After the lockdown:

Using epidemiological and macroeconomic models to set out the adjustment to the aftermath of the covid-19 pandemic in Sub-Saharan Africa

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Authors

Christopher Adam, Mark Henstridge, and Stevan Lee[1]

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Abstract

The Covid-19 pandemic is ripping around most of the world, but not in Africa; at least, not yet. At the same time, the policy response is remarkably uniform: most of sub-Saharan Africa went into lockdown from the second week in March. What happens next for the pandemic across Africa is uncertain, but the March lockdowns are unlikely to have contained the epidemic by themselves.

What is clear is that the combination of domestic lockdowns and the spill-over from the global recession means immediate and severe hardship. This paper looks beyond the public health aspects of the pandemic to examine the medium-term macroeconomic adjustment challenge confronting domestic policymakers and international donors. We combine epidemiological and macroeconomic models to calibrate the scale of the combined shock to a representative low-income African economy and to show how alternative policy options for slowing transmission of Covid-19 impact on public revenue, and on GDP in the short run, and hence shape the path to recovery. Noting that the first lockdown, however costly, does not by itself eliminate the likelihood of a re-emergence of the epidemic, we then frame the agenda for key macroeconomic and public finance policies to sustain recovery, growth, and poverty reduction in sub-Saharan Africa.

The initial hit to consumption will be up to one third. All the public policy options are grim. International donor finance of US$40-50 billion, together with domestic reform to accelerate recovery, would make a significant difference to the outlook for poverty.

Keywords: COVID-19, macroeconomic adjustment, sub-Saharan Africa, development assistance, simulation models.

JEL Codes: E27, E61, J11, O11, O55

[1] Department of International Development, University of Oxford; Oxford Policy Management (Henstridge and Lee). Corresponding author: christopher.adam@qeh.ox.ac.uk. This is an expanded version of an article published in the *Oxford Review of Economic Policy* (volume 36 S(1)), DOI: 10.1093/oxrep/graa023 (Adam *et al*, 2020b), and provides more detail on the models we used, and the insights that they offer. We are grateful to David Vines, Stephanie Allen and Alex Money for comments on the Oxford Review of Economic Policy version of the paper. The Covid-19 pandemic is fast-moving and incomplete: the analysis in this paper is based on data up to the end of May 2020.

1. Introduction

The Covid-19 pandemic is ripping around most of the world, but not in Africa; at least, not yet. Estimates to early June 2020 suggested that among one billion people there were well over 140,000 confirmed cases with about 3,500 deaths.[2] However, the public policy response is uniform: most of sub-Saharan Africa went into lockdown from the second week in March.

Lockdowns have been costly—in terms of stopping the economic activity that sustains livelihoods, and in terms of the hit to public finances from reduced revenue and increased spending on health and social protection. Equally clear is that the legacy of lockdowns and the effects of the unfolding global recession mean severe hardship for an extended period. Low-income countries in Africa are suffering from a domestic supply shock and an international demand shock, which together put at risk the economic and developmental gains posted by African countries over the last 20 years.[3]

Managing recovery from these impacts will present an immense challenge for public policy. In this paper, we look through the pandemic and the short-run immediate hit to focus on the medium-term policy agenda in response to this challenge—in particular for national fiscal policy and for official development assistance (ODA).

The scale of the policy challenge will depend on three things. First, how lockdowns are released and economies re-started, especially noting that the first lockdown, however costly, does not eliminate the likelihood of a re-emergence of the epidemic. Second, the domestic policy choices between balancing current consumption and sustaining public and private investment for future recovery; and third, the response of the international community, when donors face their own domestic pressures from recession and tighter public finances.

Governments in Africa cannot 'do whatever it takes'. The economic reach of the state is constrained by limited revenue mobilization, while low savings rates and thin financial markets limit potential domestic sovereign borrowing. With fiscal positions already highly constrained in many countries in the region, restoring fiscal balance on domestic measures alone risks prolonging a slow recovery in output and consumption.

There will be a sharply increased need for external finance, but with access to market-based sovereign borrowing extremely limited, the focus must be on official financing. Many countries have accessed emergency International monetary Fund (IMF) finance, but this can be catalytic at best: what is required is a significant short-term increase in ODA—from governments, multilateral development banks, and development finance institutions—to alleviate exceptionally difficult public finance and policy trade-offs and accelerate recovery.

Section 2 sets out the context for policy choices, highlighting the uncertainties faced as lockdowns are eased, and an international recession looms. While countries in the region differ very substantially—in terms of income levels, the structure of production, sources of government revenue and borrowing capacity—the uniformity of initial national public health

[2] Based on WHO-Africa daily situation reports for sub-Saharan Africa.

[3] See Sumner *et al*. (2020).

responses to the crisis and the scale of the global recession means that the policy challenges facing many low-income sub-Saharan African countries are very similar.

Sections 3 and 4 use epidemiological and macroeconomic models to quantify the public health and macroeconomic dimensions of the pandemic and to frame possible policy options for releasing lockdowns and the domestic policy choices for a recovery.

In Section 3 we use a standard epidemiological model combined with a simple economic model to estimate the first-round impact of the disease and the public health measures designed to control it, concluding that the lockdown enormously costly and that there is an urgent need to find much more cost-effective alternative options for slowing transmission of Covid-19 as it re-emerges. The best options will be different in different country settings.

In Section 4 we use a dynamic general equilibrium macroeconomic model to examine medium-term paths for economic recovery in more detail and in particular to examine the role that external official financing can play in supporting politically and technically feasible adjustment and recovery strategies.

To make this analysis concrete, we have calibrated both models to data from Uganda. While there is obviously a substantial heterogeneity of economic and fiscal structures across the continent – most notably between the large oil exporting nations such as Nigeria and Angola and others – the insights from the Uganda case do generalize. In part this is because the fiscal position in Uganda is largely representative of other low-income sub-Saharan African economies (see Table 1), but it also reflects the commonality across countries of the disruption emanating from the contraction in global economic activity. Given the enormous uncertainties involved, however, these simulations do not represent forecasts, either for Uganda or more generally, but they do frame key macroeconomic policy issues for governments, and for donors, to meet the challenge of recovery and poverty reduction post-pandemic.

This paper speaks as much to the imperative for domestic reform as it does to international donors: Reform will be key to accelerating recovery. In addition, an increase in net ODA flows to low-income African countries of the order of US$40–50 billion may be required to support adjustment over the next few of years. This is substantial—equivalent to double current flows—but the case for increased ODA in these exceptional times rests as much on the national interests of donors as it does on traditional developmental considerations, and on collective international action: the benefits of conquering the Covid-19 pandemic globally, so that it does not rip through the OECD again, accrue as much to donor nations as to aid recipients.

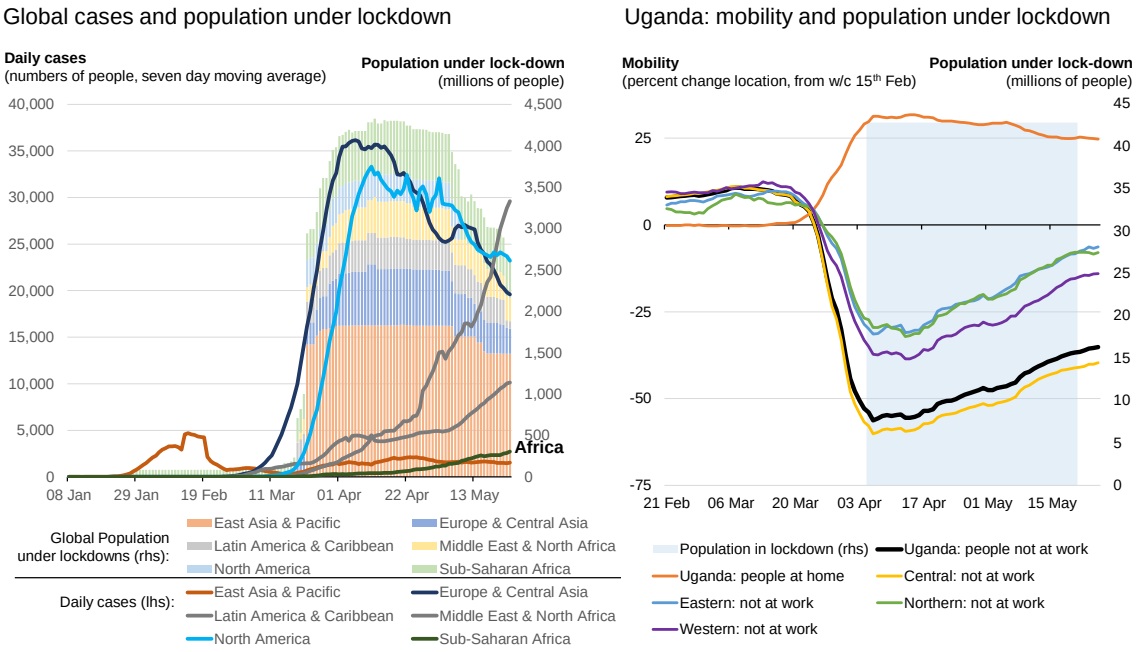
2. Macroeconomics and policy choices at the outbreak of the Covid-19 pandemic

Most countries across sub-Saharan Africa have relatively few cases of or deaths from Covid-19, yet have implemented wide-ranging and often mandatory measures

(Hale et al.,2020) (Figure 1, left-hand panel).[4] Taking decisive measures early in the path of the pandemic might have contributed to low rates of infection and death, but what happens next for the pandemic across Africa is uncertain.[5]

The purpose of a lockdown is to limit transmission of the virus by stopping mixing and social contact. The right-hand panel in Figure 1 illustrates the extent to which people did not go to work and stayed at home during the lockdown in Uganda.[6] In the absence of broad population-based testing for infection or for anti-bodies, the effectiveness of these strategies for public health is unclear and will only be revealed in data on 'excess' death rates. Few low-income countries compile regular data on causes of deaths to allow for such an analysis.[7]

Figure 1



There is a risk that the lockdowns only postpone transmission of a highly infectious virus, rather than prevent it, and if the virus does spread with the virulence seen elsewhere, the prospects are grim. Acute care capacity in public health systems across the continent is

[4] The eight elements of lockdown tracked by the data on lockdowns by the team at the Blavatnik School of Government are: (i) schools closing; (ii) work-places closing; (iii) public events cancelled; (iv) restrictions on gatherings; (v) public transport closed; (vi) requirements to stay at home; (vii) limits on domestic travel; (viii) limits on international travel.

[5] In May 2020 the World Health Organization estimates 83,000–190,000 deaths across sub-Saharan Africa from an uncontained epidemic (WHO, 2020). There are, however, still unresolved debates around the effects of youthful demographics, lower population densities, and the generally warmer climate on susceptibility and transmission, as well as about the reliability of epidemiological data, especially against the background of generally higher morbidity.

[6] The data on mobility show time spent at home or work relative to the average for the (baseline) first week of data. Source: Google: https://www.google.com/covid19/mobility/

[7] FT reporting (https://on.ft.com/2xMKWR9) and Office for National Statistics data/analysis in the UK.

severely limited; keeping a physical distance is hard in urban and peri-urban areas where the density of habitation is high and economic activity occurs on an intimate scale; and soap and clean-enough water for hand-washing is scarce.[8]

However, at the time of writing, the lockdowns are being eased. The next challenge is putting domestic economic activity back together while still limiting the transmission of the virus. This entails balancing the human needs to make a living with the human costs of a pandemic. This policy challenge is framed in section 3.

The economic and social consequences of lockdowns are clear. Domestic economic activity stops: people can't work, production drops, jobs are lost, supply chains unravel, welfare and livelihoods deteriorate, and poverty and vulnerability to risk increases. This domestic supply shock is augmented by an international demand shock, with a severe impact on the small open economies in sub-Saharan Africa. Even if the drop in domestic output is modest, the first-order economic effects of the pandemic will be felt through a dramatic contraction in countries' import capacity. Declines in primary commodity prices (perhaps with the exception of gold) and the loss of non-traditional exports, including tourism and horticulture, will depress the income terms of trade. At the same time, reductions in remittance flows, the reduction or reversal of foreign direct investment (FDI) and private capital flows will further tighten external constraints, forcing more adjustment on to domestic absorption.

