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Edward F. Buffie, Christopher Adam, Luis-Felipe Zanna, and Kangni Kpodar

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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 over the medium-run 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 analyses suggest.

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Author's E-Mail Address:	ebuffie@indiana.edu; christopher.adam@qeh.ox.ac.uk; fzanna@imf.org; kkpodar@imf.org

* Buffie: Department of Economics, Indiana University; Adam: Department of International Development, University of Oxford; Zanna: Institute for Capacity Development, IMF; Kpodar: Strategy, Policy, and Review Department, IMF (and FERDI).

WORKING PAPERS

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Prepared by Edward F. Buffie, Christopher Adam, Luis-Felipe Zanna, and Kangni Kpodar[1]

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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 has necessarily been 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 the diversion of healthcare resources to the immediate battle against Covid-19 has caused an upsurge in excess mortality from a range of other morbidities including tuberculosis, malaria, diabetes, HIV and heart disease in many developing countries.[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 dramatic 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 (2020*a*); 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 (2020*a*)). 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 wrought by the crisis in low-income countries. We start by presenting a characterization of the Covid-19 shock as it has manifested itself in many low-income countries, including in those where the *direct* initial impact from the virus itself was limited in scale and in severity. Subject to our assumptions about how adjustment is financed, this gives us a baseline measure of the output and welfare costs of the Covid-19 shock. In practice, few countries have had the luxury or the inclination to simply let the pandemic run its course and so we therefore turn our attention to potential economic recovery strategies, in particular those designed to repair the damage done to the country's health and human capital.[2] This immediately means choices over how such a program is to be structured and financed. A key issue for most low-income countries

[1] For example, Hogan, A. and co-authors (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.

[2] The model is obviously suited to examining a very wide range of other policy responses to the pandemic including concerns around short-term income and employment support and income distribution, for example. These are not discussed here.

is the extent to which they are likely to be able to secure external concessional financing from the international financial institutions – the IMF, World Bank and Regional Development Banks – and bilateral donors. The early evidence is that the capacity and willingness of official creditors to meet the full cost of the investment program is partial at best, either because of limited resources and/or concerns about debt sustainability in the borrowing country.[3] To reflect this, we allow for the financing burden to be shared between external concessional borrowing and domestic fiscal adjustment, where the latter may involve a mix of tax increases, expenditure reallocation and domestic public borrowing.

The remainder of the paper proceeds as follows. In Section 2 we briefly describe our modeling approach and the details of our calibration of the composite Covid-19 shock. Section 3 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 Modeling the Economic Effects of Covid-19 in Low-income Countries

Covid-19 ripped around the world in the first quarter of 2020 and countries' immediate responses to it triggered an economic crisis of unprecedented proportions. It was not simply the scale of the shock – at a global level the immediate economic recession was larger than anything in recorded economic history – or that it was experienced simultaneously across the world, or indeed that for many low-income countries was out of all proportion to the direct public health effects of the virus, but that it had multiple elements transmitted through multiple channels. First, and most immediately, the shock hit the supply side hard, both through the direct and immediate effects of illness and the subsequent domestic lock-down measures which led to the disruption of domestic and international trade and commerce and to a sharp reduction in domestic productivity. Second, as lock-downs and social distancing endured, the immediate effects on productivity were aggravated by the diversion of resources away from preventative and acute health treatment towards the provision of immediate Covid-related healthcare, and by the curtailment of education provision across the board but primarily at basic and secondary levels. Third, these direct 'disease and lock-down' effects were accompanied by a range of powerful demand-side effects as the shock waves of the global recession spread to developing countries. These included the effects on export earnings, the sharp decrease in commodity prices and remittance flows, and, for many countries, the collapse in international travel and tourism. Finally, these current account effects were been further magnified by a slow-down in private capital flows as creditors responded to the

[3] For example, while noting that net ODA rose by around 3.5 percent in 2020 relative to 2019, the OECD Development Assistance Committee (DAC) remained concerned that current and anticipated aid flows are likely to remain substantially lower than needs and that some of the short-run funding for direct Covid-19 related spending was secured by reprogramming existing commitments. See Organisation for Economic Co-operation and Development (2021).

twin effects of a sharp reduction in aggregate saving – particularly public saving – in developed economies and the sharp increase in the perceived credit risk of low-income countries, many of whom were already at moderate or high risk of debt distress before the pandemic hit.

