1 - \phi R),$$

where  $\bar{A}_0 > 0$  and  $\phi > 0$ . As discussed in the introduction, this could be due to the fact that donors, observing the existence of a contingency fund in the recipient country, choose to reduce their future commitments—perhaps because an increase in liquidity is perceived as a reflection of absorption capacity problems. If so, the following proposition can be established:

**Proposition 3.** *If the existence of a contingency fund creates a moral hazard problem, the optimal tax rate is lower than otherwise.*

Graphically, the effect of adding moral hazard is to entail a uniform shift of the bold curve in Figure 2. The adverse effect of self insurance on expected aid acts as a tax on the gains of marginal second-period liquidity (the expression on the right-hand side of (13)), reducing thereby optimal hoarding and the optimal tax rate. In terms of Figure 2, higher  $\phi$  shifts the downward-sloping portion of the bold curve, thereby reducing the expected discounted gain of marginal second-period liquidity, and thus lowering the optimal tax rate. This effect reflects the moral hazard resulting from the combination of aid uncertainty and aid responsiveness to holding a contingency fund.

## 4 Concluding Remarks

This paper studied the impact of aid volatility on economic performance in a simple two-period model with a traditional and modern technologies. Public spending is productive and “time to build” requires expenditure in both periods for the modern technology to be used. The possibility of a stagnation equilibrium or poverty trap (defined as a state where second-period production continues to be carried out with the traditional technology) induced by high aid volatility is first examined in a benchmark case where taxation is absent. Government spending (whose sole purpose is to provide productive services) is thus financed in its entirety by aid. The analysis is then extended to account for self insurance (taking the form of a first-period contingency fund) financed through taxation. We showed that an increase in aid volatility raises the optimal tax rate and that if expected future aid is dependent on the size of the contingency fund (as a result of a moral hazard effect), the optimal policy may entail no self insurance.

Despite the fact that they have been derived in a highly stylized setting,

our results have several broad implications. The first is that aid volatility may not only potentially exacerbate the impact of macroeconomic shocks (due to its procyclical nature, as demonstrated in some studies), but it may also contribute to the emergence, or persistence, of a poverty and low-output trap if aid exerts productive effects—either directly (because donors commit to certain projects) or through its impact on public spending. In that sense, the model’s predictions are consistent with the results of Kose, Prasad, and Terrones (2005, Table 6), which show that volatility in government spending has an adverse effect on economic growth. The second is that although an increase in aid volatility may call for an increase in (optimal) tax rates, in practice these increases may not be feasible, due to various administrative and political constraints. Aid volatility may therefore hamper resource mobilization. Finally, our results cast doubt on the wisdom of a commonly suggested policy response to aid volatility—the buildup of a contingency or buffer fund, typically in the form of accumulation of international official reserves (see for instance Eifert and Gelb (2006) and International Monetary Fund (2007)). The very existence of such a fund may lead donors to change their behavior in terms of future aid commitments—which in turn would reduce the recipient’s incentives to raise taxes, “save for a rainy day,” and maintain government spending plans at the desired level to spur growth. The extent to which these adverse moral hazard effects on individual donor behavior can be mitigated through greater donor coordination, or a common external agency, remains a matter for debate.<sup>14</sup>

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<sup>14</sup>The British proposal for an international finance facility (see the report of the Commission for Africa (2005)) was an attempt to tackle the issue. However, so far it has received only limited support by major donors.

## Appendix Derivation of Proposition 2

With the representative agent's discounted present value utility given in (1), the social surplus function can be written as

$$S = \begin{cases} \bar{L}(1 - \tau_1) + \bar{L}b\left(\frac{L_2^\gamma}{\gamma}\right)\left(\frac{\Gamma^\Omega}{1+\beta}\right) - \bar{L}\kappa_1 - 1 - \frac{L_2}{1+\beta} & \text{for } \varepsilon \leq \varepsilon_C \\ \bar{L}(1 - \tau_1) + \bar{L}b\left(\frac{L_2^\gamma}{\gamma}\right)\left(\frac{G_2^*}{1+\beta}\right)^\Omega + \frac{\Gamma - G_2^*}{1+\beta} - \bar{L}\kappa_1 - 1 - \frac{L_2}{1+\beta} & \text{for } \varepsilon > \varepsilon_C \end{cases}, \quad (\text{A1})$$

