Journal of Macroeconomics 75 (2023) 103492

Contents lists available at ScienceDirect

Journal of Macroeconomics

journal homepage: www.elsevier.com/locate/jmacro

Loss-of-learning and the post-Covid recovery in low-income countries☆

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ARTICLE INFO

JEL classification:
E62
F34
H54
H63
I25
I31
O43

Keywords:
Covid-19
Public investment
Growth
Debt
Fiscal policy
Human capital
Labor markets
Welfare

ABSTRACT

We analyze the medium-term macroeconomic impact of the Covid-19 pandemic and associated lock-down measures on low-income countries. We focus on the impact of the degradation of health and human capital caused by the pandemic and its aftermath, exploring the trade-offs between rebuilding human capital and the recovery of livelihoods and macroeconomic sustainability. A dynamic general equilibrium model is calibrated to reflect the structural characteristics of vulnerable low-income countries and to replicate key dimensions of the Covid-19 shock. We show that absent significant and sustained external financing, the persistence of loss-of-learning effects on labor productivity is likely to make the post-Covid recovery more attenuated and more expensive than many contemporary analysis suggests.

1. Introduction

Since the emergence of the Covid-19 virus in early 2020, a flood of research has sought to examine the economic impact of the pandemic on both advanced economies and those in the developing world. Much of this necessarily focused on the most direct, visible effects of the pandemic, often with the aim of assessing financing needs over the immediate two-to-five year recovery phase (for example Adam et al., 2020, Alon et al., 2020, Ansah et al., 2020, Arellano et al., 2020, Carnap et al., 2020, Hannan et al., 2020, Cakmakl et al., 2020 and Velasco and Chang, 2020).

Less attention has been paid to the implications that will play out over the medium- to long-term as a result of the deep scarring that has been inflicted on health and human capital. There is already abundant evidence that in many developing countries the

☆ We thank Mariya Brussevich, Cedric Okou, Roberto Perrelli, Yuan Xiao and colleagues in the Research and Fiscal Affairs departments of the IMF for useful comments. We are also grateful to the Editor and two anonymous referees for their thoughtful comments. The research underpinning this paper was supported by the IMF-FCDO Macroeconomic Research in Low-Income Countries project (Project ID: 60925). The views expressed in this paper are those of the authors and do not necessarily represent the views or policy of the IMF or the UK FCDO.

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https://doi.org/10.1016/j.jmacro.2022.103492
Received 12 June 2022; Received in revised form 10 December 2022; Accepted 16 December 2022
Available online 24 December 2022

diversion of healthcare resources to the immediate battle against Covid-19 caused an upsurge in excess mortality from a range of other morbidities including tuberculosis, malaria, diabetes, HIV and heart disease.[1] Perhaps more alarming for the long run is the growing evidence of harm to children's health and education – from school closures and reduced access to vaccinations – and increases in malnutrition, stunting and wasting. There is growing consensus that these assaults on health and education will have devastating long-term effects on human capital (Heady et al., 2020; World Bank, 2020a; Kaffenberger and Pritchett, 2020). According to the World Bank, for example, real GDP could permanently decrease 4 percent in less developed countries if "the human capital destruction and disruption of public infrastructure caused by Covid-19 are not quickly reversed." (World Bank, 2020a). In short, the lock-downs and containment measures of 2020–21 mark only the beginning of what promises to be a protracted battle to recover from the social and economic damage wreaked by the pandemic.

As the first intense waves of the Covid-19 pandemic pass, this paper uses a dynamic general equilibrium macroeconomic model to explore the macroeconomic and welfare implications of the human capital scarring inflicted by the crisis in low-income countries. Three central messages emerge from the analysis. The first is that, if left unaddressed, the once-and-for-all assault on health and human capital wrought by the pandemic risks turning a sharp short-run recession into a severe economic decline over an extended medium term. Second, even with a concerted public investment response, winning the economic battle against Covid-19 will likely be more difficult and more expensive than commonly thought. More difficult in the sense that even with this investment response it may take more than a decade for *per capita* incomes, formal sector employment and the real wages of the poor to return to their pre-pandemic trend levels. And more expensive in that, given its relatively long gestation period, public investment in rebuilding lost human capital entails either significantly higher external financing or, when this is not available, an extended period of accommodation elsewhere in the domestic fiscal accounts. Third, however, expensive though the investment is, the welfare gains, relatively to doing nothing are substantial, especially in circumstances where policymakers attach significant weight to the welfare of the poor.

The remainder of the paper proceeds as follows. In Section 2 we lay out the model. Section 3 discusses the calibration of the model and the composite Covid-19 shock. Section 4 then presents our core simulation results and discusses their implications, while Section 5 presents our welfare analysis. Section 6 concludes with some implications for policy, both domestic and international.

2. The model

Covid-19 was a complex set of shocks to trade, health, productivity, capital flows, and education of unprecedented proportions. To quantify the impact of this large, multi-faceted shock and evaluate alternative policy responses to it, we adapt the macroeconomic model developed by the authors under the auspices of the IMF (Buffie et al., 2020). The model tracks the paths of growth, inequality, unemployment and underemployment, public debt, and real wages in the short, medium, and long runs in a small open low-income country. The solutions for the transition path form the basis of our welfare calculations.

2.1. Production and factor demands

The economy produces two traded goods and two nontraded goods. Subscripts b, x, j, and n refer to the tourism sector, the other tradables sector, the informal nontradables sector, and the formal nontradables sector. Tourism is an export enclave within the formal sector; it sells only to foreign customers. All quantity variables except labor and land are detrended by $(1+g)^t$, where g is the exogenous long-run growth rate of per capita income. To fix ideas, we refer to sector x as agriculture.

Firms convert inputs into output via Cobb–Douglas production functions:

$$q_{x,t} = a_x z_{t-1}^{\psi_x} k_{x,t-1}^{\alpha_x} S_{x,t}^{\theta_x} H^{\chi} (e_{b,t} L_{x,t})^{1-\alpha_x-\theta_x-\chi}, \tag{1}$$

$$q_{n,t} = a_n z_{t-1}^{\psi_n} k_{n,t-1}^{\alpha_n} S_{n,t}^{\theta_n} (e_{n,t} e_{b,t} L_{n,t})^{(1-\alpha_n-\theta_n)}, \tag{2}$$

$$q_{b,t} = a_b z_{t-1}^{\psi_b} k_{b,t-1}^{\alpha_b} S_{bb,t}^{\theta_b} A_t^{\theta_a} (e_{n,t} e_{b,t} L_{n,t})^{(1-\alpha_b-\theta_b-\theta_a)}, \tag{3}$$

$$q_{j,t} = a_j z_{t-1}^{\psi_j} k_{j,t-1}^{\alpha_j} S_{j,t}^{\theta_j} (e_{b,t} L_{j,t})^{(1-\alpha_j-\theta_j)}. \tag{4}$$

All sectors utilize capital k, low-skill labor L, high-skill labor S, and government-supplied infrastructure z. Infrastructure is a public good that enhances productivity in all sectors, while H and A are sector-specific inputs in sectors x and b (land in the former, natural resources such as beaches, wildlife etc. in the latter). The variable e_b links healthcare and the quantity and quality of primary education to human capital of low-skill labor. In the formal sectors, where efficiency wage considerations apply, the productivity of low-skill labor also depends on work effort e_n.

Education capital is of two types, S_b for basic education (primary plus lower secondary) and S_u for upper-level education (upper secondary plus tertiary). Factories, infrastructure, healthcare capita,l G, and education capital are built by combining a_{im} imported machines (whose price is the numeraire and normalized to unity) with a_{in} and a_{ij} ($i = k, z, S_u, S_b, G$) units of formal and informal sector inputs. The supply prices of social and physical capital are thus

$$P_{i,t} = 1 + a_{in}(P_{n,t} - 1) + a_{ij}(P_{j,t} - 1). \tag{5}$$

[1] For example, Hogan et al. (2020) estimate that the years of life lost from the indirect effects of Covid-19 on the treatment of just HIV, tuberculosis, and malaria could be as high as 60 percent of the equivalent losses from the direct impact of the pandemic.

Competitive firms maximize profits by hiring each input up to the point at which its marginal value product equals its price:

$$P_{n,t}(1-\alpha_n-\theta_n)q_{n,t}/L_{n,t} = w_{n,t}, \quad (6)$$

$$(1-\alpha_b-\theta_b-\theta_a)q_{b,t}/L_{b,t} = w_{n,t}, \quad (7)$$

$$P_{x,t}(1-\alpha_x-\theta_x-\chi)q_{x,t}/L_{x,t} = w_{x,t}, \quad (8)$$

$$P_{j,t}(1-\alpha_n-\theta_n)q_{j,t}/L_{j,t} = w_{j,t}, \quad (9)$$

$$P_{x,t}\theta_x q_{x,t}/S_{x,t} = w_{s,t}, \quad (10)$$

$$P_{n,t}\theta_n q_{n,t}/S_{n,t} = w_{s,t}, \quad (11)$$

$$\theta_b q_{b,t}/S_{bb,t} = w_{s,t}, \quad (12)$$

$$P_{j,t}\theta_j q_{j,t}/S_{j,t} = w_{s,t}, \quad (13)$$

$$P_{n,t}\alpha_n q_{n,t}/k_{n,t-1} = r_{n,t}, \quad (14)$$

$$P_{x,t}\alpha_x q_{x,t}/k_{x,t-1} = r_{x,t}, \quad (15)$$

$$P_{j,t}\alpha_j q_{j,t}/k_{j,t-1} = r_{j,t}, \quad (16)$$

$$\alpha_b q_{b,t}/k_{b,t-1} = r_{b,t}, \quad (17)$$

$$\chi P_{x,t}q_{x,t}/H = r_{h,t}, \quad (18)$$

$$\theta_a q_{b,t}/A = r_{a,t}, \quad (19)$$

where w_s is the skilled wage, r_h and r_a are land and natural amenity rents, and w_q and r_q are the low-skill wage and the capital rental in sector $\mathrm{q} = (b, j, n, x)$. Skilled labor is intersectorally mobile, so the same wage appears in (10)–(13). Capital is sector specific, but the capital rentals differ only on the transition path. In the long run, after adjustment is complete, $r_x = r_n = r_j = r_b$.

In connection with the detailed discussion of the low-skill labor market that follows, we note two points about (6)–(9). First, the market is highly segmented, with $w_n > w_j \geq w_x$ and rationing of jobs in the high-wage formal sector (w_n is the wage in both formal sectors.) Second, w_x does not necessarily correspond to earnings of low-skill labor in sector x; in countries with smallholder agriculture and insecure land rights, w_x should be interpreted as the *shadow wage* of labor.

2.2. The labor market

Firms pay efficiency wages to low-skilled workers in the formal sector but not in the informal sector or agriculture, where self-employment and family-run farms predominate. In our formulation, this gives rise to a dualistic labor market riven by both open unemployment and extensive underemployment.

The Effort Function

Low-skill workers in the formal sector exert more effort when they are paid a higher real wage and when low pay in the informal sector and high unemployment (u) increase their gratitude for having a job, viz.[2]:

$$e_{n,t} = g_o + g_1 \ln(w_{n,t}/P_t) - g_2 \ln(w_{j,t}/P_t) + g_3 u_t, \quad (20)$$

where

$$u_t = \frac{\bar{L}_t - L_{n,t} - L_{j,t} - L_{b,t} - L_{x,t}}{\bar{L}_t}. \quad (21)$$

Efficiency Wages, Unemployment, and Underemployment

Firms in the formal sector recognize the connection between labor productivity and the real wage. Accordingly, they optimize over w_n as well as L_n. The profit-maximizing choice for w_n satisfies the Solow condition

$$\frac{\partial e_n}{\partial(w_n/P)}\frac{w_n/P}{e_n} = 1. \quad (22)$$

Eqs. (20) and (22) imply

$$e_{n,t} = g_1. \quad (23)$$

[2] The effort function in (20) may be derived either (i) in a more general version of the micro-theoretic model in Shapiro and Stiglitz (1984), where effort is a continuous variable and the utility loss from being fired for shirking is increasing in the unemployment rate and decreasing in the informal wage; or (ii) by appending a separable term in the utility function à la Collard and de la Croix (2000), Danthine and Kurmann (2004) and Danthine and Kurmann (2010) that captures the non-pecuniary loss from effort at the job. Neither method affects the other first-order conditions associated with the solution to the private agent's optimization problem.