To quantify the impact of this complex shock we deploy a version of the macroeconomic model developed by the authors under the auspices of the IMF (Buffie et al. (2020)). This model, which can be found in the Appendix, describes a representative multi-sector small open low-income economy in which smallholder agriculture plays an important role in both output and employment. The non-agricultural economy consists of an informal sector and a formal sector, one part of which is a labor-intensive services sector which we may think of as tourism which for many countries has been particularly exposed to the global collapse in international travel.[4] The economy is dominated by households that are unable to access asset market and therefore live hand-to-mouth but are accompanied by a smaller fringe of 'capitalist' households that own the private capital stock and can access financial assets. In the labor market, efficiency wage effects mean open unemployment in the formal economy co-exists with flexible wages in the informal and smallholder agricultural sector. Investment in education, all of which is publicly provided, alters the skills mix in the economy and drives labor productivity and income differentials across sectors. The government combines tax revenues with borrowing from private and official external creditors and from domestic households to finance transfers to households and public investment in physical infrastructure and education both of which are complementary to private capital accumulation.

With this framework in hand we then confront the model with our representation of the Covid-19 shock and alternative policy responses to it. The model tracks the paths of growth, inequality, unemployment and underemployment, real wages, the fiscal balance and public debt in the short, medium, and long runs. These outcomes then form the basis of our welfare calculations. To keep the analysis manageable, we treat the Covid-19 shock as an unanticipated and one-off shock occurring simultaneously around the world in 2020. This implies our analysis ignores the possibility of second or subsequent global waves of Covid-19 or, if such is to occur that vaccine roll-outs are sufficient so that national and global public policy ensures they do not trigger the same and highly disruptive seizures to the global economy as occurred with the initial outbreak. This is a modeling choice which allows us to focus on the response to a single shock and could be modified to allow for alternative pandemic trajectories.

[4]Variants of this core model can be developed to consider economies that are heavily dependent on hydrocarbon and mineral exports, for example, where the impact of the pandemic may have been no less severe but followed a slightly different trajectory. It is a straightforward task to modify the model and its calibration to reflect the structural characteristics and vulnerability of this group of countries.

2.1 Model Structure

As noted, the full model is presented in detail in the Appendix. Here we briefly describe its main features.

- *Production* The economy consists of four production sectors producing two traded and two non-traded goods. Non-traded output consists of informal goods and services, denoted by subscript j, and a formal good, n, which is a substitute in consumption with an imported good. Part of traded output is tourism, denoted by b, which is treated as an export enclave within the formal sector, selling only to foreign customers. The other traded good, x, may be thought of as cash-crop agriculture.

  Output in all four sectors is represented by Cobb-Douglas production functions with constant returns to private factors:

$$q_{x,t} = a_x z_{t-1}^{\psi_x} k_{x,t-1}^{\alpha_x} S_{x,t}^{\theta_x} H^{\chi} (e_{b,t} L_{x,t})^{1-\alpha_x-\theta_x-\chi}, \tag{1}$$
$$q_{n,t} = a_n z_{t-1}^{\psi_n} k_{n,t-1}^{\alpha_n} S_{n,t}^{\theta_n} (e_{n,t} e_{b,t} L_{n,t})^{(1-\alpha_n-\theta_n)}, \tag{2}$$
$$q_{b,t} = a_b z_{t-1}^{\psi_b} (k_{b,t-1} + k_{f,t-1})^{\alpha_b} S_{bb,t}^{\theta_b} A_t^{\theta_a} (e_{n,t} e_{b,t} L_{n,t})^{(1-\alpha_b-\theta_b-\theta_a)}, \tag{3}$$
$$q_{j,t} = a_j z_{t-1}^{\psi_j} k_{j,t-1}^{\alpha_j} S_{j,t}^{\theta_j} (e_{b,t} L_{j,t})^{(1-\alpha_j-\theta_j)}. \tag{4}$$

  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, k_f is foreign owned capital in the tourism sector, and H and A are sector-specific inputs in sectors x and b (land, some natural resource, beaches, lions, etc.) 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.