where  $\Gamma$  is given in (11). Thus,

$$\frac{dS}{d\tau_1} = \begin{cases} -\bar{L} + \bar{L}b\left(\frac{L_2^\gamma}{\gamma}\right)\Omega\Gamma^{\Omega-1}\bar{L}(1 - \lambda\tau_1) & \text{for } \varepsilon \leq \varepsilon_C \\ -\bar{L} + \bar{L}(1 - \lambda\tau_1) & \text{for } \varepsilon > \varepsilon_C \end{cases}. \quad (\text{A2})$$

The first-order condition (denoted by  $\mathbf{F}$ ) determining the optimal tax rate, and thereby also optimal liquidity hoarding, is  $\mathbf{F} = E(dS/d\tau_1) = 0$ ; it corresponds to (13) in the text. The implicit function theorem implies that

$$\frac{d\tau_1}{d\sigma_\varepsilon} = -\frac{\mathbf{F}_{\sigma_\varepsilon}}{\mathbf{F}_{\tau_1}}.$$

The second-order condition for maximization implies that  $\mathbf{F}_{\tau_1} < 0$  (it is easy to verify that  $F = 0$  and (10) implies that the second-order condition holds for all relevant tax rates). Now, note that  $dS/d\tau_1$  is a convex function of  $\varepsilon$ :

$$\frac{d^2(dS/d\tau_1)}{d\varepsilon^2} = \begin{cases} \bar{L}b\left(\frac{L_2^\gamma}{\gamma}\right)\Omega(\Omega - 1)(\Omega - 2)\bar{A}\Gamma^{\Omega-2}\bar{L}(1 - \lambda\tau_1) > 0 & \text{for } \varepsilon \leq \varepsilon_C \\ 0 & \text{for } \varepsilon > \varepsilon_C \end{cases}. \quad (\text{A3})$$

Thus, higher volatility of  $\varepsilon$  increases  $dS/d\tau_1$ , so that  $\mathbf{F}_{\sigma_\varepsilon} > 0$ . Consequently, given the sign of  $\mathbf{F}_{\tau_1}$ , we have  $d\tau_1/d\sigma_\varepsilon$ : an increase in aid volatility raises the optimal tax rate, partially offsetting the effect of such volatility by “self insurance,” in the form of hoarding liquidity in the first period. Equation (A3) also implies that curve  $E(MPG)$  in Figure 3 is weakly convex.

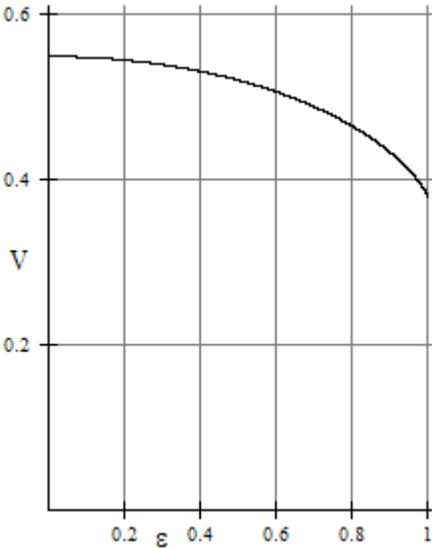
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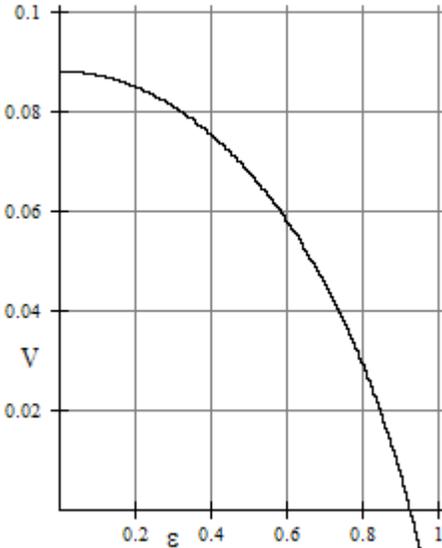
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Figure 1  
Aid Volatility and the Expected Social Surplus