Conveniently, effort is constant in general equilibrium. Without loss of generality, we set e_n equal to unity at the initial equilibrium. The *wage curve* defined by (20) and (23) then reads

$$\ln(w_{n,t}/P_t) = 1 - g_o + g_2 \ln(w_{j,t}/P_t) - g_3 \ln u_t. \tag{24}$$

Eq. (24) applies in normal periods. During the pandemic, however, firms may be reluctant to take advantage of the severely depressed labor market to pay abnormally low wages. To allow for this possibility, we replace (24) with

$$\ln(w_{n,t}/P_t) - \ln(w_{n,o}/P_o) = (1 - \mathfrak{g})\{g_2[\ln(w_{j,t}/P_t) - \ln(w_{jo}/P_o)] - g_3[\ln u_t - \ln u_o]\}. \tag{25}$$

During the crisis, $0 < \mathfrak{g} < 1$ if social norms constrain wage cuts. After the crisis has passed, $\mathfrak{g} = 0$ re-activates the normal wage curve.[3]

The Informal Labor Market

The informal sector and agriculture form an integrated labor market with flexible wages. Total labor supply is inelastic at $\bar{L}_{xj}$, and job seekers move freely between the two sectors. Perfect, frictionless labor mobility does not guarantee, however, that (shadow) wages and the marginal value product of labor (MVPL) are the same in sectors x and j. Arbitrage in the combined (x, j) labor market ensures only that

$$\begin{aligned} (1 - f_{wj})w_{j,t} &= (1 - f_{wx})(w_{x,t} + \sigma r_{h,t} H/L_{x,t}), \\ \Longrightarrow \frac{1 - f_{wj}}{1 - f_{wx}} w_{j,t} &= w_{x,t}\left(1 + \frac{\sigma\chi}{1 - \alpha_x - \theta_x - \chi}\right), \quad 0 \le \sigma \le 1. \end{aligned} \tag{26}$$

When property rights are tenuous or non-existent in agriculture, $\sigma = 1$ and labor receives its marginal value product (w_x) plus a share of land rents.[4] In this case, a reallocation of labor from agriculture to the informal sector increases aggregate labor productivity. Wage rigidity and open unemployment in the formal sector co-exists with multiple types of underemployment (in sector j relative to sector n and in sector x relative to both sectors j and n).

Sectoral Labor Supply

Two factors, one exogenous and the other endogenous, influence the sectoral supplies of low-skill labor:

$$\bar{L}_{xj,t} = L_{x,o} + L_{jo} - \Delta_{xj}(S_t - S_o) - \xi(L_{n,t} + L_{b,t} - L_{no} - L_{bo}), \tag{27}$$

$$\bar{L}_t = \bar{L}_o - (S_t - S_o). \tag{28}$$

Public investment in upper-level education converts some low-skill workers into high-skill workers. The mechanism that determines Δ_{xj} and the impact on $\bar{L}_{xj}$ lies outside the purview of the model.

New job openings in the formal sector also affect sectoral labor supply. The reflex assumption that the jobs go to the unemployed is generally incorrect. Workers in the combined (x, j) sector compete with the unemployed for prize jobs in the formal sector and may have an inside track to many of them. Hiring for wage jobs often occurs through informal channels. Employers put out the word that they are hiring and rely on referrals from existing employees to fill the jobs (Funkhouser, 1997, Fields, 2011, Fox, 2015, and Tansel et al., 2015). Again, we do not attempt to model the role played by friend–family–kinship networks in the labor market: Eq. (27) simply assumes that workers previously employed in the (x, j) sector obtain ξ percent of newly created jobs in the formal sector.

2.3. Households

There are two types of private agents, nonsavers and savers (distinguished by subscripts 1 and 2). Preferences of both agents qua consumers are given by

$$\begin{aligned} c &= \left[(1 - \kappa_1)^{1/\epsilon_1} c_{fj}^{(\epsilon_1 - 1)/\epsilon_1} + \kappa_1^{1/\epsilon_1} c_x^{(\epsilon_1 - 1)/\epsilon_1}\right]^{\epsilon_1/(\epsilon_1 - 1)}, \\ c_{fj} &= \left[(1 - \kappa_2)^{1/\epsilon_2} c_j^{(\epsilon_2 - 1)/\epsilon_2} + \kappa_2^{1/\epsilon_2} c_{nm}^{(\epsilon_2 - 1)/\epsilon_2}\right]^{\epsilon_2/(\epsilon_2 - 1)}, \\ c_{nm} &= \left[(1 - \kappa_3)^{1/\epsilon_3} c_m^{(\epsilon_3 - 1)/\epsilon_3} + \kappa_3^{1/\epsilon_3} c_n^{(\epsilon_3 - 1)/\epsilon_3}\right]^{\epsilon_3/(\epsilon_3 - 1)}, \end{aligned}$$

where c_i is consumption of good i. The bottom tier defines c_{nm} as a CES aggregate of c_n and consumption c_m of an imported consumer good. In the middle tier, c_{fj} is a CES aggregate of c_{nm} and c_j. At the upper tier, c_{fj} combines with c_x in another CES function.

The representative agents choose c_i ($i = n, m, x, j$) to minimize the cost of purchasing c at prices $P_n(1 + h)$, $(1 + h)$, $(1 + g_x h)$ and $P_j(1 + g_j h)$ respectively, where h is the VAT tax in the formal sector and $g_x, g_j \le 1$ determine the reach of the tax net in sectors j and x. This yields the set of demand functions

$$c_{n,t} = \kappa_3 \left[\frac{(1 + h_t)P_{n,t}}{P_{nm,t}}\right]^{-\epsilon_3} \kappa_2 \left[\frac{P_{nm,t}}{P_{fj,t}}\right]^{-\epsilon_2} (1 - \kappa_1) \left(\frac{P_{fj,t}}{P_{c,t}}\right)^{-\epsilon_1} (c_{1,t} + c_{2,t}), \tag{29}$$

[3] Eq. (25) delivers more realistic wage adjustment than (24) in the immediate aftermath of the pandemic. After year five, the results are virtually identical in the two specifications.

[4] Sharecropping introduces a similar wedge between w_x and the MVPL for the tenant. In the simplest sharecropping model, w_x, as viewed by the tenant, equals $MVPL(1 - \phi)$, where ϕ is the share of output paid to the landowner.

$$c_{j,t} = (1-\kappa_2)\left[\frac{(1+g_jh_t)P_{j,t}}{P_{fj,t}}\right]^{-\epsilon_2}(1-\kappa_1)\left(\frac{P_{fj,t}}{P_{c,t}}\right)^{-\epsilon_1}(c_{1,t}+c_{2,t}), \quad g_j \le 1, \tag{30}$$

$$c_{x,t} = \kappa_1\left(\frac{1+g_xh_t}{P_{c,t}}\right)^{-\epsilon_1}(c_{1,t}+c_{2,t}), \quad g_x \le 1, \tag{31}$$

$$c_{m,t} = (1-\kappa_3)\left[\frac{1+h_t}{P_{nm,t}}\right]^{-\epsilon_3}\kappa_2\left[\frac{P_{nm,t}}{P_{fj,t}}\right]^{-\epsilon_2}(1-\kappa_1)\left(\frac{P_{fj,t}}{P_{c,t}}\right)^{-\epsilon_1}(c_{1,t}+c_{2,t}), \tag{32}$$

and the associated price indices

$$P_{c,t} = \left[\kappa_1(1+g_xh_t)^{1-\epsilon_1}+(1-\kappa_1)P_{fj,t}^{1-\epsilon_1}\right]^{1/(1-\epsilon_1)}, \tag{33}$$
$$P_{fj,t} = \left\{\kappa_2P_{nm,t}^{1-\epsilon_2}+(1-\kappa_2)[(1+g_jh_t)P_{j,t}]^{1-\epsilon_2}\right\}^{1/(1-\epsilon_2)},$$
$$P_{nm,t} = \left\{(1-\kappa_3)(1+h_t)^{1-\epsilon_3}+\kappa_3[(1+h_t)P_{n,t}]^{1-\epsilon_3}\right\}^{1/(1-\epsilon_3)},$$

$$P_t = \left[\kappa_1+(1-\kappa_1)P_{fjo,t}^{1-\epsilon_1}\right]^{1/(1-\epsilon_1)}, \tag{34}$$
$$P_{fjo,t} = \left[\kappa_2P_{nm,t}{}^{1-\epsilon_2}+(1-\kappa_2)P_{j,t}^{1-\epsilon_2}\right]^{1/(1-\epsilon_2)},$$
$$P_{nmo,t} = \left[\kappa_3P_{n,t}{}^{1-\epsilon_3}+1-\kappa_3\right]^{1/(1-\epsilon_3)}.$$

P_c is the price index for aggregate consumption, inclusive of VAT taxes. For later use, we also record the exact consumer price index P.

Unemployed individuals L_u and low-skill workers in sectors x and j live hand-to-mouth, consuming all of their income each period. The group receives fractions $\mathfrak{r}$, σ, and a of remittances $\mathcal{R}$, land rents in agriculture, r_hH, and transfer payments $\mathcal{T}$ from the government, respectively; $\mathfrak{r}$ and σ are exogenous, while a equals the group's share in the labor force L. Hence the budget constraint of the representative non-saver is

$$P_{c,t}c_{1,t} = (1-f_{wx})(w_{x,t}L_{x,t}+\sigma r_hH)+(1-f_{wj})w_{j,t}L_{j,t}+a_t\mathcal{T}_t+\mathfrak{r}(1-f_{\mathcal{R}})\mathcal{R}_t, \tag{35}$$

where

$$a_t = \frac{L_{x,t}+L_{j,t}+L_{u,t}}{\bar{L}+S},$$

S is the supply of skilled labor, $\bar{L}$ is the supply of low-skill labor, f_{wj}, f_{wx}, and $f_{\mathcal{R}}$ are ad valorem taxes on low-skill wage income and remittances, and $\sigma > 0$ in the case of smallholder agriculture.[5] To reflect the fact that some individuals may migrate from this group to the saving household as a result of receiving upper-level education and/or securing jobs in the formal sector, we refer to this group as the *ex ante* poor.

Capitalists, skilled labor, and low-skill labor in the formal sector (sectors n and b) comprise the saving class. They maximize

$$V = \sum_{t=0}^{\infty}\beta^t\frac{c_{2,t}{}^{1-1/\tau}}{1-1/\tau}, \tag{36}$$

subject to

$$\begin{aligned}P_tb_t - b_{f,t} = {}& \frac{1+r_{t-1}}{1+g}P_tb_{t-1}-\frac{1+r_f}{1+g}b_{f,t-1}-\frac{\eta}{2}(b_{f,t}-\bar{b}_f)^2+(1-f_n)r_{a,t}A \\ &+(1-f_w)[w_{n,t}(L_{n,t}+L_{b,t})+w_{s,t}S_{t-1}]+(1-\mathfrak{r})(1-f_{\mathcal{R}})\mathcal{R}_t \\ &+\sum_{\mathfrak{q}=j,n,x,b}[r_{\mathfrak{q},t}-f_{\mathfrak{q}}(r_{\mathfrak{q},t}-\delta P_{k,t})]k_{\mathfrak{q},t-1}+(1-f_h)(1-\sigma)r_{h,t}H \\ &+(1-a_t)\mathcal{T}_t-P_{c,t}c_{2,t}-\mu_tz_{t-1}-P_{k,t}\sum_{\mathfrak{q}=j,n,x,b}\left(i_{\mathfrak{q},t}+\mathbb{AC}_{\mathfrak{q},t}\right),\end{aligned} \tag{37}$$

and

$$(1+g)k_{\mathfrak{q},t} = i_{\mathfrak{q},t}+(1-\delta)k_{\mathfrak{q},t-1}, \quad \mathfrak{q}=j,n,x,b \tag{38}$$

where β is the discount factor[6]; τ is the intertemporal elasticity of substitution; b is the stock of domestic bonds; $i_{\mathfrak{q}}$ is gross investment in sector $\mathfrak{q}$; δ is the depreciation rate; r_f is the exogenous real interest rate on foreign loans b_f; r is the real interest rate on domestic bonds; μ is the user fee charged for infrastructure services; η is a positive constant; and $f_{\mathfrak{q}}$, f_h, and f_w are tax rates on capital income (net of depreciation) in sector $\mathfrak{q}$,[7] land rents, and wage income in the formal sector respectively. In the budget constraint

[5] $0 < \sigma < 1$ when sector x comprises smallholder agriculture and other sectors (e.g., estate agriculture, mining, sharecroppers).