- *The labor market* The labor market has two principal features. First, the market is segmented so that jobs in the formal sector are rationed, generating (equilibrium) open unemployment in this sector. Firms in the formal sector recognize the link between labor productivity and the real wage: the resulting efficiency wage mechanism produces a *wage curve* for formal sector real wages $(w_{n,t}/P_t)$ of the form[5]

$$\ln\left(\frac{w_{n,t}}{P_t}\right) = 1 - b_o - b_1 \ln u_t + b_2 \ln\left(\frac{w_{j,t}}{P_t}\right). \tag{5}$$

  Formal sector wages are decreasing in the unemployment rate u_t and increasing in the wage in the informal sector, $(w_{j,t}/P_t)$.[6]

  Second, while efficiency wage considerations do not apply in the informal sector

[5]Without loss of generality, we have set effort equal to unity at the initial equilibrium.

[6]This effort function follows directly from the micro-theoretic model in Shapiro and Stiglitz (1984). It can be also derived by appending a separable term in the utility function (6) presented below, capturing the non-pecuniary loss from effort at the job, as in Dantine and Kurmann (2010), for instance.

and agriculture, where self-employment and family-run farms predominate, underemployment inefficiencies nonetheless prevail. Specifically, these two sectors form an integrated labor market with flexible wages, but we assume that property rights are tenuous in agriculture so that labor in this sector receives its marginal value product *plus* a share of land rents. As a result, arbitrage in this segment of the labor market ensures that the informal sector wage (net of tax) equals the net of tax shadow wage in agriculture plus its rental share. It follows that in this case, a reallocation of labor away from agriculture and into the informal sector increases aggregate labor productivity.

Whilst the overall supply of 'raw' labor is fixed, the skill composition is determined in part by public investment in upper-level education which converts some low-skill workers into high-skill workers (see below), and in part by new job openings in the formal sector, some of which secured by workers in the informal sector.

- *Households* There are two types of private agents, non-savers and savers, both of whom have preferences defined over food (the agricultural good), informal goods and services, and formal goods, where formal goods are a composite of the domestic and imported varieties. As noted, there is no domestic consumption of tourism.

  Unemployed individuals and low-skill workers in agriculture and the informal sector live hand-to-mouth, consuming all of their income each period, where income consists of net-of-tax labor income plus pro-rated shares of remittances, land rents in agriculture, and transfer payments from government. Capitalists, skilled labor, and low-skill labor in the formal sector comprise the saving class. With the capacity to save and borrow, this second group maximizes a standard iso-elastic utility function of the form:

$$V = \sum_{t=0}^{\infty} \beta^t \left(\frac{c_t^{1-1/\tau}}{1 - 1/\tau} \right) \tag{6}$$

  where: β is the discount factor; τ is the inter-temporal elasticity of substitution; and c aggregate consumption of savers. Savers' income consists of net-of-tax factor incomes, returns on financial assets (foreign and domestic bonds), and appropriately pro-rated shares of remittances, land rents in agriculture, and transfer payments. The saving household invests in physical capital and foreign bonds, both of which are subject to adjustment costs, and in domestic government bonds. All these assets allow these households to save and smooth consumption over time, as captured by standard Euler equation. The consumption path depends on the real interest rate r_t adjusted for trend growth g and changes in the VAT rate h_t.

- *Government* The government spends on household transfers, debt service and maintenance, and invests 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, some of which may

be granted on concessional terms.

The productivity of public infrastructure capital may be compromised through a combination of inefficient public investment (see Berg et al. (2019)) and/or deficient maintenance expenditures, the consequence of which is accelerated capital depreciation.