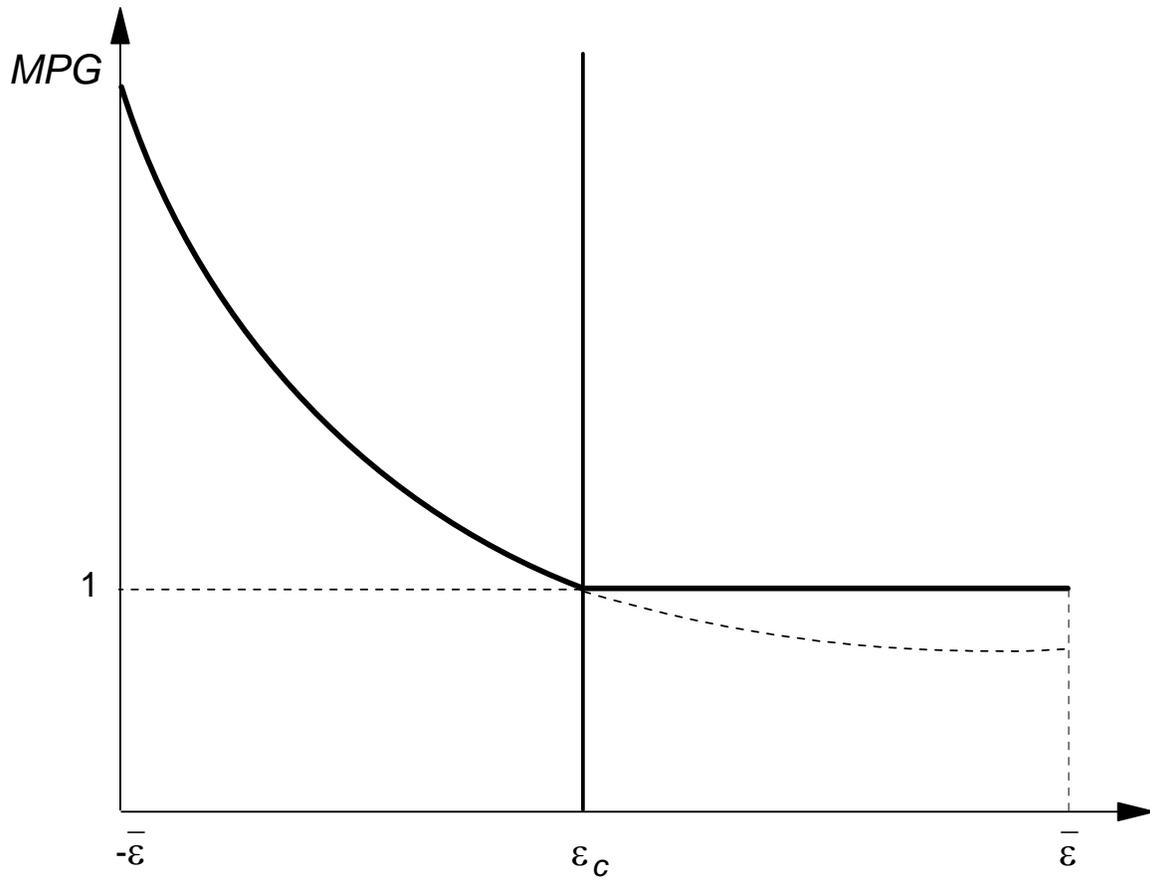
Panel A: high productivity ( $b = 0.45$ )



Panel B: low productivity ( $b = 0.4$ )