[6] Since $c_{2,t}$ is de-trended consumption, $\beta = \beta_o(1+g)^{1-1/\tau}$, where β_o is the original discount factor.

[7] Rents in the tourism sector are taxed at rate f_n.

(37), $\mathbb{AC}_{q,t} = \frac{v}{2}\left(\frac{i_{q,t}}{k_{q,t-1}} - \delta - g\right)^2 k_{q,t-1}$ captures adjustment costs incurred in changing the capital stock in sector q[8]; $\eta(\cdot)^2/2$ measures portfolio adjustment costs associated with deviations of foreign loans from their steady-state level ($\bar{b}_f$), and P_t multiplies b_t and b_{t-1} because domestic bonds are indexed to the price level.[9] Observe also that the trend growth rate appears in several places in, reflecting the fact that some variables are dated at t and others at $t-1$.[10]

On an optimal path,

$$\eta(b_{f,t} - \bar{b}_f) = 1 - \frac{1+r_f}{1+r_t}\frac{P_t}{P_{t+1}}, \tag{39}$$

$$c_{2,t} = c_{2,t+1}\left(\beta\frac{1+r_t}{1+g}\frac{P_{t+1}}{P_t}\frac{P_{c,t}}{P_{c,t+1}}\right)^{-\tau}, \tag{40}$$

and

$$\begin{aligned}(1+r_t)\frac{P_{t+1}}{P_t}\frac{P_{k,t}}{P_{k,t+1}}\left[1+\mathbb{D}_{q,t}\right] = {} & \left(\frac{r_{q,t+1}}{P_{k,t+1}} - \delta\right)(1 - f_{q,t+1}) + 1 \\ & + \mathbb{D}_{q,t+1}\left(\frac{i_{q,t+1}}{k_{q,t}} + 1 - \delta\right) - \frac{1}{2}\mathbb{D}^2_{q,t+1}, \quad q = j, n, x, b.\end{aligned} \tag{41}$$

where $\mathbb{D}_{q,t} = v(\frac{i_{q,t+1}}{k_{q,t}} - \delta - g)$. Each of these equations admits of a straightforward intuitive interpretation. Eq. (40) is a slightly irregular Euler equation in which the slope of the consumption path depends on the real interest rate adjusted for trend growth and changes in the VAT (which enter through P_c). The other four equations are arbitrage conditions. Eqs. (41) require the return on capital, net of marginal adjustment costs, to equal the real interest rate. Similarly, Eq. (39) says that marginal transactions costs offset the interest differential between domestic bonds and foreign loans.

2.4. Public investment

Public investment i_z increases the stock of physical infrastructure per the usual law of motion:

$$(1+g)z_t = i_{z,t} + (1-\delta)z_{t-1}. \tag{42}$$

Investment in human capital takes much longer to pay off than investment in infrastructure. The time lag is six years for investment in basic education, eight years for investment in upper-level education, and three years for investment in health capital[11]:

$$S_{u,t} = i_{u,t-8} + (1-\delta_u)S_{u,t-1}, \tag{43}$$

$$S_{b,t} = i_{b,t-6} + (1-\delta_b)S_{b,t-1}, \tag{44}$$

$$G_t = i_{g,t-3} + (1-\delta_g)G_{t-1}. \tag{45}$$

Fixed input–output coefficients, ($\phi_1, \phi_2,$ *and* ϕ_3) connect increases in education capital and health capital to the supply of high-skill labor and the productivity of low-skill labor:

$$S_t = S_o + \phi_1(S_{u,t-1} - S_{uo}), \tag{46}$$

$$e_{b,t} = [1 - ES_t + \phi_2(S_{b,t-1} - S_{bo})][1 - HS_t + \phi_3(G_{t-1} - G_o)], \tag{47}$$

where HS_t and ES_t are Covid-19 shocks to the health and education level of the workforce. In passing, note that health and education are gross complements and that the degree of complementarity depends positively (through ϕ_2 and ϕ_3) on the rates of return to the two types of human capital.[12]

[8] For simplicity, we assume that adjustment costs are zero when the capital stock grows at the trend growth rate g. This ensures that adjustment costs are zero across steady states as in models that ignore trend growth.

[9] The nominal value of government bonds carried over from the previous period is B_{t-1}. This is marked-up through indexation to $(P_{1,t}/P_{1,t-1})B_{t-1}$, where $P_1 = P_x[\kappa + (1-\kappa)P_n^{1-\epsilon}]^{1/(1-\epsilon)}$. After dividing by $P_{x,t}$ (the traded good is the numeraire), we get $(P_{1,t}/P_{x,t})(B_{t-1}/P_{1,t-1}) = P_t b_{t-1}$ in the private agent's budget constraint.

[10] The convention for detrending the capital stocks differs from that for other variables. Because $K_{j,t-1}$ (the capital stock before detrending) is the capital stock in use at time t, we define $k_{j,t-1} \equiv K_{j,t-1}/(1+g)^t$. Under this convention, $i_j = (\delta + g)k_j$ in the long run — as required for the capital stock to grow at the trend growth rate g.

[11] Spending on healthcare affects the productivity of the current adult workforce and, at a later date, the productivity of today's children when they enter the workforce. The correct choice for the lag in (45) depends on the age at which children start work and on the share of healthcare spending allocated to adults vs. children.

[12] Numerous studies document the joint complementarity of education and health. See, for example, Pritchett and Summers (1996), Thomas and Strauss (1997), Bhargava et al. (2001), Miguel and Kremer (2004), and Adhvaryu and Nyshadham (2012).

2.5. Fiscal adjustment and the public sector budget constraint

The government spends on transfers, debt service, and investment in infrastructure, education, and health. It collects revenue from user fees for infrastructure services, the consumption VAT, and taxes on wages, profits, and remittances. When revenues fall short of expenditures, the resulting deficit is financed through domestic and external borrowing, such that:

$$\begin{aligned}\Delta dc_t + \Delta d_t + \ P_t\Delta b_t = {} & P_{z,t}i_{z,t} + P_{g,t}i_{g,t} + P_{s,t}i_{s,t} + \frac{r_d - g}{1+g}d_{t-1} \\ & + \frac{\eth r_{dc} - g}{1+g}dc_{t-1} + \frac{r_{t-1} - g}{1+g}P_t b_{t-1} + \mathcal{T}_t - \mu_t z_{t-1} \\ & - h_t(P_{n,t}c_{n,t} + g_j P_{j,t}c_{j,t} + g_x P_{x,t}c_{x,t} + c_{m,t} + q_{b,t}) \\ & - f_{n,t}r_{a,t}A - f_{h,t}r_{h,t}H - \sum_{\mathrm{q}=j,n,x,b} f_{\mathrm{q},t}[(r_{\mathrm{q},t} - \delta P_{k,t})]k_{\mathrm{q},t-1} \\ & - f_{wx,t}w_{x,t}L_{x,t} - f_{wj,t}w_{j,t}L_{j,t} - f_{w,t}[(w_{n,t}(L_{n,t} + L_{b,t})] + w_{s,t}S_t] \\ & - f_{\mathcal{R}}\mathcal{R}_t, \end{aligned} \tag{48}$$

where $i_s \equiv i_b + i_u$; r_d and r_{dc} are the interest rates (in dollars) on concessional debt d and commercial debt dc; and $\Delta b_t = b_t - b_{t-1}$, $\Delta dc_t = dc_t - dc_{t-1}$, $d_t = d_t - d_{t-1}$. In the coefficient multiplying dc_{t-1}, $\eth$ equals zero when creditors agree (grudgingly) to temporarily suspend interest payments on commercial/semi-concessional loans.

Countries differ in their access to world capital markets. In the base case, the borrowing plus amortization schedule for non-concessional loans is fixed exogenously during the Covid crisis and for some years thereafter. Thus, in any given year, the *ex ante* financing gap (GAP) is

$$\begin{aligned}GAP_t = {} & P_{z,t}i_{z,t} + P_{g,t}i_{g,t} + P_{s,t}i_{s,t} + \frac{1+\eth r_{dc,t}}{1+g}dc_{t-1} - dc_t \\ & + \frac{r_d - g}{1+g}d_{t-1} + \frac{r_{t-1} - g}{1+g}P_t b_{t-1} + \mathcal{T}_o - \mu_t z_{t-1} \\ & - h_o(P_{n,t}c_{n,t} + g_j P_{j,t}c_{j,t} + g_x P_{x,t}c_{x,t} + c_{m,t} + q_{b,t}) \\ & - f_{n,t}r_{a,t}A - f_{h,t}r_{h,t}H - \sum_{\mathrm{q}=j,n,x,b} f_{\mathrm{q},t}[(r_{\mathrm{q},t} - \delta P_{k,t})]k_{\mathrm{q},t-1} \\ & - f_{wx,t}w_{x,t}L_{x,t} - f_{wj,t}w_{j,t}L_{j,t} - f_{w,t}[(w_{n,t}(L_{n,t} + L_{b,t})] + w_{s,t}S_t] \\ & - f_{\mathcal{R}}\mathcal{R}_t, \end{aligned} \tag{49}$$

while domestic and external concessional debt grow at the rates

$$\begin{aligned}\Delta d_t = {} & \lambda_d[GAP_t + \mathcal{T}_t - \mathcal{T}_o - (h_t - h_o)(P_{n,t}c_{n,t} + g_j P_{j,t}c_{j,t} \\ & + g_x P_{x,t}c_{x,t} + c_{m,t} + q_{b,t})],\end{aligned} \tag{50}$$

$$\begin{aligned}P_t\Delta b_t = {} & (1-\lambda_d)[GAP_t + \mathcal{T}_t - \mathcal{T}_o - (h_t - h_o)(P_{n,t}c_{n,t} + g_j P_{j,t}c_{j,t} \\ & + g_x P_{x,t}c_{x,t} + c_{m,t} + q_{b,t})].\end{aligned} \tag{51}$$

GAP is revenue collected at the initial tax rate (h_o), the current user fee for infrastructure services, and current taxes on wages, profits, and remittances less the sum of investment in infrastructure, education, and health, net non-concessional borrowing, interest payments on the debt, and initial transfers ($\mathcal{T}_o$). In the short to medium run, part of this gap can be financed by borrowing according to (50) and (51). Debt sustainability requires, however, that the VAT and transfers eventually adjust to cover the entire gap. We let policy makers divide the burden of adjustment (net windfall when GAP<0) between spending cuts and tax increases. The debt-stabilizing values for transfers and the VAT — their *long-run target* values — are

$$\mathcal{T}_t^{targ} = \mathcal{T}_o - \lambda \mathrm{GAP_t}, \quad 0 \le \lambda \le 1, \tag{52}$$

$$h_t^{targ} = h_o + (1-\lambda)\frac{\mathrm{GAP_t}}{P_{n,t}c_{n,t} + g_j P_{j,t}c_{j,t} + g_x P_{x,t}c_{x,t} + c_{m,t} + q_{b,t}}, \quad 0 \le \lambda \le 1, \tag{53}$$

where policy makers' preferences fix λ.