Countries across Africa are confronting this challenge when macroeconomic conditions are already difficult. Although there are important exceptions, most notably in East Africa and also Senegal and Côte d'Ivoire in the west, most countries have seen their growth rates slow and current account deficits widen since the end of the commodity super-cycle in 2015.[9] A corollary of this was a weakening of fiscal balances and a reversal in recent trends in public debt. On the back of widespread debt relief, low real interest rates, and rapid export-led growth, public debt declined from around 100 per cent of GDP in the mid-1990s to 40 per cent in 2013. By 2018, this was back towards 60 per cent of GDP, accompanied by increased numbers of countries facing external debt servicing problems. By late 2019, 16 of the 36 low-income countries in sub-Saharan Africa were classified by the World Bank and IMF as being in debt distress or at high risk of debt distress, and others are close to prudential external debt limits.[10] With still-limited domestic tax capacity and thin domestic asset markets, fiscal policy options are limited.

2.1 Short-run fiscal impacts and fiscal policy responses

Table 1 summarizes the impact on fiscal space of the pandemic and the lockdown for a selection of countries across sub-Saharan Africa. This is an eclectic array of countries, and across the continent there is variety in a range of economic characteristics, such as the scale of tourism or airfreighted exports, which will be hit by the aftermath of the pandemic. But there are common themes on fiscal space for the countries shown in Table 1, comparable to other sub-Saharan African low-income countries. The mean of the baseline

[8] Two-thirds of people in sub-Saharan Africa do not have access to facilities to wash their hands with soap (World Development Indicators).

[9] IMF (2019*a*).

[10] IMF (2019*b*).

revenue and grants before the hit from the pandemic and the lockdown is equivalent to 16 per cent of GDP and the mean for baseline spending is 22 per cent of GDP.[11] In calibrating our models to Uganda, we capture reasonably representative features of other low-income countries.

Table 1

IMF estimates of fiscal impact of Covid-19 and lockdowns, and IMF support, to selected countries to mid-May 2020

	Ethiopia	Ghana	Kenya	Nigeria	Sierra Leone[2/]	South Africa	Tanzania[3/]	Uganda	Mean[4/]
	(*as a percentage of GDP in current fiscal years, except as otherwise indicated*)								
Baseline revenue and grants	12.5	13.5	18.6	4.9	18.9	29.1	16.2	13.6	*15.9*
Tax revenue	10.1	11.9	13.9	3.5	12.6	28.7	10.4	11.6	*12.8*
Direct taxes: income, profits, capital gains	4.3	5.8	7.1	0.9	5.1	17.5	3.6	4.2	*6.1*
Indirect taxes: sales tax, VAT, Excise duty	2.9	4.5	4.2	0.6	4.8	10.2	5.9	6.3	*4.9*
Taxes on international trade	2.9	1.5	2.6	1.9	2.7	1.0	0.9	1.3	*1.9*
Nontax revenue	1.5	1.3	4.3	1.5	2.3	0.4	5.0	1.3	*2.2*
Grants	0.9	0.4	0.4	0.1	4.0	0.0	0.8	0.6	*0.9*
Changes in revenue and grants	*-0.2*	*-2.2*	*-1.3*	*-3.6*	…	…	…	*-2.8*	*-2.0*
Baseline spending	15.0	23.0	26.3	11.7	21.5	35.4	20.0	20.6	*21.7*
Current spending	8.6	20.8	20.2	10.6	14.9	30.9	11.4	11.3	*16.1*
Capital spending[5/]	6.5	2.2	6.1	1.1	6.6	4.5	8.7	9.3	*5.6*
Changes in spending	*1.3*	*-0.3*	*1.0*	*-1.4*	…	…	…	*1.7*	*0.5*
Estimated overall change in fiscal position[6/]	**-1.5**	**-1.9**	**-2.3**	**-2.2**	**-0.2**	**-0.2**	**0.0**	**-4.5**	**-2.5**
Memorandum items :									
Post-shock projection of GDP growth (percent)	3.7	1.5	0.8	-3.6	…		…	3.7	*1.2*
Change in GDP growth projection (percentage points)	-2.4	-4.3	-5.0	-5.9	…		…		
Overall change in fiscal position (US$m)[1/]	-1,265	-1,246	-2,013	-8,740	-7.5	-737	0.0	-1,236	-1,153.5 [7/]
Approximate nominal depreciation in 2020	3%	1%	6%	7%	23%	24%	1%	3%	9%
Estimated financing gap (US$m)	-1,667	-1,377	-2,145	14,100	…		…	-1,319	
Official international reserves (US$ billion)	3.1	5.3	8.9	36.7	0.6	51.5	5.8	2.5	4.4
Public debt (% GDP)[8/, 9/]	56.7	68.7	64.7	34.8	66.6	65.2	39.4	45.7	*55.2*
IMF financing in 2020 (US$m.)	423	1,000	739	3,400.0	21	0	0	492	663 [7/]

Notes :

1/ Estimated using 2018 current GDP from World Development Indicators (WDI)

2/ Sierra Leone fiscal data from 2019 Article IV Staff Report

3/ The Tanzanian authorities have declined permission to publish the latest Article IV Staff Report; fiscal data compiled from FSSA Staff Report and WDI

4/ These are simple means, excluding South Africa (RSA) and Nigeria for data in US$, and excluding Tanzania where there is no IMF estimate of the fiscal impact of the pandemic

5/ In the case of Ghana, capital expenditure is proxied by the line 'net acquisition of non-financial assets' in the most recent IMF staff report

6/ The estimated overall change in fiscal position for Sierra Leone, South Africa, and Tanzania is taken from Elgin et al

7/ The mean for the overall change in fiscal position and IMF financing excludes South Africa and Nigeria for having different orders of magnitude numbers, and Tanzania for no data on fiscal impact

8/ The threshold for a "high" risk level of debt in the IMF Debt Sustainability Analysis (DSA) is 70% of GDP. South Africa is current projected to go above that threshold in 2022

9/ The ratio for Sierra Leone is against non-iron ore GDP, not total GDP, but for 2020 these two denominators are much the same.

Sources :

Data compiled from latest IMF Staff Reports and tabulation of policy responses to Covid-19: www.imf.org

World Development Indicators: https://databank.worldbank.org/source/world-development-indicators

Elgin et al: http://web.boun.edu.tr/elgin/CESI_5.xlsx

The estimates made in IMF Staff Reports supporting the use of Fund resources in recent months show a mean hit to revenue of 2.0 per cent of GDP and an increase in spending of 0.5 per cent GDP: a fiscal deterioration of 2.5 per cent GDP; averaging over US$1.1 billion each for Ethiopia, Ghana, Kenya, and Uganda. Those same countries have accessed US$663m of IMF financing in the last few months.

[11] This mean includes Nigeria and South Africa as outliers. Although tax capacity has improved across Africa since the 1990s it remains low compared with other regions of the world: the revenue-to-GDP ratio for all emerging markets is around 24 per cent.

These estimates of short-term fiscal degradation may be on the low side. The IMF sharply reduced its growth forecasts for Africa in advance of its Spring Meetings in April 2020,[12] but may have been too cautious. Sandefur and Subramanian (2020) suggest the contraction in GDP may be twice as large as the Fund is projecting. If they are correct, then fiscal positions across low-income countries in sub-Saharan Africa will deteriorate by more than is shown in the IMF Staff Reports.

2.2 Monetary and exchange rate options

The simultaneous real shocks to the supply-side and the demand-side of the economy will entail some combination of real exchange rate depreciation and a squeeze on absorption. While managing this adjustment will fall primarily on real or fiscal policy measures, there will be an important role for monetary and exchange rate policy. Depreciation is unlikely to trigger a rapid export supply response—in a global shock few individual countries can export their way out—but will be important in supporting the demand switch from imports towards domestic production in a manner that eases some of the pressure on internal devaluation.

As Table 1 shows, nominal exchange rates have already started to absorb some of the pressure of adjustment. As we see in section 4, however, exchange rate depreciation will add to fiscal pressures where external debt service requirements are high (and where the tax base is predominantly non-traded).

The primary challenges facing the monetary authorities in the short run, however, are to support the banking system in the provision of domestic liquidity, to provide working capital in the formal economy and for domestic agriculture, and to support the balance sheets of the banking system during the severe phase of lockdown and recession. Central banks, particularly those where inflation is well-anchored, have already loosened monetary policy by cutting rates, reducing reserve requirements on banks, and exercising a degree of regulatory forbearance. The challenge will be to calibrate the move towards tightening when demand recovers, especially if this occurs more rapidly than supply.[13]

3. From lockdown to recovery: epidemiology, public health and first-round effects

In this and the next section we simulate the macroeconomic effects of the global Covid-19 pandemic and public policy responses for low-income African countries. We proceed in two steps. In this section wet focus on the cost-effectiveness of alternative public health strategies for reducing the spread of the disease as lockdowns get released. This analysis is

[12] IMF *World Economic Outlook* (January 2020 and April 2020). Projected constant-price GDP growth for sub-Saharan Africa for 2020 was adjusted from 3.5 per cent (January forecast) to –1.6 per cent (April forecast).

[13] This repressed inflation problem may, however, be less severe in low-income countries where governments have been unable to provide the large-scale income support scheme provided in advanced economies.

based on a standard 'susceptible-exposed-infectious-recovered/dead (SEIRD)' model for viral outbreaks augmented with a set of basic economic relations describing the first-round implications for GDP and public finances (Lee, 2020).

In Section 4, we integrate these insights with a dynamic macroeconomic simulation model that combines the effects of the domestic lockdown with the spill-over effects from the global recession. This allows us to examine the potential macroeconomic trajectory of this combined economic shock and provides a basis for considering alternative mitigation and adjustment strategies designed to bring the economy back to its pre-Covid-19 trend over the medium time.

Both models are calibrated to an initial pre-Covid-19 situation based on the national accounts and public finance data from Uganda, a representative small, open, low-income country.[14] Table 2 summarizes the key elements of the initial economic calibration, along with the key epidemiological parameters of the SEIRD model. While the core economic and demographic calibration is well-grounded in high-quality data, our characterization of the epidemiological and macroeconomic shocks is necessarily more speculative.

3.1 First-round effects

The first round economic and fiscal effects of the epidemic and the public health measures imposed to control it are estimated by modelling their impacts on the labour supply, on output and on revenues, with calibration based on Uganda. This requires an epidemiological model that breaks the population into three groups. The SEIRD model from Lee (2020) assumes an initial infection rate $R_0 = 2.4$ and mortality which might generate 173,000 deaths if left completely unchecked. It breaks the population into two age-groups, those over 70 years and those under. Over-70s are not part of the labour supply, in the model, and have much higher healthcare needs and higher expected mortality (Monnery, 2020; Verity *et al.,* 2020), so they are a distinct group for disease impact. The under 70s—which includes the labour force—are split between the agricultural and non-agricultural economy. This is done because the public health aspects impact each part of the workforce differentially. Also, the average labour productivity is significantly lower in agriculture than in the non-agricultural sector[15], and the non-agricultural sector generates a lot more public revenue than the agricultural sector.

[14] An important aspect of the economic calibration is the historically high rate of public infrastructure investment. While this reflects the specific nature of Government of Uganda's current structural transformation agenda, many other governments across Africa have recently increased their public investment to historically high levels.

[15] Mugume and Anguyo (2019) estimate the share of labour in value added at 71 per cent. Output per worker is four times higher in non-agriculture, at the top end of the estimates by Gollin *et al.* (2014).