Investment in schooling takes longer to pay off than investment in infrastructure as it takes students time to graduate, six years in the case of basic education ($S_{b,t}$) and eight years for investment in upper-level education ($S_{u,t}$). We assume investments in health capital (G_t) takes three years to be fully realized. Assuming human capital depreciates (at rates δ_b, δ_u and δ_g respectively), stocks therefore evolve according to:

$$\begin{aligned} S_{b,t} &= i_{b,t-6} + (1-\delta_b)S_{b,t-1}, \\ S_{u,t} &= i_{u,t-8} + (1-\delta_u)S_{u,t-1}, \\ G_t &= i_{g,t-3} + (1-\delta_g)G_{t-1}. \end{aligned}$$

Fixed input-output coefficients, ϕ_1, ϕ_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:

$$S_t = S_o + \phi_1(S_{u,t-1} - S_{uo}) \tag{7}$$

$$e_{b,t} = [1 - ES_t + \phi_2(S_{b,t-1} - S_{bo})][1 - HS_t + \phi_3(G_{t-1} - G_o)], \tag{8}$$

where the subscript o denotes the initial steady-state values of stocks, while ES_t and HS_t are Covid-19 induced shocks to the health and education level of the workforce. We discuss these in detail in the next section.

Since health and education are gross complements, the degree of complementarity depends positively on the rates of return to the two types of human capital. The size of returns to education and health in low-income countries is highly contested (see Buffie et al. (2020) for an extensive discussion of the evidence). Here we assume an internal rate of return (IRR) of 12 percent for basic education and 10 percent for upper-level education.[7] If anything, the evidence on returns to healthcare in terms of productivity and income are even more difficult to pin down. Numerous microeconomic studies document the large impact of child malnutrition on adult earnings and the shockingly high number of work days lost to illness and disease among the poor.[8] The few studies that rely on macroeconomic data agree with the micro-economic studies that the return to healthcare spending is high. Kara

[7]Many development economists would still regard these IRRs as upper-bound estimates, citing the insignificant effects of education variables in cross-country growth regressions (Pritchett (2001)) and the very poor educational outcomes in many low-income countries.

[8]See Bossavie et al. (2017), Vofl (2014), Alderman et al. (2006), Alderman et al. (2009), Glewwe et al. (2001), Schultz and Tansel (1997), Badiane and Ulimwengu (2013), Dercon and Porter (2014), Haddad and H.Bouis (1991) and Thomas and Strauss (1997). A long list of additional references can be found in Andriabi et al. (2020).

et al. (2016) estimate that the elasticity of output with respect to healthcare (0.22) is comparable to that for infrastructure, while Bloom et al. (2004) find that adding one year to population life expectancy (a proxy for the general quality of healthcare) increases GDP by 4 percent. Although the weight of the evidence suggests the return to healthcare is high, the results in the literature do not directly map into a range of internal rates of return. So while there is plenty of room for disagreement about the right value of $\mathrm{IRR}_{\mathrm{g}}$, we take the view that the return on healthcare is no lower than the return on education and perhaps much higher: to reflect this we set $\mathrm{IRR}_{\mathrm{g}} = 0.12$ in the baseline calibration.

- *Fiscal Adjustment and Market-Clearing* Fiscal adjustment is achieved through simple rules. Conditional on external financial flows, public debt sustainability requires that taxation and transfers eventually adjust to satisfy the fiscal balance, although in the short/medium run, part of this gap can be financed by borrowing. In principal, of course, external concessional finance may be sufficient to satisfy fiscal balance without domestic fiscal adjustment. Finally, the model is closed in a conventional manner. Flexible wages and prices equate demand to supply in the market for skilled labor, the market for low-skill labor, and the markets for the two non-traded goods, with the efficiency wage mechanism determining formal sector wages and equilibrium unemployment. The fiscal balance is satisfied through tax and debt adjustments depending on the fiscal rule while overall external balance is satisfied when the (sustainable) growth in the country's net foreign debt equals the current account deficit.

3 Calibration and the Covid-19 Shock

3.1 The Core Model

The model is calibrated to an initial equilibrium following the procedure outlined in Buffie et al. (2020). The key calibration parameters are shown in Table 1, but readers are referred to our earlier work for a detailed discussion on the basis for these values. Given the focus of this paper, we restrict the discussion here to the calibration of the complex Covid-19 shocks which includes lock-downs and disruptions to global supply chains, sharp decreases in commodity prices and remittances, a collapse in tourism, and shocks to health and education. There is wide variation in how these shocks have affected different countries. In the baseline scenario, we calibrate to average values for low-income countries on the basis of estimates from a range of sources. We start with the immediate economic shock before turning to the health and human capital shock.