Eqs. (52) and (53) are paired with targets for the long-run levels of domestic and external commercial debt. The reaction functions that govern the paths of h and T incorporate this target as well as socio-political constraints on how much and how fast fiscal policy can change:

$$\begin{aligned}h_t = Min\Big\{ & h_{t-1} + \lambda_1(h_t^{targ} - h_{t-1}) + \lambda_2\frac{d_{t-1} - d^{targ}}{P_{n,t}q_{n,t} + P_{j,t}q_{j,t} + P_{x,t}q_{x,t} + q_{b,t}} \\ & + \lambda_5\frac{b_{t-1} - b^{targ}}{P_{n,t}q_{n,t} + P_{j,t}q_{j,t} + P_{x,t}q_{x,t} + q_{b,t}},\ \bar{h}\Big\},\end{aligned} \tag{54}$$

$$\mathcal{T}_t = Max\left\{\mathcal{T}_{t-1} + \lambda_3(\mathcal{T}_t^{targ} - \mathcal{T}_{t-1}) - \lambda_4(\ d_{t-1} - d^{targ}) - \lambda_6(b_{t-1} - b^{targ}),\ \bar{\mathcal{T}}\right\}. \tag{55}$$

$\bar{h}$ is the upper bound on the VAT and $\bar{\mathcal{T}}$ is the lower bound on transfers. Inside the bounds, the parameters λ_1-λ_6 determine whether policy adjustment is fast or slow.

2.6. Market-clearing conditions

Flexible wages and prices equate demand to supply in the market for skilled labor, the market for low-skill labor in the (x, j) sector, and the markets for the two nontraded goods:

$$S_t = S_{x,t} + S_{n,t} + S_{j,t} + S_{bb,t}, \tag{56}$$

$$\bar{L}_{xj,t} = L_{x,t} + L_{j,t}, \tag{57}$$

$$q_{n,t} = c_{n,t} + \sum_{\mathrm{q}=j,n,x,b} a_{kn}\left[i_{\mathrm{q},t} + \mathbb{AC}_{\mathrm{q},t}\right] + a_{zn} i_{z,t} + a_{sn} i_{s,t} + a_{gn} i_{g,t}, \tag{58}$$

$$q_{j,t} = c_{j,t} + \sum_{\mathrm{q}=j,n,x,b} a_{kj}\left[i_{\mathrm{q},t} + \mathbb{AC}_{\mathrm{q},t}\right] + a_{zj} i_{z,t} + a_{sj} i_{s,t} + a_{gn} i_{g,t}. \tag{59}$$

External Debt Accumulation and the Current Account

The model is closed by the accounting identity that growth in the country's net foreign debt equals the current account deficit. Adding the public and private budget constraints produces[13]

$$\begin{aligned}
\Delta d_t + \Delta dc_t + \Delta b_{f,t} = {} & P_t(c_{1,t} + c_{2,t}) + P_{z,t} i_{z,t} + P_{s,t} i_{s,t} + P_{g,t} i_{g,t} \\
& \sum_{\mathrm{q}=j,n,x,b} P_{k,t}\left[i_{\mathrm{q},t} + \mathbb{AC}_{\mathrm{q},t}\right] \\
& + \frac{r_d - g}{1+g} d_{t-1} + \frac{\eth r_{dc} - g}{1+g} dc_{t-1} + \frac{r_f - g}{1+g} b_{f,t-1} \\
& + \frac{\eta}{2}(b_{f,t} - \bar{b}_f)^2 - P_{n,t} q_{n,t} - q_{b,t} - P_{j,t} q_{j,t} - P_{x,t} q_{x,t} \\
& \mathcal{R}_t - h_t g_b q_{b,t}.
\end{aligned} \tag{60}$$

3. Calibration and the Covid-19 shock

3.1. The core model

The model is calibrated to an initial pre-pandemic equilibrium following the procedure outlined in Buffie et al. (2020). The calibration parameters are shown in Table 1, but readers are referred to our earlier work for a detailed discussion on the basis for these calibration values. Here we restrict the discussion to the calibration of the multi-faceted economic shock triggered by Covid-19 and the associated shocks to health and education. In order to isolate the effects of the pandemic itself, these are based on IMF and World Bank forecasts formed as the pandemic emerged but before subsequent non-pandemic global events occurred. There is wide variation in how these shocks have affected different countries and so we calibrate to average values for low-income countries. We start with the immediate economic shock before turning to the health and human capital shock.

3.2. The economic shock

Table 2 reports the paths for the exogenous variables driving the principal economic elements of the Covid-19 shock which consisted of included lock-downs and disruptions to global supply chains, sharp decreases in commodity prices and remittances, a collapse in tourism, and a range of capital market developments.

Lockdown and global supply chain shocks

We represent domestic lock-downs and interruptions to global supply chains as temporary productivity shocks. The sectoral distribution of the shocks is asymmetric: we assume the productivity shock is most severe in the formal sector, followed by the informal sector and (smallholder) agriculture.[14,15] The direct hit to productivity, inclusive of the tourism shock (see below), reduces GDP by 6.3 percent in the first year. The shocks then wear off quickly, disappearing altogether by year four. This accords with IMF, World Bank, and Asian Development Bank forecasts for per capita GDP in the median LDC, in Asia, and in Sub-Saharan Africa (International Monetary Fund, 2021; World Bank, 2020a; Asian Development Bank, 2020).

[13] VAT revenues collected in the tourism sector increase national income and reduce the current account deficit because the tax falls entirely on foreign tourists.

[14] This is, of course, not always the case. For example, lockdown-induced labor shortages have severely disrupted agricultural production in India (Ray and Subramanian, 2020; Rawal and Verma, 2020).

[15] Given the initial relative productivity differential between formal and informal sectors, the more the productivity shock falls on the rural and urban informal sectors, the lower the aggregate output loss relative to the baseline (the cumulative output loss relative to the pre-pandemic trend over the first five years is about three quarters of one percent of initial GDP, namely 19.1 percent compared to 19.85 percent in the baseline). The bigger effects in this case are, as expected, distributional, with informal wages and hence the incomes of the low-skilled and poor, falling more rapidly through the crisis and recovering more slowly afterwards. By contrast, skilled wages and incomes of the rich are more protected than in the baseline case.

Table 1
Baseline calibration.

Parameter/Variable	Value
Consumption shares of the imported, formal and informal goods ($\gamma_m, \gamma_n, \gamma_j, \gamma_x$)	0.1, 0.4, 0.2, 0.3
Intertemporal elasticity of substitution (τ)	0.4
Elasticity of substitution between good x and goods n, j, and m (ϵ_1)	0.5
Elasticity of substitution between formal and informal traded goods (ϵ_2)	0.5
Elasticity of substitution between imported good and the formal good (ϵ_3)[a]	5
Wages in the formal and informal sectors (w_s, w_n, w_j)	3, 1, 0.6
Factor shares in the formal sector (α_n, θ_n)	0.5, 0.3
Factor shares in the informal sector (α_j, θ_j)	0.2, 0.2
Factor shares in agriculture (χ, α_x, θ_x)	0.3, 0.2, 0.05
Factor shares in the tourism sector ($\alpha_b, \theta_b, \theta_a$)	0.4, 0.3, 0.15
Depreciation rates ($\delta, \delta_z, \delta_b, \delta_u$)	0.05
Real interest rates on concessional and semi-concessional loans (r_d)	0.013
Real interest rates on external commercial debt (r_{dc})	0.045
Trend growth rate (g)	0.023
Ratio of user fees to recurrent costs (f)	0.5
Consumption VAT rates (h, g_j, g_x)	0.2, 0.3, 0.1
Taxes on profits (f_n, f_j, f_x, f_b)	0.15, 0.03, 0.02, 0.15
Taxes on wages and land rents (f_w, f_{wj}, f_{wx}, f_h)	0.12, 0.01,0.01, 0.01
Tax rate on remittances (f_R)	0.1
Return on infrastructure (R_z)	0.2
Real interest rate on domestic bonds (r)	0.06
Real interest rate on foreign loans held by the private sector (r_f)	0.06
Interest elasticity of private capital flows (Γ)	1
Ratio of infrastructure investment to GDP $\left(P_z i_z/GDP\right)$	0.06
Ratios of education investment to GDP $\left(P_s i_b/GDP, P_s i_u/GDP\right)$	0.028, 0.012
Ratio of public investment in health to GDP $\left(P_g i_g/GDP\right)$	0.019
Ratio of remittances to GDP (base case)	0.072
q-elasticity of investment spending (Ω)	2.5
Share of VAT adjustment in long-run fiscal adjustment (λ)	1
Ratio of domestic public debt to initial GDP (b/GDP)	0.15
Ratio of private foreign debt to initial GDP (b_f/GDP)	0
Ratio of concessional public external debt to initial GDP (d/GDP)	0.18
Ratio of non-concessional public external debt to initial GDP (dc/GDP)	0.2
Long-run targets for public domestic and concessional debt ($b^{\text{target}}, d^{\text{target}}$)	0.15, 0.18
Share of new skilled workers drawn from unskilled workers pool in sector x-j (Δ_{xj})	0.8
Fraction of newly created/vacant formal sector jobs filled by workers from sector x-j (ξ)	0.5
Unemployment rate (u)	0.06
Elasticity of the real wage in formal sector w.r.t. the real wage in informal sector (g_2)	0.1
Elasticity of the real wage in formal sector w.r.t. the unemployment rate (g_3)	0.5
Non-traded cost shares in private capital goods (α_{kj}, α_{kn})	0.35, 0.15
Non-traded cost shares in infrastructure (α_{zj}, α_{zn})	0.35, 0.15
Non-traded cost shares in education capital (α_{sj}, α_{sn})	0.2, 0.6
Non-traded cost shares in health capital (α_{gj}, α_{gn})	0.35, 0.15
Gross return to infrastructure (R_z)	0.27
Gross returns to education (R_u, R_b)[b]	0.3, 0.3
Gross return to health (R_g)	0.2
Relative return on maintenance to new infrastructure investment (R_{mz})	1
Ratio of elasticities of sectoral output w.r.t. infrastructure ($\psi_n/\psi_x, \psi_j/\psi_x$)	1, 1
Share of tourism sector in GDP	0.04

[a]This elasticity implies the formal and imported consumption goods are close substitutes.
See Buffie et al. (2020) for a discussion of the implications for the case where the elasticity of substitution is low.
[b]For the assumed time lags, the internal rate of return is 12 percent for basic education and 10 percent for upper-level education.

Tourism

Our initial calibration sets the initial share of tourism at 4 percent of GDP, the average value in low- and lower-middle income countries (World Development Indicators), and reduces the sector's output in year one by 40 percent, consistent with the decrease in global tourism revenue in 2020.[16] In line with industry projections, recovery is expected to be much slower than other sectors, with tourism revenues only regaining their pre-pandemic level four or more years after the onset of the pandemic (Behsudi, 2020).[17]

[16] See https://www.Statistica.com.

[17] A substantial number of low-income countries, particularly small island economies are much more dependent on the tourism sector as a source of export earnings and employment. Recognizing this, Buffie et al. (2022b) considers the vulnerability of heavily tourism-dependent island economies.

Table 2
Baseline economic shocks.

	t = 1	t = 2	t = 3	t = 4	t = 5 - ∞
Lockdown and global supply chain shocks (% decrease in TFP)					
Formal Sector	8	5	2	0	0
Informal Sector	4	3	1	0	0
Agriculture	2.7	1.5	1	0	0
Tourism	40	30	20	10	0
Commodity price shock (% decrease from baseline)	3	2	1	0	0
Remittances shock (decrease as % of GDP)	0.5	0.5	0.3	0.1	0
Suspension of wage curve (Value of $\mathfrak{z}$ parameter in wage curve)/2	1	1	0.5	0	0
G20 Debt Service Suspension Initiative (interest rate on non-concessional borrowing)	0%	0%	0%	4.5%	4.5%
SDR Allocation taken as grant financing (percent of GDP)	0	1	1	0	0

Notes: 1/ For years 5 and beyond, all shocks are zero. 2/ See text for derivation of wage curve.

Commodity price shock

The recession in developed countries greatly depressed the demand for developing country exports. Prices dropped for all commodities at the beginning of 2020, particularly so for oil, other fossil fuels and base metals. For those exporters of other commodities, the global demand squeeze generated smaller but still significant price drops through 2020 and into 2021.[18]

Remittances

One of the biggest areas of uncertainty at the onset of the pandemic was the response of remittances. Initial estimates by the World bank suggested a decline of as much as 20 percent in remittance flows to developing countries (Sayeh and Chami, 2020). In fact, remittance flows appeared to have been much more resilient than first thought, partly because furlough and other income support mechanism were applied more widely and more generously in developed countries than originally anticipated, and partly because of the nature of employment patterns through the pandemic (Kpodar et al., 2021). It may also have been the case that migrants reduced their own consumption to sustain their remittance flows. In some regions, recorded remittances rebounded strongly in the second half of 2020 to the point where they matched or exceeded pre-Covid levels in Latin America and the Caribbean, the Pacific, and Southeast Asia.[19] While the detailed analysis of the drivers of remittances is far from conclusive, and while *measured* remittances may be biased upwards as a result of limits on mobility leading to the substitution from informal to formal channels, this emerging evidence saw the World Bank revise its estimates upwards. By October 2020 it was projecting decreases of 7.2 percent in 2020 and 7.5 percent in 2021 (World Bank, 2020b). The shock path in Table 2 applies this projected contraction to the average value of remittances in low-income countries (7.2 percent of GDP, according to World Development Indicators).