Table 2

Uganda Model: Stylized Baseline Model Calibration (FY 2019/20)

1. Economic Calibration

Output	
Tradable (%)	41.4%
Non-Tradable (%)	58.9%
Aggregate Demand (as share of GDP)	
Consumption	
Private	71.2%
Public	5.3%
Investment[1/]	
Private	22.9%
Public	12.0%
Net exports	-11.4%

Balance of Payments (as share of GDP)	
Balance of trade deficit	11.4%
External Interest payment	2.8%
Current Account Deficit	14.2%
Financing	
Grants	1.7%
Remittances	8.5%
Net Debt	4.0%

Public Debt (as share of GDP)	
External[2/]	
Non-concessional	15%
Concessional	15%
Domestic[3/]	16%
Total	46%

Fiscal Accounts (as share of GDP)	
Revenue	16.8%
Direct taxes	8.9%
Indirect taxes[4/]	7.9%
Expenditure	19.8%
Recurrent	5.3%
Development	12.0%
Debt Service	2.5%
Balance (before financing)	-3.0%
Grants	1.7%
Debt financing[5/]	1.3%

Memorandum Items :

Data are based on 2019/20 projections reported in Uganda: 2019 Article IV Staff Report (IMF Country Report No. 19/125).
Adjustments and re-classifications have been made by authors to reflect model structure.
GDP per capita 2019/20 (proj) US$ 784 (Current US$).
GDP per capita 2018 US$2,038 (current US$, PPP adjusted).

Notes :

1/ Gross investment; depreciation of public and private capital estimated to be 5% per annum.
2/ Split between concessional and non-concessional is authors' estimate.
3/ Domestic debt assumed to be short-term (1 year) government paper.
4/ Indirect taxes include excise, trade taxes, domestic sales taxes/VAT as well as non-tax revenues.
5/ Debt financing is a combination of external and domestic borrowing which is pro-rated to outstanding stocks of debt in initial calibration.

2. Epidemiology

Population and Demography:	**Uganda**	**OECD**
Share of Population		
Over 70	2%	15%
Under 70	98%	85%
Age-specific mortality (baseline)		
Over 70	8.8%	7.9%
Under 70	1.3%	1.0%
Health Care		
ICU per million population	2	150
Cost of soft public health measures ($ per capita)	$2	
Infection Rate [R]		
Baseline	2.4	
with blanket lockdown	1.2	50%
with soft public health measures	1.6	33%
Combined (during lockdown)	0.8	

As noted in Figure 1, lockdown measures were widely and consistently applied from mid-March 2020 across a large number of countries. Lockdowns impose social distance between individuals to reduce the susceptible population over the period of the lockdown, and hence dampen rates of exposure and subsequent infection. For Uganda, these initial lockdown measures—the 'reflex response', which lasted for 7 weeks—disproportionately affects the non-agricultural workforce, removing half of all employees from work, compared to 15 per cent of the agricultural workforce (this is because the non-agricultural workforce is so much more vulnerable to infection).[16] The net effect of this reduction in the labour supply, given

[16] The first-round economic impact of both the disease and the public health measures stem from their impact on labour supply:

$$L = \sum_{i=1}^{p} l_i \left(S_i - D_i + (1 - \sigma_i)(E_i + I_i) + R_i\right)$$

where for each of the *p* population groups we assume a participation rate, l_i, applied to the population $S_i + E_i + I_i + R_i$, which excludes deaths, M_i , and is denuded by a proportion of infected people who are off sick, σ_i, and by D_i which is the share of the population temporarily removed from social and work-related circulation by lockdowns or other social distancing policies. Assuming capital stocks are

differential labour productivities, is a full-year equivalent reduction in output of 6.3 per cent compared to a no-pandemic baseline and a corresponding fall in public revenues of 1.7 per cent of GDP (equivalent to approximately 10 per cent of total revenues). Whilst reductive, the three population groups allow us to reflect that the lockdown measures affect the non-agricultural (more urban) workforce disproportionately and also that those economic sectors pay more tax than agriculture. So lockdowns hit GDP hard and public revenue even harder.

Note that at this stage, we are not including the general equilibrium effects of the labour supply shock OR the impact of the international recession: see section 4 for this.

The model does look at the impact of infection and death on output, but this is small compared to the impacts of lockdowns.

Without further public action or external events such as the rapid discovery and distribution of a vaccine or effective treatment for COVID 19, this lockdown delays but does not reduce infections and deaths if the model is projected long enough to allow for the re-emergence of the epidemic, which takes a matter of months.

Vaccines and treatments are still theoretical possibilities but there are options for controlling the epidemic for prolonged periods of which repeated lockdowns is one. Non-pharmaceutical, non-lockdown public health measures could be far more cost effective. A combination of follow-on public health measures including public health campaigns on hand-washing and masks, localised movement limitations and limits on particular types of economic activity could reduce the force of transmission by as much as 50 percent. This could be enough to postpone the re-emergence of the epidemic for a full year, at an additional output cost of approximately 1 percent of GDP, compared to the 7-week lockdown's 6.3% of GDP, making at about 20 times more cost effective than a repeated lockdown.

Targeting the over 70s could be very cost effective. In a country with Uganda-like demographics, this is a small group with potentially very high mortality so protecting this group is not very costly but does not save as many lives as in a more aged population.

Measures will not work in the same way in every country. The epidemic returns around 3 months after lockdown if it is based on a reproductive rate, R_0, of 2.4, based on Italian conditions. The R_0 may be lower in Uganda because it is more rural, which would mean the non-pharmaceutical, non-lockdown public health measures would last for longer. Moderate public health measures might work very well in rural areas and hardly work at all in very dense urban areas. We did not have special data on this and so the epidemiology here is not sophisticated enough to recommend a detailed course of action for a particular country. But the orders of magnitude indicate that lockdowns alone are a very costly way of delaying the emergence of the epidemic by roughly the amount of time the lockdown lasts.

Integrating the SEIRD model with the macroeconomic data for Uganda illustrates the short-run impact of the pandemic and associated policy responses. The lockdowns will need to be followed-up with other public health measures. But it is clear from the estimation of the full

fixed in the short run, changes in labour inputs fully determine aggregate output given the marginal product of labour.

impacts of the first lockdown combined with the international recession, to which we now turn, that a second lockdown would be almost impossibly costly. To avoid the unwelcome trade-off between very severe mortality and deep and lasting economic harm, the priority has to be on developing public health measure that can contain the epidemic without a second lockdown.

4. The macroeconomics of the pandemic in the medium term

In this section we integrate these short-run direct effects of lockdown with the associated knock-on effects and the spill-over from the global economic slowdown into a medium-term dynamic macroeconomic model. The model, which is described in detail Appendix I, is a simple modification of the 'debt-investment-growth' (DIG) model developed by the IMF to examine public investment and debt sustainability (see Zanna *et al*., 2019).

4.1 Model structure

The heart of the model is a Salter–Swan dependent economy core, which describes a two-sector, two-household, small open economy facing exogenously determined global terms of trade. Firms produce both tradable and non-tradable goods and services under constant returns to private inputs but increasing returns in the presence of public infrastructure capital. There is an underlying exogenous trend rate of *per capita* growth and factor markets are competitive with full employment (real wages are fully flexible and will adjust to remove open unemployment). Public capital needs to be maintained through operations and maintenance (O&M), the retrenchment of which adversely affects private productivity.

On the demand side, there are two groups of private households. Approximately three-quarters of households depend entirely on net-of-tax labour income, remittances from abroad, and transfers from government. These households have no access to asset markets through which to smooth consumption in the face of income shocks.[17] The second group consists of richer households who sell their labour primarily to the skill-intensive tradable goods sector and who own and maintain the private capital in the economy. They have access to asset markets, so are able to smooth consumption inter-temporally. Investment is driven by a simple 'Tobin's q' mechanism, where expected returns to private capital are a function of the provision of effective public capital services. Investment responses are rendered sluggish as a result of adjustment costs to changing the capital stock. Both household groups have the same preferences and consume a basket of tradable goods (manufactures and imported food) and non-tradables (domestically produced basic foods plus services).

The government invests in public infrastructure capital and spends on social protection, productive expenditures (O&M), and debt service. Expenditure is financed by a mixture of taxes (on consumption, wages, and profits) and debt (domestic and external) plus an exogenous volume of concessional lending and grants. The model can also consider a case

[17] Some portion of this labour income is rental income from self-employment in small-holder traditional agriculture.

where the government budget is supported by natural resource revenue.[18] All taxes are distortionary and are characterized by incomplete collection—some combination of the prevalence of exemptions and/or corruption in tax collection—so that relatively high marginal tax rates co-exist with low revenue mobilization.

Fiscal policy is conducted through a set of simple expenditure and tax-and-borrowing rules, conditional on the flow of external development assistance (both grants and concessional lending which, we assume, are determined by donors and drawn down to the maximum available) and revenues from natural resources, if they exist. The government's domestic debt position is initially sustainable but close to its desirable target level which, in turn, is reasonably close to its prudent maximum level. Thus, while it may choose to increase public indebtedness in response to a shock in the short run, the economy is anchored by a target long-run debt-to-GDP target equivalent to that in the initial equilibrium, so that debt accumulation is unwound over time.

When the economy is hit by a shock, which could external, through the current account or capital account of the balance of payments, or internal, as a result of disruption to supply, or some combination of both, adjustment will occur on a number of dimensions. First, the real exchange rate and real interest rate adjust to ensure that domestic absorption is consistent with simultaneous equilibrium in the tradable goods and services market (i.e. external balance) and the market for non-tradable goods and services (internal balance), given exogenous supplies of labour and external debt and remittance flows and the world terms of trade. Second, the real wage adjusts to clear the labour market.[19] Finally, the fiscal balance is satisfied by adjustments in taxation and short-term domestic borrowing, conditional on exogenously determined levels of public investment, recurrent spending and external official flows.

The model does not, however, have a monetary dimension, so while it allows for real frictions in the economy, there are no nominal rigidities. It is thus silent on policy issues around inflation, liquidity management, and financial sector stability. Likewise, the model is silent on questions of nominal exchange rate policy: the implicit assumption is that the nominal exchange rate is sufficiently flexible to facilitate the necessary real exchange rate adjustment. In reality, many countries operate heavily managed exchange rate regimes. In terms of our model, real exchange rate adjustment requires greater domestic price flexibility.

[18] The natural resource sector in this model, were it to exist, is treated as an off-shore foreign-owned enclave sector where the only linkage to the domestic economy is via a revenue-sharing contract that sees government receive a fraction of the current value of production: in principle this can be taken as current revenue or managed through a sovereign wealth fund. While this model can simulate a post-pandemic policy challenge for such an economy, we don't have space here, and the fiscal policy reform challenges would be similar to the Uganda-calibrated architype we analyse in this paper.

[19] Labour market clearing is a strong assumption, especially if one element of the lock down is the complete closure of individual sector. Outside the small government-dominated formal sector, the labour market in Uganda and in other low-income countries is characterised by significant downward wage flexibility so that layoffs in sub-sectors are absorbed elsewhere, primarily in agriculture and the informal service sector of the economy. In our simulations we reflect the associated inefficiencies generated by skills mis-matching or increased under-employment that results from this reallocation by assuming a deterioration in total factor productivity during the lockdown and its aftermath.

4.2 Calibrating the Covid-19 shock

Building on the short-run analysis in Section 3, we define the Covid-19 shock in terms of six key elements. On the domestic side, the economy experiences: (i) a temporary withdrawal of labour across the economy, primarily in the tradable production and services sector; (ii) a temporary reduction in total factor productivity in both sectors, reflecting the economic consequences of social distancing and other public health measures that disrupt the availability of intermediate inputs of goods and services; and (iii) the temporary loss of private capital—a hysteresis effect—as shops and factories closed during lockdown do not re-open when the lockdown ends.[20]

The domestic shock also includes some increase in public healthcare and social protection spending. In practice, much of the 'hardware' of the healthcare response—such as ventilators or personal protective equipment (PPE)—will be externally funded. The elements that fall directly on the government balance sheet consist of increased social protection spending and related public health measures which are defined as an increase in spending on recurrent transfers to the private sector.