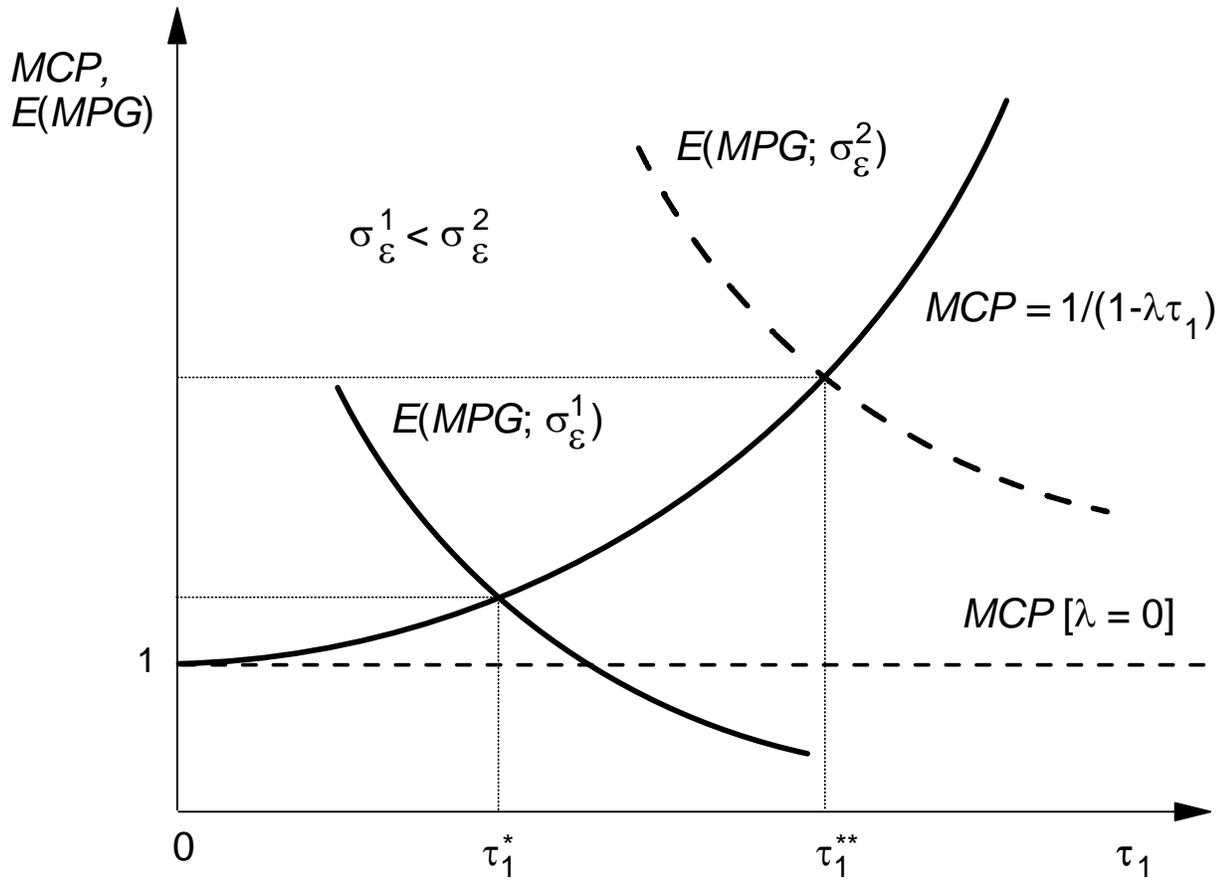
Note: The simulations assume that  $\alpha = 0.5, \gamma = 2/3, \bar{L} = 34, \bar{A} = 1, \beta = 0, \kappa_1 = 0$ .

Figure 2  
Determination of the Optimal Tax Rate



Note:  $MPG$  denotes the marginal productivity of public spending in period 2.

Figure 3  
Aid Volatility and the Optimal Tax Rate



Note:  $MCP$  stands for the marginal cost of public funds. The upward-sloping  $MCP$  corresponds to  $\lambda > 0$  and the flat  $MCP$  corresponds to  $\lambda = 0$ .