Formal sector wage setting

We assume the efficiency wage mechanism is temporarily suspended during the pandemic as social norms may constrain firms' willingness to take advantage of the severely depressed labor market to pay abnormally low wages (see (25)). This puts a floor under formal sector wages throughout the crisis. Compared to the case where the wage curve operates, formal sector wages are 3 to 5 percent higher, holding all other elements of the shock constant. The overall adverse impact on output and consumption is very small at little more than 0.1 percent of GDP.

18 Commodity prices have, of course, risen since 2021 but for the purpose of isolating the effects of the pandemic, we rely on projections made in 2021.

19 See for example Lopez-Calva (2020), Guild (2021) and Howes and Surandiran (2020).

Debt service on non-concessional debt

The G20's Debt Service Suspension Initiative (DSSI) provided for suspension of interest payments on non-concessional loans from governments and international organizations (but not private investors), initially through to the end of 2021 (World Bank, 2021). For the average low-income country, IDA eligibility means that the value of this concession has been modest.

The 2021 SDR Allocation

The US$ 650 billion Special Drawing Right (SDR) issue approved by the IMF in August 2021 represented an additional one-off resource flow to the median low-income country of approximately 2 percent of pre-pandemic GDP: countries could add this to reserves or draw it down as financing. We assume the SDR inflow is treated as additional financing that is drawn down over two years starting in year $t = 2$.

Concessional financing

The final capital account component is concessional financing.[20] Many, but not all, of the IFIs have moved quickly to increase flows of concessional lending during the pandemic (Centre for Global Development, 2021). Since we treat concessional financing as an element of the financing program, it becomes a (partially) endogenous financing flow, adjusting to satisfy the residual external and fiscal balance. We return to this in Section 4 below.

3.3. Shocks to health and human capital

However difficult it has proven to be in advanced economies, remote teaching and learning has been almost totally ineffective in low-income countries, particularly at the basic education level (York et al., 2020). As Goldberg and Reed (2020) note, less than a third of low-income countries have been able to provide any kind of distance learning to their students. In the short term, therefore, school closures map directly into lost learning. Psacharopoulos et al. (2020) calculate the associated decrease in adult earnings of the affected cohort by multiplying the time out of school by an estimate of the return to schooling. Writing in May 2020, they postulated a return of 8 percent per year of school — conservative in their view — and assumed three months of lost learning. The implied decrease in the aggregate effectiveness of human capital (the HS_t term in Eq. (47)) then equals the decrease in future earnings, 2.67 percent, multiplied by the weight of the affected cohort in the aggregate low-skill labor force. At its peak, the latter is approximately 20 percent, so the decrease in e_b bottoms out at 0.53 percent.

A loss of around a half of one percent is, however, probably too small, for at least two reasons. First, it ignores the cumulative self-productivity of human capital. Loss of learning at one grade reduces learning in subsequent grades (Kaffenberger, 2021). Consequently, short-term learning losses compound into larger learning losses in later years and, as research by Andriabi et al. (2020) and Kaffenberger and Pritchett (2020) on the consequences of a major education shock in Pakistan demonstrates, this compounding effect is large. The 2005 earthquake in northern Pakistan closed schools for fourteen weeks. Andriabi et al. (2020) found that four years later the cumulative learning loss had reached 1.5 school years at all grade levels. Extending this idea and calibrating to a small data set of low- and middle-income countries, the pedagogical production function developed by Kaffenberger and Pritchett (2020) gives the same number at grade ten from three months of lost learning at grade three (Kaffenberger, 2021). Assuming a 10 percent return per year of schooling, Kaffenberger (2021) and Andriabi et al. (2020) conjecture that adult earnings of the affected cohort may decline 15 percent.

Second, in many places, school closures lasted much longer than three months. On the basis of data from 157 countries (Azevedo et al., 2020) suggest the average decrease in learning-adjusted years was 0.6 years across the entire sample, 0.8 years in East Asia and the Pacific, and 0.6 years in Sub-Saharan Africa. Combining this with Kaffenberger's estimate of cumulative learning loss results in a much larger decrease in productivity of low-skill labor: at its peak, when all of the affected cohort has entered the workforce, e_b is 5.5 percent below its pre-pandemic level.[21]

Pulling this evidence together we characterize the shock to low-skill labor productivity as playing out over three distinct phases (see Table 3). In the first phase, the shock increases (in absolute value) at an increasing rate, reaching its peak level when the last (i.e., the youngest) member of the affected cohort joins the workforce.[22] The second phase, the interregnum where the shock remains at its peak level, lasts until the oldest member of the cohort arrives at retirement age. In the final phase, the shock decreases at an increasing rate (mirroring the path in Phase 1), returning to zero on the day the last member of the cohort retires.

Lock-downs not only impacted basic education but also badly affected higher education systems across the world, although there is very little if any evidence on how loss-of-learning at this level affected the supply of skilled labor, if at all. In the absence of such evidence we adopt a limiting case and assume the supply of skilled labor, as shown in Eq. (46) is unaffected by the Covid-19 crisis. This is one reason why, dramatic though it already is, our calibration of the learning shock probably remains biased toward optimism. But in addition, it abstracts from any inter-generational transmission of learning losses and from the impact of extreme poverty on dropout and enrollment rates. Lacking data useful for calibration, we do not speculate about the magnitude of these

[20] The picture on other external private finance is difficult to evaluate. Whilst there was an initial sharp fall and bounce-back in cross-border FDI flows in developed economies, preliminary evidence suggests flows to low-income countries changed relatively little through the pandemic from their comparatively low levels (United Nations Conference on Trade and Development, 2021). We adopt a passive calibration, assuming no change in net private capital flows.

[21] This is also in line with the decrease in e_b implied by the new estimates of cumulative learning loss in Kaffenberger (2021).

[22] The shock increases at an increasing rate because the youngest children who have more years of schooling left to complete suffer the greatest cumulative learning loss.

Table 3
Health and education shocks.[a]
(Percentage decrease in effective labor e_b).

Shock	Year																
	1	2	3	4	5	6	7	8	9–46	47	48	49	50	51	52	53	54
Education	0.2	0.5	0.9	1.4	2.0	2.7	3.5	4.4	5.4	5.2	4.9	4.5	4.0	3.4	2.7	1.9	1.0
Shock	Year																
	1–5	6	7	8	9	10	11	12	13	14	15	16	17–49				
Health: Current Adults	1	0.97	0.94	0.91	0.88	0.85	0.82	0.79	0.76	0.73	0.70	0.68	0.66…0.02				
Shock	Year																
	1–9	10	11	12	13	14	15	16	17	18–54	55	56	57	58	59	60	61
Health: Children	0	0.034	0.067	0.1	0.133	0.166	0.192	0.211	0.224	0.230	0.196	0.163	0.130	0.097	0.64	0.038	0.019
Shock	Year																
	1–9	10	11–16	17	18–49	50–61											
Health: Combined	Adult Shock	0.88	0.89	0.88	0.87…0.25	Child Shock											

[a]For years not shown, all shocks are assumed to be zero.

effects, even though they clearly operate to some extent and their inclusion would increase both the size and the duration of the learning shock.[23]

Covid-19 has also taken a toll on the health of the general population in low-income countries. In the first two years of the pandemic, the direct effect on mortality has been substantially smaller than in developed countries, but the indirect effects stemming from increases in extreme poverty, suspension of childhood vaccinations, and diversion of healthcare resources from treatment of HIV, tuberculosis, malaria and a host of other morbidities look to be much larger. In the near term, the path of health shock reflects only the shock to health of the current adult population. Further out, it depends also on the shock to child health (ages 0–5). Calibration of both shocks involves a fair bit of educated guesswork. For the adult population, we use the estimates in Schultz and Tansel (1997) of how disability days in Cote d'Ivoire and Ghana affect earnings to make crude, back-of-the-envelope calculations of the impact on e_b. Pairing their estimates with the guess that Covid-19 reduces effective work time by five days yields decreases in e_b of 0.7–1.5 percent. We assume e_b declines by 1 percent in the first five years, while the pandemic runs its course,[24] and then recovers slowly over the next forty years as the affected adult cohort gradually exits the workforce.

To calibrate the shock to children's health, we relied on estimates of how early childhood malnutrition affects adult earnings. These vary, but the majority of estimates suggest that adult earnings decrease 10–20 percent.[25] Early on, moderate and severe wasting among children was projected to increase 15 percent in low- and middle-income countries (Heady et al., 2020). We bump this number up to 25 percent because child malnutrition has increased more in low-income than in middle-income countries and because the pandemic is lasting longer than originally forecast. If the affected cohort comprises children ages 0–5 between 2020 and 2024, the decrease in aggregate labor productivity when the full cohort has entered the workforce is 0.16–0.31 percent. We chose the average, 0.23 percent, to calibrate the shock path in Table 3.

4. Results

In the absence of detailed data with which to tightly discipline the model and calibration of the shock, our simulations are necessarily tentative. The results we present here are not offered as forecasts for any individual or group of countries. They are designed to assess the broad contours and duration of the macroeconomic adjustment requirements facing low-income countries and how the burden of adjustment may be distributed between domestic fiscal adjustments and external finance. All the results can and ought to be subject to extensive sensitivity analysis: we have conducted some of this ourselves and are confident that the main analytical messages that emerge below are reasonably robust to plausible variations in the key parameters of the calibration. To keep the analysis manageable we consider on a small number of simulations here: please see Buffie et al. (2022b) for a more extended analysis. High level results are summarized in Table 5, while Figs. 1 through 3 illustrate the dynamics of adjustment.

Before presenting these results in detail, we first note that the short-run costs over the one-to-three years are already quite well understood and are broadly consistent with the picture of modest recovery generated by the IMF and others over this horizon (see

[23] Kaffenberger (2021) find a strong relationship between the dropout rate and learning in estimates based on longitudinal data for children ages 8–15 in Ethiopia, India, Peru, and Vietnam. Jaume and Wilen (2019) present evidence of significant inter-generational effects of learning loss in Argentina.

[24] Current expert opinion holds that only half of the low-income country population will have been vaccinated by the start of 2024.

[25] See Alderman et al. (2006), Alderman et al. (2009), Glewwe et al. (2001), Haddad and Bouis (1991), Thomas and Strauss (1997), Bossavie et al. (2017), Vofl (2014), and Dercon and Porter (2014). The decrease in adult earnings stems in large part from the adverse effects of childhood malnutrition on school attendance, completed years of schooling, and learning while in school.