On the external side, the effects of the global lockdown are transmitted as an external demand shock through three further channels: (iv) the contraction in global economic demand via a decline in the income terms of trade, reflecting both the decline in commodity prices and the contraction in other export sectors such as tourism; (v) a substantial fall in remittance flows from migrants and the diaspora resident in developed countries; and (vi) a 'sudden-stop' in net FDI and portfolio private capital inflows as international investors retreat to safe-haven locations. Official financing flows, both grants and concessional loans, are treated as policy choices by donors (see below).

We organize the simulation runs in two steps. First, we examine how local and global responses to the Covid-19 pandemic shape medium-term economic and public finance prospects, while holding both the fiscal policy stance and any purposive donor response at their pre-shock configuration. This generates a measure of the latent fiscal pressures generated by the pandemic, *ceteris paribus*. In the second stage we consider a set of domestic and international policy responses designed to mitigate the adverse short- to medium-term effects of the shock. In doing so we focus primarily on the paths for output and aggregate demand, as well as the paths for the real exchange rate, the fiscal balance, taxation, and public debt. The simulation runs are described in detail in Table 3 and the summary results in Table 4.

4.3 Lockdown and global recession

Taken in isolation, and consistent with the short-term results presented earlier in this section, the short-term labour supply shock has a relatively modest impact on the economy and is short-lived (Table 4, panel A). Output contracts in both sectors, by around 6 per cent in aggregate over the first year, and consumption shrinks by a similar amount. The overall

[20] This may be because social distancing restrictions make it impossible to operate at minimum efficient scale, or because whole sub-sectors, such as international tourism, are eliminated over the medium term.

fiscal hit from this aspect of the lockdown is mild—the incipient fiscal gap increases by around 1.8 per cent of initial GDP.[21]

Table 3

Simulation experiments

Simulation	Notes
Domestic Lockdown	Two-quarter contraction in effect labour supply (contraction in skilled labour supply twice that of unskilled); productivity disruption in both sectors, persists for three quarters before returning to trend over next six quarters; 4.5% loss of capital stock in both sectors. Social protection and other recurrent health expenditures increased by 1% per annum over four quarters.
Lockdown with External Spillover	Domestic Lockdown with: (i) contraction in world prices of exports (initial negative 25% shock in first two quarters, recovering to tend over following two years); (ii) remittances fall by 25% from second to fourth quarter, recovering to trend after 10 quarters; (iii) net private capital inflows reverse over first two quarters (gross inflows halt and amortization continues, equivalent to 3% of initial GDP over first two quarters);
Mitigation from Domestic Resources	Public investment expenditure reduced by 67% over first two quarters, recovering to tend over following two years; productive O&M expenditures reduced by 25% from trend; increased domestic borrowing.
Enhanced Net ODA support	Public investment reduced by 16% and O&M expenditures ring-fenced; public health expenditure increased; short-term domestic borrowing reduced; net ODA inflows calibrated to keep required domestic tax requirement below 3% of initial GDP. Net ODA balanced between concessional debt and grants.
Net ODA support with domestic fiscal reforms	As simulation D with domestic fiscal reforms restoring O&M to efficient levels and reduction in tax leakages by 10%

But this does not fully reflect the disruptive nature of a lockdown. Panel B introduces the additional effects of the lockdown (the temporary slowdown in productivity in both sectors, the associated loss of private capital in both sectors;[22] and a 6-month increase of 1 per cent of GDP per quarter in recurrent spending on social protection initiatives. This dramatically changes the picture. Aggregate output and consumption fall by around 16 per cent in the first year and, crucially, remain below trend well beyond the end of the lockdown, reflecting both the persistent effects of the short-term loss of productivity and the impact of the hit on savings and investment (which both fall as households seek to protect current consumption). In the short run, the incomes of skilled households fall by less so that income distribution moves slightly in their favour. The contraction in the tax base combined with increased spending on social protection translates into substantially higher fiscal pressures, with the incipient fiscal deficit rising by over 5 per cent of initial GDP over the first year.

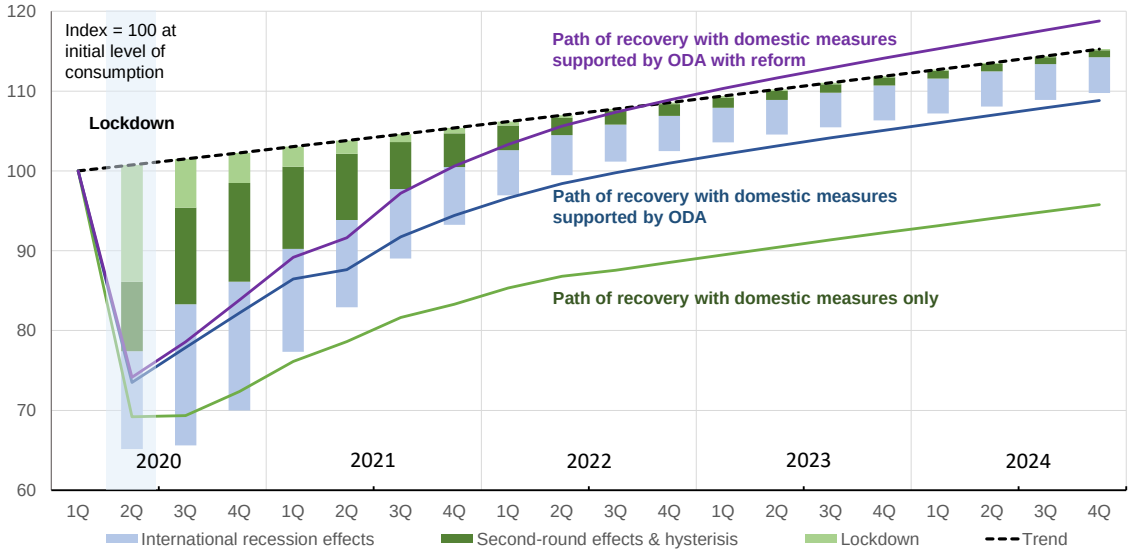
Finally, in panel C we introduce the external component shock which is transmitted both through the current account and the capital account. On the current account, the contraction in global aggregate demand is represented by an adverse movement in the country's income

[21] We refer to this as 'incipient' as it measures the adjustment required to bring about fiscal balance, *before* we consider purposive fiscal policy responses chosen by the authorities. By default, at this stage, the incipient fiscal gap is filled by a mixture of domestic borrowing and adjustment to tax rates on a pro-rated basis. Later, in section 4.4, we consider specific fiscal responses.

[22] There is no reliable evidence on which to calibrate either of these effects: here, *faute de mieux,* we assume that total factor productivity declines by 10 per cent relative to the pre-pandemic level for three quarters (effectively April–December 2020) before recovering in the first two quarters of 2020. The loss of private capital is assumed to be 5 per cent in the first quarter and a further 2.5 per cent in the second quarter of lockdown.

terms of trade as commodity prices fall, and markets such as tourism and hospitality atrophy.[23] On the capital account, the slowdown and potential reversal of net private capital inflows are combined with the precipitous decline in remittance flows and a 'sudden stop' in gross private capital inflows.[24]

Figure 2: Simulated paths for aggregate private consumption



Adding these external elements generates a picture that describes a set of economic and fiscal pressures that are potentially more severe than anything most of the low-income countries of sub-Saharan Africa have confronted outside of conflict (Figures 2 and 3).[25] Over the first two quarters following lockdown, while domestic output measured in constant prices falls by only slightly more than before, the effects of the global slowdown sharply constricts the current account and transmits a much larger recessionary impulse to aggregate demand. This reduction is spread between aggregate consumption, which contracts by about one-third in the first year (equivalent to 21 per cent of initial GDP) while the private investment falls by a further 5 percentage points of GDP as the private sector seeks to restore the balance between aggregate savings and investment in the face of the shrinkage in foreign savings. The contraction in investment is a central mechanism that extends the short-term crisis into the future. As we discuss below, the effect of public policy choices that undercut private returns to investment further attenuates the negative effects of the crisis.

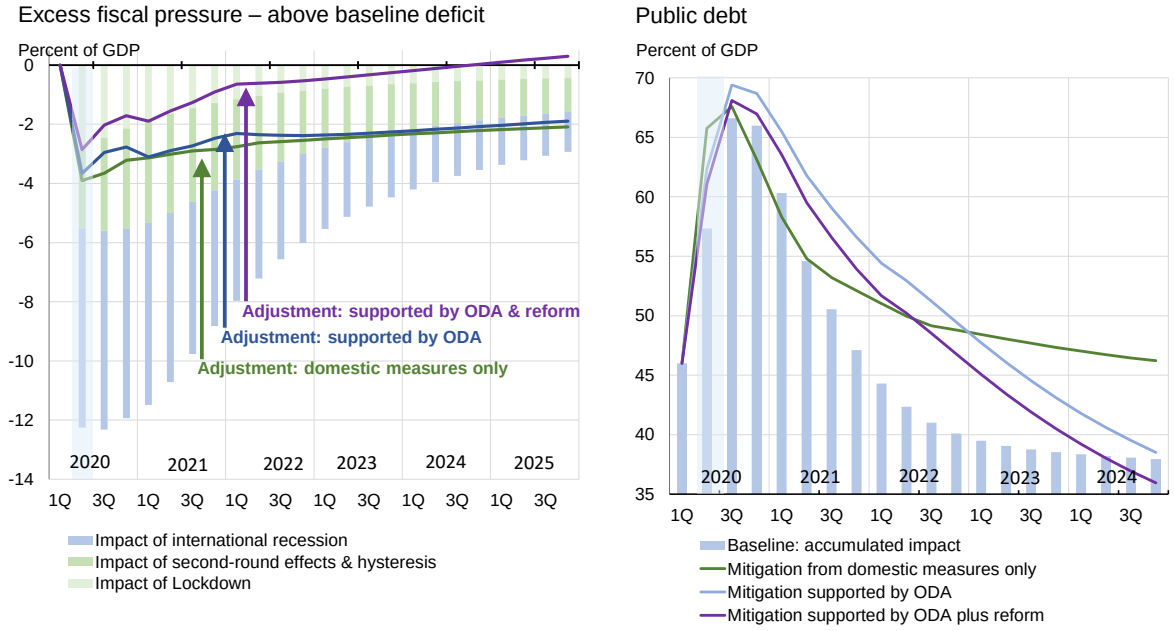
[23] It is less obvious what is likely to happen on the import side. Global import prices have not risen sharply (and have indeed fallen for net energy importers), but the drift towards protectionism in key sectors, reduced availability of trade financing, and the (temporary) disruption of global supply chains arguably put upward pressure on the shadow price of importables, exacerbating the deterioration in the terms of trade for developing countries. See Baldwin and Tomiura (2020).

[24] World Bank (2020) predicts remittances to fall by around 25 per cent in 2020, while Bolton *et al.* (2020) document the rapid fall in net flows of private capital to emerging and developing countries.

[25] Note that in the panel of Figure 3 showing fiscal adjustment, it appears that the adjustment which includes ODA is close to that without that international finance: the difference is in the accelerated path of recovery illustrated in Figure 2.

Accompanying the private-sector adjustment, an equally large fiscal adjustment is required in order to sustain government spending, including on debt service, in the face of a sharply reduced tax base. Absent any other fiscal mitigation methods, to which we return below, restoration of macroeconomic balance would require an enormous fiscal adjustment, around 11.5 per cent of initial GDP in the first year post-lockdown and a further 8 per cent in the second year. Even assuming an aggressive level of domestic borrowing in the short run this would, if financed from domestic taxation alone, require tax rates to rise by as much as 50–75 per cent above their pre-pandemic rates. Total public debt as a share of GDP would rise sharply, in part because of new domestic borrowing of around 9 percentage points of GDP in the first year, but also because of revaluation effects on external debt as a result of the real exchange rate depreciation required to restore external and internal balance.