3.2 The Economic Shock

Tables 2 and 3 report the paths for the exogenous variables driving the principal economic elements of the Covid-19 shock. Where data permit, we calibrate these to be consistent with the most recent IMF and World Bank forecasts.

- *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.[9,10] The direct hit to productivity, inclusive of the tourism shock (see below), reduces GDP 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*b*); World Bank (2020*a*); Asian Development Bank (2020)).

- *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 or extract abnormally high effort.[11] This has two effects, the first of which is to put a floor under formal sector wages through 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 second is that this protection of formal wages reduces effort which is reflected in lower-than-counterfactual output through the crisis period and consequentially lower skilled and informal wages. These secondary effects are, however, very small: the output effect at its maximum is little more than 0.1 percent of GDP.

- *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 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. Oil prices have begun to recover quite rapidly in 2021 and forecasts suggest this recovery is being shared for other commodities (International Monetary Fund (2021*b*)).

[9]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)).

[10]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.

[11]To be precise, we allow for the wage curve in (5) to flatten, up to the point where it is horizontal and thus freezes formal sector wages at their pre-pandemic level.

- *Remittances shock*. One of the biggest areas of uncertainty around the likely impact of the pandemic is the response of remittances. Early on, around June 2020, the World bank estimated that remittance flows to developing countries would decrease by as much as 20 percent in 2020 (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 appear to have 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.[12] 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 (2020*b*)). The shock path in Table 2 applies this estimated contraction to the average value of remittances in low-income countries (7.2 percent of GDP, according to World Development Indicators).

- *Tourism shock*. 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.[13] In line with industry projections, recovery is expected to be much slower than other sectors: revenues do not regain their pre-pandemic level until at least four years after the onset of the pandemic (Behsudi (2020)).[14]

- *Capital account shocks*. Finally, a number of developments triggered by the pandemic have impacted capital flows. The key elements are described in Table 3. First, 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. Second, the US 650 billion Special Drawing Right (SDR) issue approved by the IMF in June 2021 provided an additional resource flow to developing countries (International Monetary Fund (2021*a*)). SDRs accrue directly to central banks and are typically treated as contributing to international reserves. Based on current IMF quota shares, the allocation will enhance reserves

[12] See for example Lopez-Calva (2020), Guild (2021) and Howes and S.Surandiran (2020).
[13] see https://www.Statistica.com.
[14] 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, in the Appendix, we consider the vulnerability of tourism-dependent island economies.

for a median low-income country in SSA by a one-off amount of approximately 2 percent of pre-pandemic GDP. Countries hold different views on whether the additional SDR allocation is added to reserves or is used, either directly or indirectly, as financing: we do not explicitly model reserve management but assume that reserves are initially at their target level so that the SDR inflow creates an equivalent financing flow that is drawn down over two years starting in year $t = 2$. Finally, the picture on commercial private flows 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)). *Faux de mieux*, we adopt a passive calibration, assuming no change in net private capital flows.

The final capital account component is, of course, concessional financing. 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) notes, 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, the duration of school closures closely approximates years of lost learning. Psacharopoulos et al. (2020) calculate the associated decrease in adult earnings of the affected cohort by multiplying 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 e_b term in in equation (8)) 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 big. The 2005 earthquake in northern Pakistan closed schools for fourteen weeks. An-

driabi 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. Azevedo et al. (2020) have collected data on school closures in 157 countries. The average decrease in learning-adjusted years is 0.6 years in 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: when all of the affected cohort has entered the workforce, e_b is 5.5 percent below its pre-pandemic level.[15]

Pulling this evidence together we characterize the shock to low-skill labor productivity as playing out over three distinct phases (see Table 4). 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.[16] Phase 2, 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 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 equation (7) 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 effects, even though they clearly operate to some extent and their inclusion would increase both the size and the duration of the learning shock.[17]

Covid-19 has also taken a toll on the health of the general population in low-income countries. The direct effect on mortality has, to date, been substantially smaller than in

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

[16] 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.

[17] 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.

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 are set 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,[18] 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.[19] 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 4.

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. High level results are summarized in Table 6, while Figures 1 through 4 illustrate the dynamics of adjustment.

Before presenting these results in detail, we first note that the short-run costs over the

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

[19]See Alderman et al. (2006), Alderman et al. (2009), Glewwe et al. (2001), Haddad and H.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.