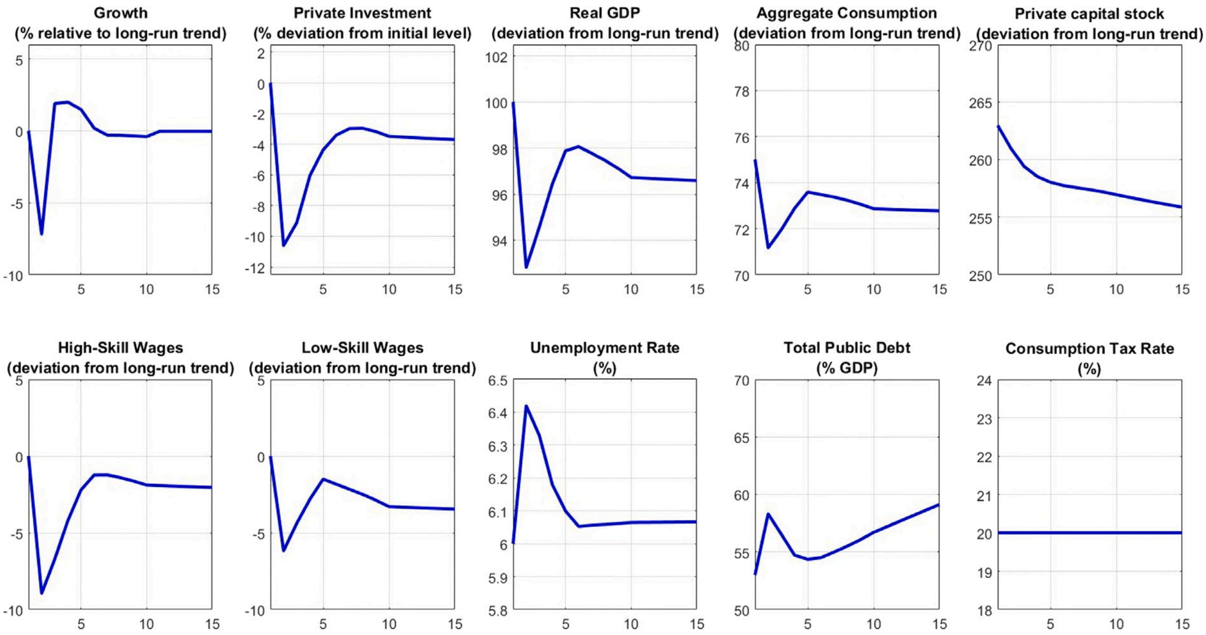

Fig. 1. Baseline shock with external concessional financing.
Notes: Dynamic response of baseline economy to Covid-19 shock with 'passive' domestic fiscal policy (no change in public spending or to domestic tax rates) and external concessional finance.

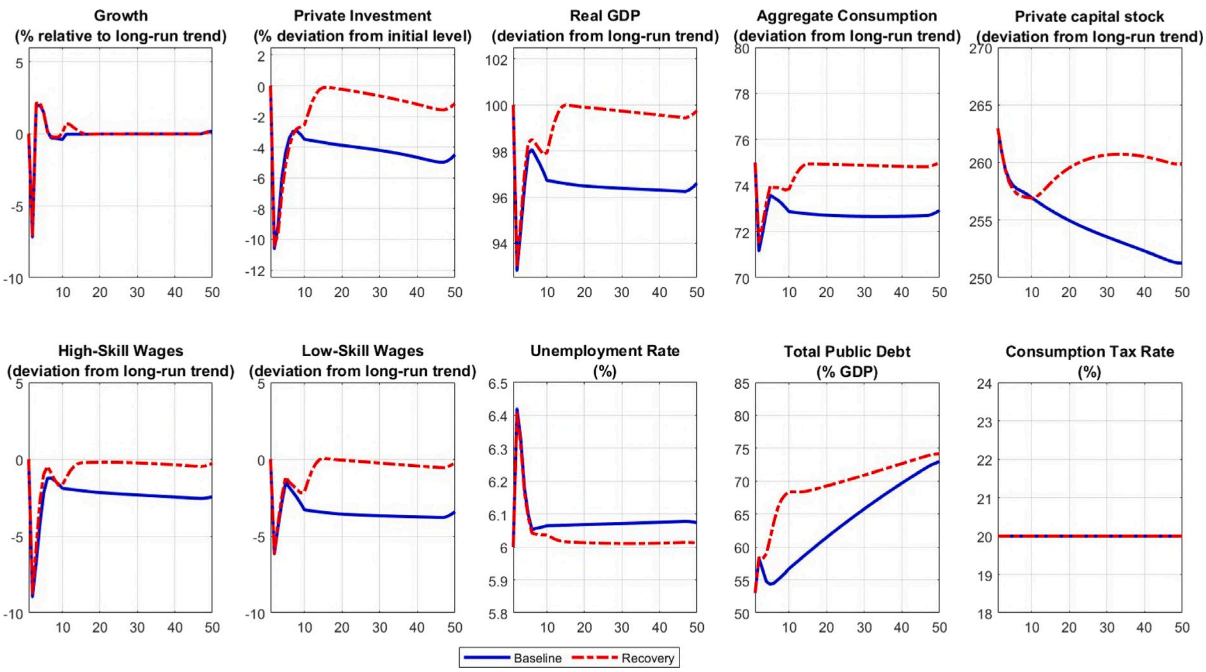

Fig. 2. Fighting back vs. passive baseline response.
Notes: Public investment program, rises by 3 percent of initial GDP by $t = 3$, providing an additional 12.95 percent of initial GDP over first eight years. Two thirds of expenditure is allocated to supporting basic education spending. External concessional finance adjusts to satisfy external and fiscal balance.

for example International Monetary Fund, 2021). This is so regardless of choices over financing. Where our analysis contributes is beyond this horizon where the effects of the scarring of human capital start to bite. What we see at this point is the short-run recovery slowing, as labor productivity and hence export competitiveness weakens, and as the restoration of a growth-supporting fiscal stance is compromised. Without significant restorative investment in human capital the risk of the recovery dissipating is elevated. It is

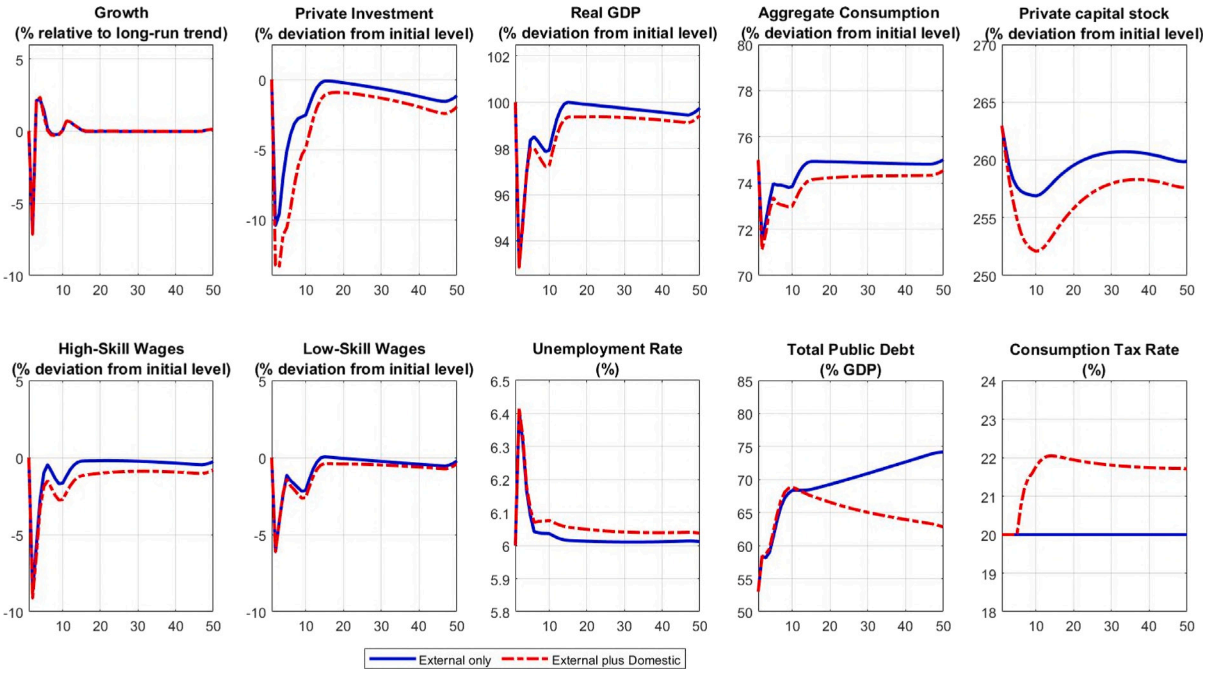

Fig. 3. Fighting back with domestic financing.
Notes: Public investment program as per Fig. 2. Plot compares full external concessional finance with case where donors provide only an additional 10 percentage points of initial GDP in concessional funding, which covers approximately 50 percent of the additional public investment.

this process that gives substance to the widely-cited claim that the pandemic risks rolling back twenty years of development (United Nations Development Programme, 2020).

4.1. Baseline scenario: Riding out the pandemic

We start with a baseline scenario in which the government tries to ride out the pandemic without fundamentally changing the stance of domestic public policy, even as the domestic tax base shrinks. This gives us a benchmark against which to later assess the impact of public investment. Fig. 1 shows the outcome when donors supply concessional loans as needed to forestall cuts in public investment while holding domestic taxes, transfers and borrowing constant. Domestic fiscal policy is thus completely passive; the government does not spend a nickel to combat the economic fallout of the pandemic.[26] Real GDP, aggregate private consumption, private capital, unemployment and the consumption tax are measured in levels, while growth, investment and wage rates are measured as percentage deviations from their long run trend. Public debt is expressed as a percentage of current GDP.[27]

As expected, the short run is brutal. Year one is all misery: GDP, the real high-skill wage, and the real informal wage for low-skill labor decrease 7.2, 9.1, and 6 percent, respectively; the private investment rate and formal sector employment plunge by around 10 percent. The collapse of the domestic economy sees the debt to GDP ratio jump from around 53 to 58 percent of GDP when adjustment is externally financed – with about half of this coming from additional borrowing – and the domestic tax rate jump by two percentage points when adjustment is tax financed. In years 2–4, as the initial shock dissipates the economy rebounds and the debt ratio begins to decline. These results conform to the prevailing narrative for the short-run economic impact of Covid-19 in low-income countries. The recession in year one and the ensuing recovery in years 2–4 are in line with assessments and projections made by the IMF (International Monetary Fund, 2021), while the decrease in real wages in the informal sector agrees with the data for Asia in 2020 (Jurzyk et al., 2020) and forecasts by International Labour Organisation (2020).[28]

Where we part company with much of the literature is in our prognosis for the medium and long term. Four years after the onset of the pandemic, GDP, real wages, and formal sector employment have climbed back to within 1–2 percent of their pre-pandemic

[26] Passivity in this case entails that the debt service costs associated with additional non-concessional borrowing are themselves capitalized through further borrowing.

[27] The numerical simulations are free of approximation error — in all scenarios, they track the global nonlinear saddle path. The solutions were generated by set of programs written in Matlab and Dynare 4.4.3.

[28] As shown in Table 5, the simulated cumulative shortfall from trend output in the first two post-pandemic years is between 12.2% and 12.6% depending on financing; the corresponding cumulative loss measured in constant price GDP from the World Bank World Development Indicators is 11.4%, after adjusting for the assumed model trend growth. See World Development Indicators, GDP per capita (constant 2015 US$) Ref:NY.GDP.PCAP.KD.

Table 4
Public investment program
(in Percent of Initial GDP).

Shock	Year							
	1	2	3	4	5	6	7	8…
Education (i_b)	0.2	1	2	2	1.5	1	0.5	0.2
Health (i_g)	0.2	1	1	0.75	0.75	0.5	0.25	0.1
Total ($i_b + i_g$)	0.4	2	3	2.75	2.25	1.5	0.75	0.3

levels, absent any further Covid or other shocks. But the recovery then falters as the adverse effects on health and education start to take their toll, reducing both human and non-human capital formation. Since human and non-human capital are gross complements in production, the decrease in labor productivity depresses the return to and volume of private investment and hence the capital stock and output. By year ten, GDP is still 3.2 percent below its pre-pandemic level, and the cumulative output and private consumption losses relative to trend since the onset of the pandemic are staggeringly high at 34 and 21 percent, respectively. Even then, output, wages and consumption are still falling: indeed, were we to roll this forward, real aggregates are still some 2.5–3 percent lower than their initial levels and still slowly decreasing over the long-run. In present value terms, the cumulative losses of output and aggregate consumption that are *directly* attributable to the long-term effects of the combined loss-of-learning and health shocks are approximately 54 percent and 36 percent of initial GDP respectively (see Table 5).