Figure 3: Simulated paths for excess fiscal pressure and public debt



Domestic fiscal adjustments of these magnitudes are not only historically unprecedented but are both technically and politically infeasible in the circumstances of the pandemic. But this simulation provides a basis against which to assess a range of mitigation strategies, to which we now turn.

4.4 Domestic and International policy responses

As noted above, fiscal balance is restored through a combination of public expenditure cuts and increases in tax and domestic borrowing. In principle, and given a well-defined government objective function, the model can be used to solve for the 'optimal' fiscal policy response.[26] In this application, however, we find it more useful to take a 'non-optimizing' approach and use the model to explore the implications of a range of alternative feasible

[26] A standard approach would be to assume the government acts as a benevolent social planner setting its fiscal instruments to maximize private welfare as defined in equation A8 in Appendix I. We could, alternatively, define a specific government objective function.

fiscal policy rules that better reflect the actual constraints under which government in sub-Saharan Africa are currently operating.

On the assumption that statutory debt service obligations are met in full, governments can distribute expenditure cuts across new public investment spending; recurrent spending on maintenance and efficient operation that governs the sustained flow of services to the private sector from the already-installed public capital; and transfer payments to the private sector, were the latter will include social protection and other Covid-19 related payments. On the revenue side, government can adjust rates across a range of taxes, on consumption, labour and profits. Government may also seek to increase cost recovery through the levy of user fees for the use of public services (see equation A25 and A26 below). The balance of revenue mobilization across different taxes is governed by a set of 'tax targets' as defined in equations A29 – A34. There is, however, a lag between the announcement of tax changes and the mobilization of revenue; during this adjustment period, the residual fiscal gap is filled by short-term borrowing from the domestic bond market (see equation A35).[27]

4.5. Policy response experiments

Even with a relatively small number of policy instruments at the authorities' disposal, the range of potential policy packages is vast. In order to discipline our analysis, therefore, we first examine three cases that span the policy space and then explore some variations on these cases. In the first, we consider a case where the authorities do not have access to additional external aid financing and seek to make the required fiscal adjustment primarily though draconian public expenditure cuts, both recurrent and capital and short-term domestic borrowing in a manner that takes the pressure off the need for domestic tax financing. The second examines the extent to which enhanced external development finance can substitute for domestic adjustment, mitigating the depth of the domestic recession and accelerating the return to trend, and the third illustrates the potential gains to combining external finance with domestic fiscal reforms.

In the second stage we examine in more detail the effects of altering the balance between individual fiscal instruments.

Adjustment through domestic resources only

Panel D in Table 4 illustrates the case where the authorities seek to address the immediate fiscal imbalance through drastic cuts in public investment, from 12 to 4 per cent of initial GDP in the short run, rising back to the original level over the next 2 years, and at the same time reallocate a further 0.75 per cent of GDP in recurrent expenditure from O&M expenditures towards enhanced spending on social protection. As part of this strategy, residual deficit financing is tilted from taxation and revenue measures towards domestic borrowing.

Compared to the unmitigated shock, this programme evidently reduces the tax adjustments required to close the fiscal gap, but the costs of doing so are substantial. The contraction in

[27] Domestic borrowing is in terms of real (i.e. indexed) bonds either sold directly to households or intermediated through the banking system. Increased government borrowing drives up the domestic interest rate in the short run, directly crowding out private investment.

consumption is ameliorated in the short run—aggregate consumption falls by around 8 per cent less (because the tax-inclusive price of real consumption is lower) but it remains depressed for an extended period of time and beyond the end of the lockdown and its associated effects. This is a corollary of the impact of the cut in new public investment and the neglect of O&M of the existing public capital stock: hence a slight amelioration of the short-run costs of adjustment has come at the cost of a much more protracted recession.

It is tempting to hope that committed effective governments would avoid policy programmes of this character, and as we shall see below it may be possible to identify a slightly less damaging response. But it is difficult to construct alternative responses that do not confront the authorities with an unpalatable trade-off. Ring-fencing public investment—which is key to a sustained post-pandemic recovery—can only be achieved at the cost of either severe squeezes on private incomes and consumption in the short run, or by reductions in public health spending which raises the risks that lockdown measures gain even less purchase against the pandemic.

External concessional finance

The implication is clear: given the nature of the shock, any and all responses financed from domestic resources alone entail very substantial costs either in the short or medium term. Hence, only by accessing enhanced external resources are countries going to be able to navigate a path through the crisis without exposing public finances to excessive stress.

Panels E & F in Table 4 show how a substantial inflow of net ODA allows government to engineer such an adjustment path: one which protects infrastructure investment and public service delivery while maintaining tax and domestic debt financing within plausible limits in the short to medium term.

Panel E illustrates the case where the donor community provides sufficient funding (denoted G_t in equations A26 and A38) to allow the draconian cutbacks in public investment to be softened (the cut in this case is from 12 to 10 per cent of GDP), O&M expenditures to be ring-fenced, and social protection and public health spending to be held at elevated levels over the period of the pandemic. Some domestic fiscal adjustment is still required, but this is kept within feasible margins, while domestic debt increases by only 2.4 percentage points of initial GDP on a full-year basis (compared to around 5 percentage points in the previous case). Net ODA in this case is split equally between concessional debt and pure grants.[28]

[28] Concessional debt is assumed to be contracted on World Bank International Development Association (IDA) terms with a 40-year maturity after a 10-year grace period and interest rates at just under 2 per cent per annum.

Table 4

Summary Macroeconomic Effects of Lockdown and Responses

	Macroeconomic outturns at the end of:			
	Year 1	Year 2	Year 3	5 Year Average[6/]
[A] Domestic Lockdown (labour supply contraction only)				
Aggregate Output[1/]	-6.1%	-0.4%	-0.3%	-1.4%
Aggregate Consumption[1/]	-6.7%	-0.9%	-0.2%	-1.6%
Real exchange rate depreciation[2/]	1.7%	0.6%	0.3%	
Skilled Household share in income[/3]	0.1%	0.0%	0.0%	
Incipient excess fiscal pressure[4/]	1.8%	1.1%	0.8%	1.0%
Domestic Borrowing[4/]	1.6%	1.1%	0.8%	0.9%
Net ODA	0	0	0	
[B] Full Domestic Lockdown				
Aggregate Output	-16.4%	-4.5%	-1.9%	-5.1%
Aggregate Consumption	-17.3%	-6.0%	-1.8%	-5.4%
Real exchange rate depreciation	3.6%	4.0%	2.2%	
Skilled Household share in income	0.3%	-0.1%	-0.2%	
Incipient excess fiscal pressure	5.3%	3.9%	2.8%	3.2%
Domestic Borrowing	4.3%	3.7%	2.6%	2.8%
Net ODA	0	0	0	
[C] Lockdown with External Spillover				
Aggregate Output	-16.7%	-5.2%	-2.5%	-5.8%
Aggregate Consumption	-31.8%	-13.8%	-6.0%	-12.3%
Real exchange rate depreciation	29.5%	17.6%	14.7%	
Skilled Household share in income	-1.7%	-1.8%	-2.1%	
Incipient excess fiscal pressure	11.5%	8.0%	5.5%	6.5%
Domestic Borrowing	9.0%	6.3%	3.4%	4.2%
Net ODA	0	0	0	
[D] Mitigation from own resources				
Aggregate Output	-23.7%	-18.1%	-16.1%	-17.6%
Aggregate Consumption	-23.3%	-21.7%	-18.5%	-19.6%
Real exchange rate depreciation	23.4%	15.7%	14.1%	
Skilled Household share in income	-3.5%	-2.3%	-2.1%	
Incipient excess fiscal pressure	3.1%	2.8%	2.5%	2.6%
Domestic Borrowing	4.9%	5.5%	5.4%	5.2%
Net ODA	0	0	0	
[E] Net ODA resource inflow				
Aggregate Output	-17.0%	-6.4%	-3.8%	-6.7%
Aggregate Consumption	-22.0%	-10.9%	-7.9%	-10.8%
Real exchange rate depreciation	21.7%	15.7%	16.0%	
Skilled Household share in income	-3.2%	-2.2%	-2.0%	
Incipient excess fiscal pressure	3.1%	2.3%	2.4%	2.4%
Domestic Borrowing	2.4%	2.1%	2.0%	2.0%
Net ODA[5/]	8.0%	1.2%	0.7%	
[F] Net ODA resource inflow with domestic reforms				
Aggregate Output	-12.5%	-5.2%	1.2%	-2.1%
Aggregate Consumption	-18.0%	-4.1%	-0.3%	-3.6%
Real exchange rate depreciation	23.1%	16.5%	16.4%	
Skilled Household share in income	-3.4%	-2.4%	-2.2%	
Incipient excess fiscal pressure	1.9%	0.6%	0.5%	0.6%
Domestic Borrowing	2.6%	2.0%	1.7%	1.7%
Net ODA[5/]	8.0%	1.2%	0.7%	

Notes :

1/ Average annual percentage shortfall in constant-price output and aggregate real consumption relative to pre-pandemic level.

2/ Percentage depreciation in consumption real exchange rate (pc/pm).

3/ Percentage point gain in share of household income accruing to skilled households.

4/ Fiscal gap before purpose fiscal and domestic borrowing as percentage of pre-pandemic GDP.

5/ Increase in total net ODA inflow as percent of initial GDP (split equally between grants and loans secured on IDA terms).

6/ Average annual deviation from pre-pandemic values as percent of initial GDP.

With external financial support, the protection of public capital, along with the moderation of tax rates and the reduced crowding out of private investment, substantially moderates the squeeze on consumption over the medium term—aggregate consumption falls by approximately 9 percentage points of initial GDP per annum less than in Panel D over the first 5 years. Nonetheless, the private-sector recession is still deep. As elsewhere in Africa, even if donors provide substantial support to governments, the state cannot provide more than very partial protection to private incomes and welfare.

Achieving even this outcome, however, entails a substantial cumulative inflow of foreign resources—the equivalent of a gross inflow of 8 per cent of recipients' initial GDP in the first 12 months after lockdown and a further 1.2 per cent of initial GDP over the subsequent year. Under this calibration, this increase is approximately twice the level of net ODA in the pre-pandemic setting.

These are indicative numbers for just one country, but other countries' experiences of lockdown are similar, and recognizing similarities in structure, we can use these to assess the broader implications for net ODA. As at the end of 2018 (the last year for which comprehensive data exist), net ODA to all recipients was approximately US$165 billion, of which about 25 per cent flowed to countries in Africa. Excluding the large oil-exporting countries and South Africa, net ODA flows averaged between 6 and 8 per cent of recipient GNI (albeit with a standard deviation of the same magnitude). On this basis, net ODA inflows to Africa would need to roughly double—in other words, an increase in the order of $40–$50 billion of net ODA flows over the next few years to replicate the post-lockdown path illustrated here for all of Africa's low-income countries.

This would be a very substantial increase in net flows but not unprecedented. Between 2001 and 2005, donors committed to large-scale debt relief measures and net ODA flows increased from around US$50 billion to over US$100 billion. Moreover, when measured in simple cost–benefit terms, an aid flow of this magnitude has a high return. Measured in terms of the increase in private consumption over the 5 years from the onset of the crisis relative to the domestic adjustment case in Panel D, the internal rate of return to the aid flow is as high as 25 per cent.[29]

Before leaving this case, it is instructive to consider the case where we compute the net ODA inflow that would be required not simply to support a feasible *fiscal* adjustment but to effectively fully insure the private sector from the aggregate consumption loss arising from the lock-down and associated economic losses. To do so, we run the following experiment: starting from the position described in panel C, where the fiscal instruments – tax rates, levels of spending etc -- are held at their pre-pandemic levels, net ODA is channelled through government transfers directly to household on a per capita basis. These transfers are denoted T_t in equations A13, A16 and A26. The sums involved are substantial, requiring at least a doubling of the increase in net ODA shown in Panel E.