Moreover, as output fails to recover over the medium term, the fiscal burden remains elevated long after the initial shock has passed which explains a long slow rise in public debt to a peak of 72 percent of GDP at $t = 52$ before slowly returning to its initial value. This trajectory of public debt might not be of concern if it purchased a quick recovery to the pre-pandemic trend growth. But it does not. Because of long-lasting damage to human capital, the recovery stalls out. The message is simple: left unaddressed, the degradation of health and human capital occasioned by the pandemic converts the short-run contraction into a severe economic decline over an extended medium term.[29]

4.2. *Fighting back with public investment*

We now consider the outcomes when the government seeks to repair the damage done to the country's human capital by ramping up investment in health and basic education (i.e., primary and lower-secondary education spending) in the short/medium run (See Table 4). The aggregate public investment rate, measured in terms of initial GDP, rises from 10.7 to 13.7 percent in the third year after the crisis hits and provides an additional 12.95 percent of initial GDP to health and education in total over the first eight years. Two-thirds of the new spending goes to education and the balance to healthcare.[30] We examine this fighting-back strategy under two alternative public finance scenarios. In the first, we again assume official creditors make available sufficient concessional loans to finance the entire investment program, and do so at a constant and highly-subsidized interest rate (of 1.3 percent compared to a real rate on non-concessional finance of 6 percent per annum). In reality, however, the supply of concessional finance may be constrained, either because of concerns about exposure to default risk in specific countries, or simply because of excess demand for such funding. In our second scenario, therefore, we consider the case where external concessional finance meets only half of the costs of the program, with the balance falling on domestic fiscal instruments. Domestic financing may come from tax increases, recurrent or investment expenditure adjustment or some combination of all three. Here we focus on a combination of adjustments to the consumption tax and domestic public borrowing.[31]

4.2.1. *Public investment fully funded by external concessional debt*

Consider first the case where the investment program is fully financed by raising external concessional debt. Fig. 2 compares the outcome of this program against the passive baseline. Although the catastrophic short-run hit to the economy remains effectively baked-in, the medium term outcome for the real economy is substantially improved. Nonetheless, given the initial hit to private investment and to human capital and the attenuated recovery of both, it still takes *more than a decade* for per capita incomes, formal sector employment, and real wages of the poor to reconnect with their pre-pandemic trend levels. The cumulative output loss over the first decade is around a third lower than in the baseline but still remains appalling high at 20.3 percent.

[29] These general pattern described above repeats under alternative assumptions about the financing of adjustment although the quantitative impact differs. For example, if adjustment is financed by unrequited grants from donors rather than by concessional loans, the cumulative output loss over the first ten years is approximately two percentage points lower at 32 percent and the cumulative loss of consumption around 1 percent lower. By contrast, if adjustment is accommodated by a reduction in recurrent government spending on transfers, cumulative output losses are around 1 percent higher and private consumption losses 3 percent higher, with these differences primarily reflecting variation in the extent of crowding out of domestic private investment spending which, in turn, reflects the path of output and consumption.

[30] In a detailed analysis of Mexico's response to the Covid-19 crisis, Hannan et al. (2020) estimate that public investment needs to increase in these proportions by up to 1.5 percent of GDP over the medium term to effectively combat Covid-19. This is in addition to short-term expenditures on social safety nets and support to firms, and assumes a significant increase in investment efficiency.

[31] Clearly, adjustment could also entail no external finance or domestic tax adjustment, in which case private absorption would adjust to satisfy internal and external balance. We do not explore this case.

The trajectory of public debt implied by this response is striking. Total public debt rises rapidly in the short-medium run, increasing by 15 percent of GDP to 68 percent of GDP within the first decade, peaking at 74 percent of GDP at $t = 50$. This is superficially unnerving, but, on reflection, not necessarily a cause for concern. After year ten, the debt continues to rise, but the pace slows to 1.4 percent per decade. Moreover, because the loans are highly concessional, the run up in the debt-to-GDP ratio is sustainable without any additional fiscal adjustment. Indeed, given the degree of concessionality, such that beyond the initial impact of the shock, $r_d - g < 0$, conventional debt dynamics are 'inverted' with the implication that rolling over the debt creates *more* fiscal space. This, together with the higher path for tax revenue (relative to the counterfactual), pays for the entire increase in public investment. If the supply of concessional funding is indeed unconstrained, the favorable debt arithmetic argues in support of an even more aggressive reconstruction program than considered here. In reality, however, and despite initiatives aimed at relaxing these, there are tight constraints on the supply of concessional external finance, either because of limited resources or due to concerns about creditors' capacity to carry and service additional debt.[32]

4.2.2. Exogenous concessional financing and domestic fiscal adjustment

In this second simulation, official concessional lending is capped at an additional 10 percentage points of initial GDP and is disbursed over six years. This level of external finance covers approximately 50 percent of the cost of the public investment surge. The residual fiscal deficit is then financed by adjustments to the consumption tax rate and domestic public borrowing. Changing tax rates is politically difficult, particularly in the midst of a crisis, and we therefore assume that the maximal increase is capped at 2 percentage points above the baseline rate of 20 percent and cannot be introduced until the four years after the crisis emerges. Since we are assuming, at present, no other public expenditure adjustments, this delay means short-run fiscal adjustment falls wholly on domestic borrowing.

Fig. 3, show how this changes things. The profile for total public debt is substantially altered: the debt-to-GDP ratio peaks at $t = 10$ and then falls away sharply, with external concessional borrowing peaking at 24 percent of GDP at $t = 9$ (against an initial level of 18 percent of GDP). Given the ceiling on domestic taxation – which is hit at $t = 11$ – domestic borrowing remains above 20 percent of GDP for an extended period of time. This higher sustained domestic borrowing means domestic real interest rates remain higher for longer, dampening the private investment response and hence slowing the recovery in output and private consumption relative to the case when public investment is wholly externally financed, with similar consequences for the recovery in both skilled wages, unemployment and the income of low-skilled workers.

This pattern of response is broadly proportional to the distribution of the costs of adjustment between external and domestic financing; the more generous external financing the less pressure on domestic taxation and borrowing and the more rapid the recovery. However, the simulations presented here span only a small range of policy responses. Although not reported here, we can show that broadly similar patterns emerge if the tax adjustment occurs on the intensive margin through measures designed to widen the tax base for the consumption tax.[33]

It may also be that there is insufficient political space to achieve even this modest fiscal adjustment, tempting the authorities to contribute the financing of the public investment program by economizing on spending on the recurrent costs of maintaining public infrastructure. We can show that while cutting back on maintenance expenditure during the front-loading of the public investment surge does indeed release resources for new investment, taking the pressure off both tax and borrowing, the increased depreciation of the public capital that is occasioned by the scale-back in maintenance expenditures reduces the effective capital stock which, in turn, slows the recovery of output and consumption: such a strategy is thus ultimately self-defeating. Although we do not report the results here, we do consider these variations in domestic financing choices in the next section.[34]

5. Welfare analysis

We conclude by examining the implications of these alternative runs for welfare and, in particular, the welfare of the poor. Since our model is not built from a detailed household- or group-level disaggregation, a natural way to incorporate the welfare effects of poverty reduction among the *ex-ante* poor, i.e. those households initially unemployed or working in the agricultural and informal sectors, is to employ a social welfare function that reflects an aversion to inequality, in the spirit of Atkinson (1970) or Shorrocks (1980). We therefore define social welfare as a function of $c_t + \zeta c_t^{eap}$, where c_t is aggregate private consumption, c_t^{eap} is the consumption of the *ex ante* poor, and ζ is a measure of the relative welfare weight placed on the consumption of this latter group.[35] We embed this composite in the social welfare function:

$$SW = \sum_{t=0}^{\infty} \beta_s^t \frac{(c_t + \zeta c_t^{eap})^{1-1/\tau}}{1 - 1/\tau}, \tag{61}$$

32 See, e.g., the IMF's attempts to recycle the advanced economies' share of the 2021 SDR allocation through its new 'Resilience and Sustainability Trust' at https://blogs.imf.org/2021/10/08/sharing-the-recovery-sdr-channeling-and-a-new-trust.

33 In terms of the model this entails increasing the parameters g_x and g_j, which alters the effective tax inclusive prices confronting consumers.

34 Buffie et al. (2022b) further extend the analysis to explore how the same shocks and policy responses are likely to play out in two groups of countries that were hit especially hard by the pandemic, namely tourism-dependent and remittance-dependent economies.

35 $1 + \zeta$ measures the marginal rate of substitution in utility terms between consumption of the *ex ante* poor and the consumption of the non-poor in social welfare. See Buffie et al. (2022a).

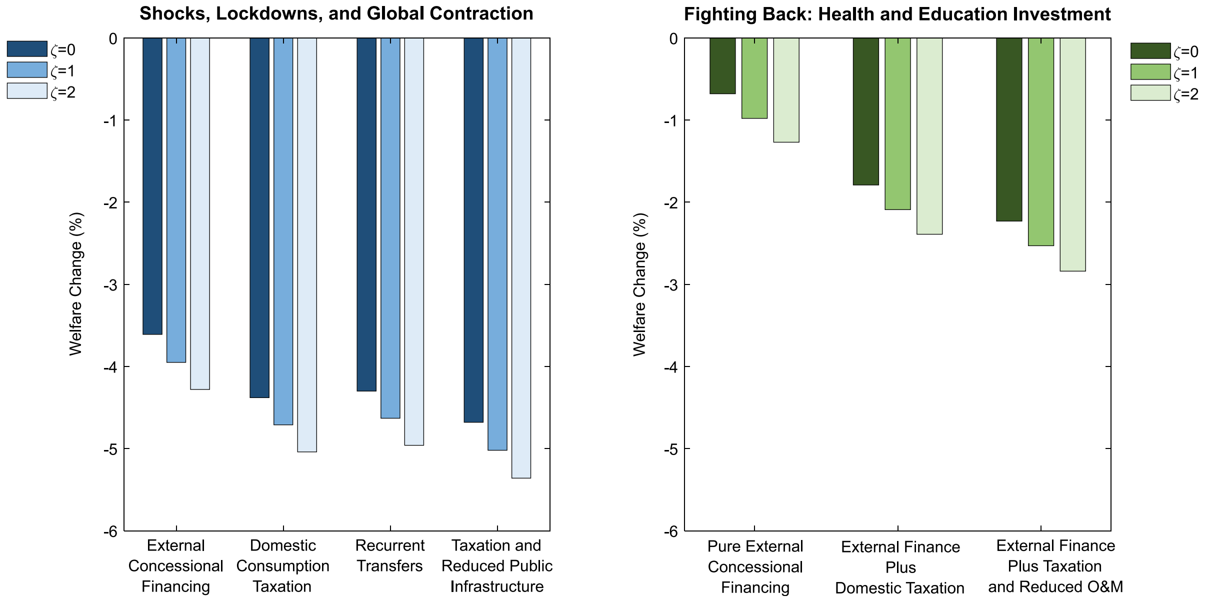

Fig. 4. Welfare: Covid-19 shock and fighting back strategies, varying the distributional weight ζ.
Notes: Welfare evaluated at the private discount rate under different distributional weights ζ. The first two runs of the left hand panel correspond to those reported in Table 5. See notes to Table 5 for detailed description of each of these runs. The final two runs correspond to cases where the fiscal authorities are unwilling or unable to adjust the domestic consumption tax but instead reduce transfers to households or reduce recurrent spending on maintenance of public infrastructure. The third run on the right hand panel considers the case described in the text where the domestic fiscal adjustment consists of reduced spending on the maintenance of the public capital stock).

where β_s is the *social* discount factor and τ is the elasticity of inter-temporal substitution in consumption. Three comments are in order. First, since the model does not allow us to directly observe the consumption of the *ex ante* poor within aggregate consumption c_t, we rely on the income of this group, y_t^{eap} which we can measure, to proxy for their consumption. Second, given that some members of the *ex ante* poor (i.e. those who secure jobs in the formal sector) will find it optimal to save following the public investment surge, using their income to proxy for their consumption will tend to marginally *understate* the welfare gains of this group, although given the amount of between-group movement, this approximation error is small. Finally, because the effects of the Covid-19 shock is long-lived and the investment and financing processes are attenuated, welfare analysis is sensitive to the choice of social discount rate. The private discount rate in the baseline is $\beta = \frac{(1+g)}{1+r} = 0.965$ (see Table 1). In both advanced and developing countries the social discount factor used to evaluate public sector projects is usually much higher.[36] The results summarized in Figs. 4 and 5 below report measures for $\zeta = 0$, $\zeta = 1$ and $\zeta = 2$ for the weight on the consumption of the poor and for the discount factor values $\beta_s = \beta = 0.965$ and $\beta_s = 0.990$.

Four key messages stand out. The first is the patently obvious observation that the welfare cost of the shock itself is very large and hence, by extension, so are the welfare costs not responding (Fig. 4, the blue-shaded bars relative to the green). Second, the poor are disproportionately hurt by this shock, and even when a recovery reform is in place, the recovery is relatively favorable to the non-poor, as indicated by the relative rankings of both the pure-shock and recovery scenarios as we increase ζ. The more weight our social welfare function places on inequality the more severe the welfare costs of the shock are on the poor (the lighter shaded bars relative to the darker shaded ones). Notice that this result emerges even though we have assumed that the adverse productivity effects of the shock fall predominantly on the formal sector. Third, as anticipated, the more that adjustment can be financed externally, the less severe the welfare cost. This is particularly so if domestic fiscal choices are so severely constrained that the authorities are forced to cut back (high-return) infrastructure spending in order to restore fiscal balance post- crisis. Finally, as Fig. 5 indicates, from a social welfare perspective, a sufficiently far-sighted view on public investment in health and education 'justifies' the accumulation of external debt (the $\beta_s = 0.990$ bars for the recovery scenarios in Fig. 5).

6. Conclusions and policy implications

Pulling the threads together, the analysis in this paper highlights four main points central to the public policy debate around responses to the Covid-19 crisis for low-income countries.

[36] For example the UK Treasury *Green Book: Guidance on Appraisal and Evaluation*, (2018) recommends $\beta_s = 0.966$–0.979 for infrastructure investments and substantially higher for health-related projects, $\beta_s = 0.993$.

Table 5
Summary macroeconomic effects of lockdown and responses.

	Year 1	Year 2	Year 5	Year10	Year20	Long Run (year 50)
[A] Shock, Lockdowns and Global Contraction 1/						
External concessional financing 2/						
Aggregate Output 4/	-7.2%	-5.4%	-1.8%	-3.1%	-3.3%	-3.0%
Aggregate Consumption 4/	-5.0%	-4.0%	-1.9%	-2.7%	-2.9%	-2.4%
Skilled Wage 4/	-9.1%	-7.0%	-1.8%	-2.6%	-2.8%	-2.7%
Income of ex ante poor 4/	-5.7%	-4.0%	-1.6%	-2.9%	-3.1%	-2.7%
Domestic Debt/GDP (initial = 15%)	16.2%	15.9%	15.3%	15.5%	15.5%	15.5%
Total External Debt / GDP (initial = 38%)	42.0%	40.6%	51.7%	41.5%	45.9%	56.2%
PV of GDP loss due to loss of learning (% of initial GDP) 5/	0.0%	0.0%	2.3%	9.9%	26.0%	54.1%
PV of consumption loss due to loss-of-learning (% of initial GDP) 5/	0.0%	0.0%	2.3%	7.4%	17.8%	35.8%
[B] Fighting back: health and education investment 1/						
External concessional financing 2/						
Aggregate Output	-7.1%	-5.1%	-1.5%	-1.4%	-0.1%	-0.1%
Aggregate Consumption	-4.6%	-3.6%	-1.5%	-1.1%	-0.1%	0.2%
Skilled Wage	-8.7%	-5.8%	-0.5%	-1.2%	-0.2%	-0.1%
Income of ex ante poor	-5.7%	-3.8%	-1.3%	-1.3%	-0.1%	0.0%
Domestic Debt/GDP (initial = 15%)	15.1%	15.1%	15.1%	15.1%	14.9%	14.7%
Total External Debt / GDP (initial = 38%)	56.9%	57.1%	46.1%	58.5%	58.7%	53.5%
External finance plus domestic taxation 3/						
Aggregate Output	-7.2%	-5.3%	-2.0%	-2.1%	-0.6%	-0.4%
Aggregate Consumption	-5.2%	-4.2%	-2.5%	-2.2%	-1.0%	-0.5%
Skilled Wage	-9.1%	-6.3%	-1.5%	-2.3%	-1.0%	-0.7%
Income of ex ante poor	-5.7%	-3.9%	-1.6%	-1.6%	-0.3%	-0.2%
Domestic Debt/GDP (initial = 15%)	22.9%	22.8%	22.7%	22.1%	20.1%	19.2%
Total External Debt / GDP (initial = 38%)	40.7%	40.6%	37.4%	39.9%	39.0%	38.0%

Notes :
1/ See text for description of baseline shock ('Riding out the pandemic') and the health and education investment responses ('Fighting back')
2/ Domestic tax rates and recurrent and investment spending held at baseline levels with all fiscal adjustment financed from external concessional borrowing.
3/ Concessional external finance capped at 50% of additional public investment increase with residual fiscal financing from consumption tax (subject to an initial 5-year freeze) and domestic borrowing.

4/ Percentage deviation from initial baseline
5/ Future output and consumption losses discounted at subjective discount rate of 3.61%.

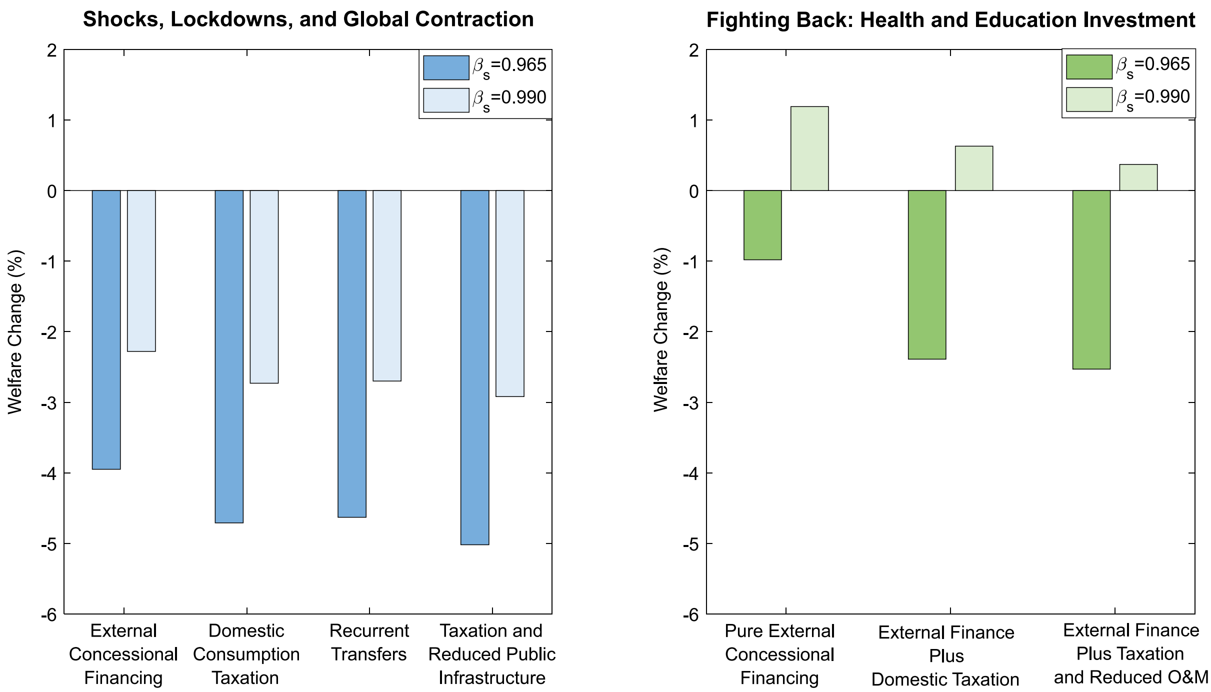

Fig. 5. Welfare: Covid-19 shock and fighting back strategies, varying the social discount factor β_s.
Notes: Welfare evaluated at $\zeta = 1$ under different social discount factors β_s. Runs correspond to those described in Fig. 4.

First, the direct and indirect short-run economic effects of the Covid-19 pandemic have already been brutal and despite a rapid response from some global institutions, notably the IMF and through the concessional IDA window of the World Bank, the costs have been highly concentrated on low-income countries themselves and to a degree that is out of proportion with the direct health costs of the pandemic.

Second, under plausible assumptions about the returns to education and the size and duration of loss-of-learning effects, the medium- and long-term effects on growth and welfare are likely to be severe if the indirect losses to human capital wrought by public policy responses to the pandemic are allowed to metastasize. Increased public investment in education and health designed to restore previously-diverted preventative and primary health spending and recover the loss of learning *can* repair the damage done to human capital. But even a large front-loaded program that injects 13 percent of initial GDP over the short/medium run does not return the economy to its pre-pandemic trend, *ceteris paribus* until more than a decade has passed and the cumulative loss in potential output reaches over 20 percent of GDP.

Third, if this public investment recovery cannot be financed externally from grant or concessional-lending, a substantial and attenuated fiscal adjustment burden will fall on already stressed domestic public finances which will further delay the eventual post-pandemic recovery. Clearly, the more substantial and more rapid the disbursement of concessional finance, the less severe this fiscal adjustment needs to be, although this comes at the cost of an external debt profile that remains elevated for longer.

Fourth, there are limits on the amount of fiscal adjustment that can be shouldered by governments of low-income countries and in many cases this capacity was already highly constrained in the run-up to the pandemic in early 2020 (and indeed has been worsened by post-pandemic events). Thus if the public investment is to be sustained, so that the recovery from the pandemic does not stall out, a rapid run-up in external and total public debt in the short- to medium-term is unavoidable. Shifting too much adjustment onto debtors' balance sheets risks derailing recovery as government are forced to scale back 'regular' public investment, raise domestic tax rates and/or seek to sharply raise domestic borrowing (which rapidly becomes significantly more expensive than external concessional financing). In these circumstances, the (welfare) returns to concessional lending are high, both in terms of limiting the divergence between advanced and developing countries and through helping restore a measure of fiscal resilience that will allow countries to address other equally challenging issues, including climate change. 'Doing whatever it takes' in this context means official creditors' reevaluating their tolerance of otherwise uncomfortably high external debt burdens over an extended period. Having said this, there may be greater scope than our calibration allows for structural reforms – to the extent they can be implemented through the crisis – to increase revenue mobilization through improved tax capacity and tax effort (see for example, Benedek et al., 2021).

Finally, we note some important caveats that may yet still impart an optimism bias to our analysis and which point to extensions in further work. First, and perhaps reflecting more optimism than is warranted, we treat the 2020 Covid-19 outbreak as a single event: we do not model resurgent second and subsequent waves and/or associated lock-downs at the global and national level, nor do we explore the consequences of a slower-than-anticipated vaccine distribution and uptake which may further slow the recovery of critical sectors such as tourism. All or any of these factors will place the recovery under further stress but modifying the runs to reflect a repeated or more protracted forcing shock is straightforward. Second, as noted, we have adopted a 'neutral' position on developments on the private capital account, both for debt and equity flows, and have assumed that fast scaling up of public investment can be achieved without substantial cost overruns or efficiency losses. Again, factoring in the possibility of higher risk premiums on external public and private commercial debt and a less optimistic outlook for FDI and other capital flows to low-income countries can easily be achieved. Third, other key elements of the calibration, including the role of remittances, remain contested. Finally, although we undertake some sensitivity analysis around returns to education, our analysis on the loss and restoration of human capital, both health and education remains necessarily tentative. Experimenting with differing assumptions about 'normal' returns to education is straightforward although this may cut both ways (reducing both the economic costs of loss of learning and of the returns to rebuilding). But even then, our runs are agnostic on the extent and duration of additional learning losses that may arise from lower enrollment and higher dropout rates. As the micro-economic evidence on the resilience of education systems and the capacity for children and students to rebuild education capital improves, we will be able to further refine our core simulations.

CRediT authorship contribution statement

Edward F. Buffie: Conceptualization, Methodology, Software, Validation, Writing – original draft. **Christopher Adam:** Conceptualization, Methodology, Software, Validation, Writing – original draft. **Luis-Felipe Zanna:** Conceptualization, Methodology, Software, Validation, Writing – original draft. **Kangni Kpodar:** Conceptualization, Methodology, Software, Validation, Writing – original draft.

Data availability

Data will be made available on request.

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