The final scenario returns to Panel E and considers how the outcome may change if this aid-supported fiscal adjustment programme was matched by fiscal reforms targeted at improving

[29] This calculation is clearly an upper-bound for two reasons: it ignores costs associated with transferring donor resources to the private sector through the government budget; and it assumes the resource flow is exclusively in terms of grants.

the quality of public financial management (PFM). The initial calibration of our model embodies two familiar PFM inefficiencies: (i) inefficiently low expenditure on the O&M of public capital, and (ii) leakages in domestic revenue collection. The latter assumed that only 80 per cent of notional revenues were collected, with the remaining 20 per cent (equivalent to around 3 per cent of GDP) leaking back to the private sector by way of exemptions, other loopholes, and corruption, resulting in larger growth-reducing distortions in the tax system than in a second-best tax regime.[30]

We compute the gains that would accrue if donor flows were accompanied both by reforms to revenue mobilization and a strengthening of budget management that protected essential O&M of the public capital stock. Three features stand out. First, from a narrow fiscal perspective, reforms can pay for themselves. Even though O&M expenditures themselves rise from 3.2 per cent of GDP to more than 4 per cent, the payoff from a more effective public capital stock, combined with lower required taxes on factors and consumption, actually expands fiscal space. This additional fiscal headroom could be allocated to even higher social protection, or preventative public health measures, as well as lowering marginal tax rates. The second result is that not only do output and consumption recover from the lockdown shock more rapidly, but long-run output and employment growth take the economy back above trend post-recovery. Finally, reflecting the well-known feature of many low-income economies, the distributional effects of fiscal reforms are progressive: the recovery is associated with a permanent improvement in the aggregate income distribution. Consumption recovers for all groups but more so for the unskilled groups.

4.5 Exploring domestic policy options

The three scenarios described in bottom half of Table 4 span a wide policy space, from the case in Panel D, where the authorities are highly constrained on revenue mobilization and are forced to implement drastic spending cuts, to Panel F where rapid and substantial foreign inflows combine with decisive domestic policy reforms that hold out the prospect of a rapid recovery to trend growth and possibly beyond. In this section we examine how different policy mixes modify these paths.

Table 5 focuses on the mix of domestic policy options, holding net ODA flows at their pre-pandemic level, and focusing on the effect of shifting the balance of fiscal adjustment between expenditure cuts and taxation. Panels D1 to D3 examine the effect of moderating the cut in public investment with the additional tax burden shared across all tax instruments, pro rata [D1]; concentrated on factor taxation [D2]; and concentrated on trade taxes [D3]. The final two runs, D4 and D5, assume that cuts to productive public expenditure are also pared back. In D4, these reduced expenditure cuts are accommodated by tax adjustments across-the-board, as in D1, while in D5 we assume that the authorities are able to introduce modest user fees for the use of public capital.[31]

[30] This figure is consistent with estimates reported in IMF (2018, chapter 2).

[31] The user fee is set at 20% of the flow value of services from public capital, where these are computed as the sum of the costs of operations and maintenance plus depreciation plus the opportunity cost of funds devoted to public investment. At these rates, a 20% across-the-board user fee would raise around 1.5% of GDP in steady-state. Since user fees are levied on a per capita basis, this fee operates as a non-distortionary lump sum tax.

Table 5

Summary Macroeconomic Effects of Lockdown and Responses

	Macroeconomic outturns at the end of:					
	Year 1	Year 2	Year 3	Year 4	Year 5	5 Year Average
[D] Mitigation from own resources						
Aggregate Output	-23.7%	-18.1%	-16.1%	-15.4%	-14.9%	-17.6%
Aggregate Consumption	-23.3%	-21.7%	-18.5%	-17.6%	-16.9%	-19.6%
Incipient excess fiscal pressure	3.1%	2.8%	2.5%	2.3%	2.2%	2.6%
Domestic Borrowing	4.9%	5.5%	5.4%	5.2%	4.9%	5.2%
[D1] Reduction in public investment 50% of Table 4, Panel D with balanced tax financing						
Aggregate Output	-22.8%	-16.6%	-14.4%	-13.8%	-13.4%	-16.2%
Aggregate Consumption	-25.9%	-22.5%	-17.7%	-16.7%	-16.0%	-19.8%
Incipient excess fiscal pressure	8.3%	4.6%	2.4%	1.9%	1.7%	3.8%
Domestic Borrowing	2.4%	5.5%	5.4%	5.2%	4.9%	4.7%
Indirect tax rates - domestic[1/]	13.7%	12.0%	6.9%	4.0%	2.7%	7.9%
Indirect tax rate - trade taxes	7.9%	6.8%	3.8%	2.2%	1.5%	4.4%
Wage taxes	5.2%	4.6%	2.6%	1.5%	1.0%	3.0%
Profit taxes	5.5%	4.8%	2.8%	1.6%	1.1%	3.2%
[D2] D1 with tax financing all on factor taxes						
Aggregate Output	-22.9%	-16.7%	-14.6%	-14.0%	-13.6%	-16.4%
Aggregate Consumption	-25.5%	-21.8%	-17.4%	-16.7%	-16.0%	-19.5%
Incipient excess fiscal pressure	8.7%	5.5%	3.0%	2.3%	2.0%	4.3%
Domestic Borrowing	4.3%	3.7%	2.6%	2.0%	1.5%	2.8%
Indirect tax rates - domestic	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Indirect tax rate - trade taxes	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Wage taxes	17.6%	16.8%	10.3%	6.2%	4.1%	11.0%
Profit taxes	11.8%	11.3%	7.0%	4.3%	2.9%	7.4%
[D3] D1 with tax financing all on trade taxes						
Aggregate Output	-22.7%	-16.5%	-14.3%	-13.7%	-13.3%	-16.1%
Aggregate Consumption	-26.5%	-23.7%	-18.4%	-16.8%	-16.1%	-20.3%
Incipient excess fiscal pressure	8.0%	4.3%	2.2%	1.7%	1.6%	3.6%
Domestic Borrowing	9.0%	6.3%	3.4%	1.6%	0.5%	4.2%
Indirect tax rates - domestic	85.9%	75.7%	40.6%	21.7%	13.5%	47.5%
Indirect tax rate - trade taxes	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Wage taxes	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Profit taxes	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
[D4] D1 balanced tax financing with partial protection of O&M						
Aggregate Output	-20.1%	-13.1%	-10.4%	-9.5%	-8.9%	-12.4%
Aggregate Consumption	-23.2%	-18.3%	-12.9%	-11.5%	-10.8%	-15.3%
Incipient excess fiscal pressure	8.4%	4.3%	1.9%	1.4%	1.2%	3.4%
Domestic Borrowing	4.9%	5.5%	5.4%	5.2%	4.9%	5.2%
Indirect tax rates - domestic	13.4%	11.2%	5.9%	3.0%	1.6%	7.0%
Indirect tax rate - trade taxes	7.8%	6.3%	3.3%	1.7%	0.9%	4.0%
Wage taxes	5.1%	4.3%	2.2%	1.1%	0.6%	2.7%
Profit taxes	5.4%	4.5%	2.4%	1.2%	0.7%	2.8%
[D5] D4 with user costs for public capital services						
Aggregate Output	-20.0%	-13.0%	-10.3%	-9.4%	-8.7%	-12.3%
Aggregate Consumption	-23.8%	-18.2%	-12.9%	-11.7%	-11.0%	-15.5%
Incipient excess fiscal pressure	5.1%	1.2%	-0.6%	-1.1%	-1.3%	0.7%
Domestic Borrowing	2.4%	2.1%	2.0%	1.8%	1.6%	2.0%
Indirect tax rates - domestic	8.9%	5.2%	0.7%	-1.7%	-2.8%	2.1%
Indirect tax rate - trade taxes	5.2%	3.0%	0.4%	-0.9%	-1.6%	1.2%
Wage taxes	3.4%	2.0%	0.3%	-0.6%	-1.1%	0.8%
Profit taxes	3.5%	2.1%	0.3%	-0.7%	-1.1%	0.8%

Notes See Table 4 plus 1/ increase in tax rates above baseline

Compared to the original Panel D case (reported at the top of Table 5) reducing the contraction in public investment improves the path for the recovery in output but at the cost of a tighter squeeze on private consumption and the fiscal balance in the short run (panel D1 vs D). This trade-off is exacerbated the more the authorities seek to shift the tax burden either to the taxation of factors (panel D2 where the output recovery is slower) or to trade

(which improves the output recovery but exacerbates the compression of consumption). But as panel D3 shows, attempting to load the tax burden on trade taxes implies implausibly large increases in tariff rates which in turn reflects the very sharp contraction of the import capacity induced by the global economic recession.

The final two panels of Table 5 illustrate the potential gains to protecting productive recurrent expenditures through the recession. The simulation in D4 is for the case where the original cuts in both public investment and O&M expenditures are 50% smaller than in the original panel D case. This clearly adds to the short-run fiscal pressures but the gains over the medium term are more than 'self-financing'; over the five-year post-pandemic period, the squeeze on both output and consumption is substantially reduced but without any significant increase in fiscal pressure.

The reason for this is that O&M expenditures protect the infra-marginal, installed, capital stock as well as the new capital stock. Both are required for output growth and although we have not done so here, these results suggest it would be possible to derive an optimal mix of cuts to O&M on the one hand and new public investment on the other, that will deliver the least-worst recovery trajectory for given external and domestic financing capacities. In reality, the trade-off between O&M expenditures and new investment is more complicated than illustrated here. One major difficulty is the very limited evidence on returns to O&M (the numbers used in this paper are based on estimates that themselves are 30-40 years old. See Adam and Bevan, 2014). But in addition, if there are vintage effects in public investment so than newer capital is more resilient or more productive than installed capital, this will shift the equilibrium in favour of new investment.

Given the structure of the user-fee defined in the model, the final panel of Table 5 are unsurprising. User fees, if levied on a uniform per capita basis, slightly improve the path for output, slightly worsen the path for consumption and significantly improve the fiscal balance. This follows directly since user fees act as a non-distortionary lump-sum tax, allowing the authorities to reduce distortionary taxes elsewhere in the system. In reality, of course, how closely user fees approximate this neutral non-distortionary benchmark depends on their design, particularly on exemptions and the scope for evasion.

These same considerations carry over to the final set of policy variations in which we our final sets or runs laid out in Table 6. The first panel reports Panel E from Table 4 where, as before we report the change in indirect and factor income tax rates relative to their baseline. As noted earlier, with significant and rapid net ODA inflows, the pressure of domestic taxes is relatively muted. The second panel, F1, considers the case when the authorities progressively eliminate tax leakages. This clearly improves the fiscal balance (by over 4% points of GDP over the five-year period and contributes to a sharp reduction in marginal tax rates across the board. Lower tax rates entail a lower aggregate tax distortion in the domestic economy and hence a marginally more rapid recovery in output. By definition, however, the gains in terms of private welfare are ambiguous. Household face less distortionary tax rates but forego the income accruing to the exploitation of loopholes and leakages. In the runs shown here, the gains are less than the losses, primarily because the bulk of tax revenue is raised from taxation of consumption which is already less distortionary than the taxation of wage and profit incomes. Although not reported here, we can show that this result is overturned if a revenue-equivalent tax reform is concentrated exclusively on

factor taxes; in this case, the output and consumption gains accruing to lower factor taxes exceed the loss of private income from the closure of the tax loopholes.

Table 6

Summary Macroeconomic Effects of Lockdown and Responses

	Macroeconomic outturns at the end of:					
	Year 1	Year 2	Year 3	Year 4	Year 5	5 Year Average
[E] Net ODA resource inflow						
Aggregate Output	-17.0%	-6.4%	-3.8%	-3.3%	-2.9%	-6.7%
Aggregate Consumption	-22.0%	-10.9%	-7.9%	-7.0%	-6.3%	-10.8%
Incipient excess fiscal pressure	3.1%	2.3%	2.4%	2.2%	2.0%	2.4%
Indirect tax rates - domestic[1/]	1.0%	1.0%	0.7%	0.5%	0.4%	0.7%
Indirect tax rate - trade taxes	1.8%	1.8%	1.1%	0.6%	0.4%	1.1%
Factor taxes	1.5%	1.2%	0.7%	0.6%	0.3%	0.9%
[F1] Case E with slow improvement in tax loopholes						
Aggregate Output	-16.9%	-6.3%	-3.7%	-3.1%	-2.6%	-6.5%
Aggregate Consumption	-22.3%	-11.1%	-8.2%	-7.2%	-6.5%	-11.1%
Incipient excess fiscal pressure	-1.1%	-2.8%	-1.0%	-1.7%	-2.2%	-1.8%
Indirect tax rates - domestic[1/]	-3.0%	-3.5%	-3.9%	-4.2%	-4.2%	-3.8%
Indirect tax rate - trade taxes	-1.6%	-2.4%	-0.9%	-1.5%	-1.9%	-1.7%
Factor taxes	-1.2%	-1.6%	-0.6%	-1.0%	-1.4%	-1.2%
[F2] Case E with slow improvement in O&M efficiency						
Aggregate Output	-15.8%	-3.2%	0.5%	1.2%	3.8%	-2.7%
Aggregate Consumption	-20.6%	-5.5%	-0.7%	1.0%	2.2%	-4.7%
Incipient excess fiscal pressure	1.3%	-2.9%	-2.1%	-2.9%	-3.5%	-2.0%
Indirect tax rates - domestic	0.7%	-0.3%	-1.2%	-2.5%	-3.2%	-1.3%
Indirect tax rate - trade taxes	0.4%	-1.8%	-1.4%	-1.9%	-2.3%	-1.4%
Factor taxes	0.2%	-1.3%	-1.0%	-1.4%	-1.6%	-1.0%
[F3] Case E with rapid closure of loopholes and improvement in O&M efficiency						
Aggregate Output	-12.5%	-5.2%	1.2%	1.4%	4.8%	-2.1%
Aggregate Consumption	-18.0%	-4.1%	-0.3%	1.5%	2.7%	-3.6%
Incipient excess fiscal pressure	1.9%	0.6%	0.5%	0.2%	-0.3%	0.6%
Indirect tax rates - domestic	0.2%	-3.2%	-2.0%	-2.8%	-3.5%	-2.3%
Indirect tax rate - trade taxes	0.1%	-1.8%	-1.1%	-1.6%	-2.0%	-1.3%
Factor taxes	0.0%	-1.2%	-0.7%	-1.1%	-1.3%	-0.9%

Notes : See Table 4 plus 1/ increase in tax rates above baseline

In Panel F2, reforms do not address tax loopholes but rather assume that PFM reforms address leakages and inefficiencies in O&M expenditures ('budget reforms') so that over the first two years post-pandemic, productive expenditures are increased gradually to their fully efficient level.

As with Table 5, there are significant gains here; indeed it is this element of PFM that sees output and, shortly thereafter, consumption recover and exceed their pre-pandemic trend levels. As a by-product of this more rapid recovery of the tax base, required tax rates also fall in this run, even though O&M expenditures are 20% higher, relative to the capital stock, than in the baseline.

The final panel reproduces case F from Table 4, which both combines the reforms in panels F1 and F2 and assumes they are implemented in the course of the first post-pandemic year.

That reforms can strengthen growth when they remove economic distortions is not a surprise, it is more of a surprise when they get implemented. Whether these gains can be realized in practice partly depends on whether this crisis can create the political space for such reform, or whether the crisis just allows the elite to consolidate their control of rents and

resist reforms. The track record of donors engaging with the political economy of reform is undistinguished. Nonetheless, how the political economy plays out will also depend on how the aid transfer is structured. These issues matter a great deal, but they are beyond the scope of this paper.

5. Conclusion

The Covid-19 pandemic and policy responses to it, both nationally and globally confronts the low-income countries of Africa with an economic crisis which is potentially bigger than anything most have ever had to deal with outside of war or civil conflict. The disruption of domestic economic activity from early and stringent lockdowns is augmented by the global economic slowdown, which has reduced countries' import capacity, and which means a severe squeeze on domestic absorption.

African governments are being confronted by grim policy choices. To balance competing demands in a manner that protects the economically vulnerable without jeopardizing recovery and growth will depend on development partners' willingness to support domestic spending during the crisis and recovery.

We conclude with four key observations. First: uncertainty. Our simulations are disciplined by coherent epidemiological and macroeconomic models but calibrated under uncertainty; our central assumptions about depth of the global recession, the effect of domestic lockdown measures, and the capacity of the government to respond coherently are all highly contingent. It would be most welcome if our assumptions were too pessimistic and the adjustment problem less severe. But it is possible that reality turns out to be even worse: on the difficulties of re-starting economies, on the impact of the global recession, and on the risks that lockdown measures just delay rather than suppress the virus. A second-wave lockdown would dramatically increase the burden of adjusting to a second economic shock just as economies seek to exit the present one.

The second observation follows directly. However configured, adjustment is going to be painful and risks destroying the development gains achieved in Africa over the last quarter-century. In these exceptional circumstances the case for a substantial temporary increase in net ODA to support adjustment is overwhelming. Our preliminary estimates of what is required to support feasible and progressive adjustment programmes suggest a doubling of net ODA flows—possibly in the order of an additional US$50 billion per annum for 2–3 years—representing a significant challenge to donors at a time when domestic pressures on funding are substantial. This a significant increase, but not unprecedented, either in the context of sub-Saharan Africa, being comparable to the HIPC (heavily indebted poor countries) debt relief programme in the mid-2000s, or in comparison to the 9 trillion dollars that advanced economy governments have deployed to protect their own economies. In addition, the returns to packages of international budget support, in these exceptional times, are high; especially if there are also reforms to systems for taxation and public service delivery.

The case for increased support can be based as much on national self-interest as on the developmental arguments that hinge on growth and poverty reduction, especially at the bottom of the income distribution. There is a clear imperative to conquer the Covid-19 pandemic at a global scale so that it does not rip through the OCED again, and there is a powerful case in terms of the projection of soft power that this is an economic and social crisis which will reveal who is a reliable friend in a time of need. Moreover there is potential scope to 'build back better' with public investment that contributes to reduced carbon emissions, and supports economies make the most of the potential demographic dividend offered by a youthful labour force across sub-Saharan Africa.

Third, our model does not yet factor in the medium-term damage to human capital and growth that will arise if (public) investment in health and education are curtailed by or diverted towards addressing the Covid-19 pandemic. The combination of short-term interruptions to education, at primary, secondary and tertiary levels, and the likelihood of a much tighter fiscal position over the medium-term risks undermining investment in human capital and skills, to the detriment of the economy as a whole as well as to specific age-cohorts in society. Likewise for the diversion of health care resources away from the treatment of chronic and non-communicable diseases. Together this threat to human capital accumulation is likely to have long-term effects on countries' capacity to restore growth. Further modelling work is required to examine these medium- to longer-term effects of the pandemic.

Finally, it is clear from our coherent modelling that serious reform which releases growth from the binding constraints of weak revenue systems and inefficient public expenditure management—especially sustaining operations and maintenance of public capital—pays off with an accelerated recovery, and a faster subsequent trend growth. There is a particular challenge for policy reform across low-income African countries to mobilize that potential, and for international donors to support any such commitment.

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Appendix I: Model Structure

Our model is based on the 'Debt, Investment and Growth' (DIG) model described by Zanna *et al* (2019) but includes modifications to the fiscal block by Adam and Bevan (2014).

The equations describe a dynamic two-sector small open economy producing tradable (x) and non-tradable (n) goods indexed $j = \{x, n\}$. Output is produced by three factors: sector-specific private capital (k_j); sector-specific labour (L_j); and government-supplied infrastructure (z). In addition, there is an exogenously-determined trend rate of growth of *per capita* technical progress (g). Time is indexed by t.

There are two types of household: 'rationed' or 'hand-to-mouth' households (indexed h); and 'saver' households (indexed s). All households consume the same basket of three goods: imports (c_m); exportable goods, which can be exported or consumed at home (c_x); and non-tradable goods produced and consumed at home (c_n).

Inefficiencies in the public investment process drive wedges between the notional or desired public capital (z) and that that is eventually installed (z_i), and between installed and effective public capital (z^e).

Production

Sectoral production functions are Cobb Douglas with constant returns to scale in private factors and increasing returns in the presence of effective public capital (denoted by ψ_j).

$$q_{j,t} = a_j (z^e_{t-1})^{\psi_j} \left(k_{j,t-1}\right)^{\alpha_j} \left(L_{j,t}\right)^{1-\alpha_j} \tag{A1}$$

Prices of private and public capital reflect fixed proportions of imported and non-traded goods (P_n is the price of the non-traded good and P_m the price of imported machinery).

$$P_{k,t} = (1 - a_k) P_{m,t} + a_k P_{n,t} \tag{A2}$$

$$P_{z,t} = (1 - a_z) P_{m,t} + a_z P_{n,t} \tag{A3}$$

Private factor demands

Firms' desired quantities of labour and capital in each sector are determined from their first-order conditions

$$P_{j,t}\left(1 - \alpha_j\right) \frac{q_{j,t}}{L_{j,t}} = (1 - \theta_{w,t}) w_t \tag{A4}$$

$$P_{j,t} \alpha_j \frac{q_{j,t}}{k_{j,t-1}} = (1 - \theta_{j,t}) r_{j,t} \tag{A5}$$

where P_j is the output price for good j, w is the net-of-tax wage, r_j is the gross return to capital in sector j inclusive of depreciation, δ_j, and θ_w and θ_j are tax rates on labour and (sector-specific) capital income respectively. Given (A5), private investment in sector j is defined by:

$$(1+g)k_{j,t} = i_{j,t} + (1-\delta_j)k_{j,t-1} \tag{A6}$$

Changing the level of capital stock is costly which is reflected by adjustment costs of the form:

$$AC_{j,t} = \left(\frac{\nu_j}{2}\right) k_{j,t-1} \left[\left(\frac{i_{j,t}}{k_{j,t-1}}\right) - \delta_j - g\right]^2 \tag{A7}$$

where ν_j is the sector specific adjustment parameter.

Households

Utility and consumption

Household welfare for household type $i = s, h$ is defined by an iso-elastic utility function where β is the discount factor, and τ is the inter-temporal elasticity of substitution in consumption

$$U^i = \sum_{t=0}^{\infty} \beta^t \left[\frac{\left(c_t^i\right)^{1-1/\tau^i}}{1-1/\tau^i}\right] \tag{A8}$$

Aggregate consumption by each household type is a CES composite defined over exportables, imports and non-tradables where ε is the intra-temporal elasticity of substitution in consumption and ρ_l are shares with $l = \{m, x, n\}$ and $\sum \rho_l = 1$.

$$c_t^i = \left[\rho_x^{1/\varepsilon}\left(c_{x,t}^i\right)^{1-1/\varepsilon} + \rho_m^{1/\varepsilon}\left(c_{m,t}^i\right)^{1-1/\varepsilon} + \rho_n^{1/\varepsilon}\left(c_{n,t}^i\right)^{1-1/\varepsilon}\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{A9}$$

The aggregate consumer price index is defined as

$$P_{c,t} = \left[\rho_x P_{cx,t}^{1-\varepsilon} + \rho_m P_{cm,t}^{1-\varepsilon} + \rho_n P_{cn,t}^{1-\varepsilon}\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{A10}$$

with demand functions for each good $l = \{m, x, n\}$

$$c_{l,t}^i = \rho_l \left(\frac{P_{cl,t}}{P_{c,t}}\right)^{-\varepsilon} c_t^i \tag{A11}$$

Consumer prices, where θ_{hl} denotes the consumption tax rate on good c_l , are given by

$$P_{cl,t} = (1+\theta_{hl})P_{l,t} \tag{A12}$$

Household Budget Constraints

The budget constraint of the saving household is given by:

$$\Delta b_t = (1+(1-t_x)\theta_x)r_{x,t}k_{x,t-1} + (1+(1-t_n)\theta_n)r_{n,t}k_{n,t-1} + \frac{1}{1+a}\left[(1+(1-t_w)\theta_w)w_t\left(L_{n,t} + L_{x,t}\right) + T_t + R_t + \sum_l (1-t_{cl})\theta_{hl}P_{l.t}c_{l,t} - \mu z_{t-1}^i\right] + r_{t-1}b_{t-1} - P_{k,t}\left(i_{x,t} + AC_{x,t} + i_{n,t} + AC_{n,t}\right) - P_{c,t}c_t^s \tag{A13}$$

where $\Delta b_t = b_t - b_{t-1}$ is domestic borrowing in terms of short-term bonds; $\{t_x, t_n, t_w, t_{cm}, t_{cn}, t_{cx}\}$ the proportion of levied taxes remitted to government, so that $(1-t)$ denotes 'tax leakage'); T denotes transfers from government; and R remittances from overseas.

Optimal intertemporal consumption for the saving households is defined by the Euler equation

$$\left(\frac{c^s_{t+1}}{c^s_t}\right) = \left(\beta \frac{1+r_t}{1+g} \frac{P_{c,t}}{P_{c,t-1}}\right)^{\tau s} \tag{A14}$$

with sectoral investment arbitrage condition equalizing the net return to capital with the return to bonds

$$\frac{r_{j,t+1}}{P_{k,t+1}} + 1 - \delta_j = (1+r_t)\frac{P_{k,t}}{P_{k,t+1}} \tag{A15}$$

By contrast, 'hand-to-mouth' households earn income, pro-rated, from labour (net of effect tax), transfers, remittances and 'leakages' from consumption tax revenues, net of any user fees charged for the use of public capital.

$$P_{c,t}c^h_t = \frac{a}{1+a}\left[(1+(1-t_w)\theta_w)w_t\left(L_{n,t}+L_{x,t}\right) + T_t + R_t + \sum_l (1-t_{cl})\theta_{hl}P_{l.t}c_{l,t} - \mu z^i_{t-1}\right] \tag{A16}$$

Government

Infrastructure and public investment

The *notional* public capital evolves given government investment

$$(1+g)z_t = (1-\delta_z)z_{t-1} + i_{z,t} \tag{A17}$$

Installed public capital reflects inefficiencies in public investment, where $s \leq 1$ denotes investment inefficiency

$$z^i_t = \bar{s}\bar{z} + s(z_t - \bar{z}) \tag{A18}$$

This implies a dynamic equation for *installed* public capital stock

$$(1+g)z^i_t = (1-\delta_z)z^i_{t-1} + s(i_{z,t} - \bar{\imath}_z) + \bar{s}\bar{\imath}_z \tag{A19}$$

where public investment is subject to adjustment costs

$$AC_{z,t} = \left(\frac{\nu_z}{2}\right) z^i_{t-1}\left[\left(\frac{i_{z,t}}{z^i_{t-1}}\right) - \delta^i_z - g\right]^2 \tag{A20}$$

Operations and Maintenance Expenditure

The depreciation rate of (installed) public capital is given by

$$\delta_z^i = \delta_z[1 + (1 - \gamma_m)\beta_\delta] \quad \text{(A21)}$$

where $0 < \gamma_m \leq 1$ is the ratio of actual to efficient maintenance expenditure. Effective capital, is the ratio of actual to efficient operations expenditure, where $0 < \gamma_p \leq 1$:

$$z^e = \gamma_p z^i \quad \text{(A22)}$$

The price of O&M is equivalent to the price of capital

$$P_{om,t} = (1 - a_k)P_{m,t} + a_k P_{n,t} \quad \text{(A23)}$$

O&M spending (where q_m and q_p denote maintenance and operations inputs per unit of installed capital) is thus

$$P_{om,t}(q_m + q_p)z_{t-1}^i \quad \text{(A24)}$$

Revenues from user fees are defined:

$$\mu_t = [P_{om,t}\big(f_{m,t}q_m + f_{p,t}q_p\big) + (f_{d,t}\delta_{z,t}^i + f_{r,t}r_t)P_{z,t}/s] \quad \text{(A25)}$$

where $0 < f_n \leq 1$ for $n = p, m, d, r$ are the recovery rates for each financing component.

Public Sector Budget Constraint

The overall fiscal balance is

$$\Delta b_t + \Delta d_{c,t} + \Delta d_t = P_{z,t}\big(i_{z,t} + AC_{z,t}\big) + P_{om,t}\big(q_m + q_p\big)z_{t-1}^i + T_t + \frac{r_{t-1}-g}{1+g}b_{t-1} + \frac{r_{d,t-1}-g}{1+g}d_{t-1} + \frac{r_{dc,t-1}-g}{1+g}d_{c,t-1} - t_x\theta_x r_{x,t}k_{x,t-1} - t_n\theta_n r_{n,t}k_{n,t-1} - t_w\theta_w w_t\big(L_{n,t} + L_{x,t}\big) - t_{cm}\theta_{hm}P_{m,t}c_{m,t} - t_{cx}\theta_{hx}P_{x,t}c_{x,t} - t_{cn}\theta_{hn}P_{n,t}c_{n,t} - G_t - \mu_t z_{t-1}^i \quad \text{(A26)}$$

where d_c denotes commercial external debt, d concessional external debt with associated interest rates r_d and r_{dc}. T are recurrent transfers to households and G denotes grants.

The interest rate on external commercial debt, with r_f the world risk-free rate; ed_t total external debt; and

$$r_{dc,t} = r_f + \nu_g e^{\eta_g(ed_t - \overline{ed})} \quad \text{(A27)}$$

Fiscal adjustment and policy rules

Fiscal Gap

The fiscal gap is defined as the difference between committed expenditures (excluding domestic bond financing) and notional revenues *at initial tax rates,* where the latter are denoted by the subscript 0.

$$\Omega_t = P_{z,t}\left(i_{z,t} + AC_{z,t}\right) + P_{om,t}\left(q_m + q_p\right)z_{t-1}^{i} + T_0 + \frac{r_{t-1}-g}{1+g}b_{t-1} + \frac{(1+r_{d,t-1})}{1+g}d_{t-1} - d_t + \frac{(1+r_{dc,t-1})}{1+g}d_{c,t-1} - d_{c,t} - t_x\theta_{x0}r_{x,t}k_{x,t-1} - t_n\theta_{n0}r_{n,t}k_{n,t-1} - t_w\theta_{w0}w_t\left(L_{n,t} + L_{x,t}\right) - t_{cm}\theta_{hm0}P_{m,t}c_{m,t} - t_{cx}\theta_{hx0}P_{x,t}c_{x,t} - t_{cn}\theta_{hn0}P_{n,t}c_{n,t} - G_t - \mu_t z_{t-1}^{i} \quad \text{(A28)}$$

Government allocates the financing of the *long term* fiscal gap according to a set of fiscal rules

$$\theta_{hm}^{target} = t_{cm}\theta_{hm0} + \lambda_{hm}\frac{\Omega_t}{P_{m,t}c_{m,t}} \quad \text{(A29)}$$

$$\theta_{hx}^{target} = t_{cx}\theta_{hx0} + \lambda_{hx}\frac{\Omega_t}{P_{x,t}c_{x,t}} \quad \text{(A30)}$$

$$\theta_{hn}^{target} = t_{cn}\theta_{hn0} + \lambda_{hn}\frac{\Omega_t}{P_{n,t}c_{n,t}} \quad \text{(A31)}$$

$$\theta_{x}^{target} = t_{x}\theta_{x0} + \lambda_{kx}\frac{\Omega_t}{r_{x,t}k_{x,t}} \quad \text{(A32)}$$

$$\theta_{n}^{target} = t_{n}\theta_{n0} + \lambda_{kn}\frac{\Omega_t}{r_{n,t}k_{n,t}} \quad \text{(A33)}$$

$$\theta_{w}^{target} = t_{w}\theta_{w0} + \lambda_{w}\frac{\Omega_t}{w_t(L_{n,t}+L_{x,t})} \quad \text{(A34)}$$

where $\sum \lambda_j = 1$ for $j = \{hm, hn, hx, kx, kn, w\}$.

For each tax, the gap between target and actual tax rate is closed at rate λ_j^d for $j = \{hm, hn, hx, kx, kn, w\}$ with the 'gap' filled by short-term domestic borrowing, Δb_t

$$t_j\theta_{j,t} = t_j\theta_{j,t-1} + \lambda_j^d(\theta_{hj}^{target} - t_j\theta_{j,t-1}) \quad \text{(A35)}$$

Market Clearing Conditions

Labour Market

$$L_{n,t} + L_{x,t} = \bar{L}_s + \bar{L}_h \quad \text{(A36)}$$

Non-tradable equilibrium (internal balance)

$$q_{n,t} = \rho_n\left(\frac{P_{n,t}}{P_t}\right)^{-\epsilon}c_t + a_k\left(i_{n,t} + AC_{n,t} + i_{x,t} + AC_{x,t}\right) + a_z\left(i_{z,t} + AC_{z,t}\right) + a_k(q_{m,t} + q_{p,t})z_t^{i} \quad \text{(A37)}$$

Current Account (external balance)

$$\Delta d_{c,t} + \Delta d_t = \frac{r_{d,t-1}-g}{1+g}d_{t-1} + \frac{r_{dc,t-1}-g}{1+g}d_{c,t-1} + P_{k,t}\left(i_{n,t} + AC_{n,t} + i_{x,t} + AC_{x,t}\right) + P_{z,t}\left(i_{z,t} + AC_{z,t}\right) + P_{om,t}\left(q_m + q_p\right)z_{t-1}^{i} + P_{c,t}c_{ct} - P_{n,t}q_{n,t} - G_t - R_t \quad \text{(A38)}$$

Appendix II

Baseline Calibration Parameters

Parameter	Value	Description
g	0.015	Trend per capita growth per quarter
a	0.75	Share of hand-to-mouth households
α_x, α_n	0.60,0.40	Capital shares in tradable and non-tradable production
ψ^n, ψ^x	0.2,0.2	Returns to public capital
$a_k, a_z, a_{om},$	0.50,0.50,0.50	Non-tradable share in capital, government and O&M price composite
$\rho_x, \rho_n, \rho_m,$	0.05,0.40,0.50	Consumption shares
ε	0.5	Elasticity of substitution in consumption
τ	0.5	Inter-temporal elasticity of substation
β	0.9364	Discount factor
$\delta_x, \delta_n, \delta_z$	0.05,0.05,0.05	Depreciation rates
β_δ	1.0	'Excess' depreciation factor
θ_x, θ_n	0.15, 0.10	Profit taxes by sector
θ_w	0.125	Labour tax
h_x, h_n, h_m	0.10,0.10,0.20	Consumption taxes by good
ν_x, ν_n, ν_z	25,25,25	Adjustment cost parameter
q_p, q_m	0.025,0.025	Efficient operations and maintenance per unit of capital
γ_p, γ_m	0.8,0.8	Efficiency of operations and maintenance
ν_g, η_g	0.085,3.0	Country risk parameters
f_q, f_p, f_d	0.2,0.2,0.2	User fee rates
$\lambda_{hx}, \lambda_{hn}, h_{hm},$	0.05,0.25,0.30,	Tax adjustment shares by tax
$\lambda_w, \lambda_{kn}, h_{kx}$	0.20,0.1,0.1	
λ_j^d	0.5	Dynamic tax adjustment parameter