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 for example International Monetary Fund (2021*b*)). This is so regardless of choices over financing. Where our analysis contributes, however, 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 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 assess the impact of public investment. To evaluate this baseline, however, we need to decide what adjusts to restore macroeconomic balance. The short list of candidates include domestic adjustment, through tax adjustment and/or expenditure adjustment, or external adjustment through concessional borrowing, private capital or grant financing.[20] There are arguments on both sides as to which basis is most plausible. Figure 1 plots two limit cases: the solid blue lines show the outcome when donors supply concessional loans as needed to forestall cuts in public investment while holding domestic taxes, transfers and borrowing constant. Policy is thus completely passive; the government does not spend a nickel to combat the economic fallout of the pandemic.[21] By contrast, the dashed red lines show the outcome when donors maintain external financing at the same level as pre-crisis and and the governments spending program, inclusive of debt service costs, are financed by adjustments to domestic consumption taxes.

In Figure 1, the paths for growth, GDP, the private capital stock, tax rates and the domestic interest rate are in level form while debt is expressed as a percentage of current GDP. All other paths track the percentage deviation of the variable from its initial steady-state level.[22] 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; private investment 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

[20]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.

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

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

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 existing 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 predictions made by the IMF and the World Bank, 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). Beyond the obvious fact that the paths for tax and debt diverge, the main differences between the alternative financing strategies is in terms of the impact on skilled wages and consumption, both of which are lower when adjustment is domestic.

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 levels, absent any further 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 3.5 - 4 percent lower than their initial levels and still slowly decreasing (see Table 6). As output fails to recover over the medium term, the fiscal burden remains elevated long after the initial shock has passed, whether this is in terms of tax rates which remain around 1.5 percent higher than baseline more that 40 periods, or in terms of public debt which explains a long slow rise 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 once-and-for-all assault on health and human capital occasioned by the pandemic turns a sharp short-run recession into a severe economic decline over an extended medium term.[23]

[23]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. See Table 6.

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 5). 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.[24] We examine this fighting-back strategy under a number of alternative public finance scenarios. In the first, we again assume official creditors make available sufficient concessional loans to finance the 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 part of the costs of the program, with the balance falling on domestic fiscal instruments.[25]

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. Figure 2 plots 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.

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 with-

[24]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.

[25]In contrast to the baseline we do not report the case where the whole of the investment program is financed domestically as this is only possible if the domestic tax rates rose to almost 30 percent for a period of more than five years; we regard this as politically infeasible.

out any additional fiscal adjustment. In fact, 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.[26] In our second simulation, we therefore turn to the case where concessional external finance covers only a proportion of the gross costs of the public investment program.

4.2.2 Exogenous Concessional Financing and Domestic Fiscal Adjustment

In this 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 2.0 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.

Figure 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 aggregate 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 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. Likewise, an almost identical pattern emerges if the tax adjustment occurs on the intensive margin

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

through measures designed to increase the collection rate for the VAT. We do not report the details of this run here but, in summary, the baseline calibration assumes high levels of leakage in the VAT and tax reforms entail an increase in the collection rate in the informal sector from 30 to 50 percent and from 10 to 20 percent in agriculture. The process takes five years to complete and raises tax revenue an extra 1.2 percent of GDP. In contrast to the across-the-board tax increase shown in Figure 3, these reforms to collection rates alter the relative consumption price of formal and informal (and agricultural goods) inducing a substitution toward consumption of formal good and imports, which further boosts domestic revenue mobilization.

Both the previous cases place significant pressure on the domestic taxation. It may 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. This is shown in Figure 4. Cutting back on maintenance expenditure during the front-loading of the public investment surge – from around 1.6 to 0.8 percent of GDP – releases resources for investment, taking the pressure off both tax and borrowing helping to dampen the rise in the interest rate and hence reduce the downward pressure on private investment, in the short-run. However the increased depreciation of the public capital that is occasioned by the scale-back in maintenance expenditures (where the effective depreciation rate rises from 5 to 6.2 percent) reduces the effective capital stock and, given its complementarity with private factors, reduces the return to private investment which, in turn, further slows the recovery of output and consumption.

The simulations presented in this Section span only a small range of policy responses and while substantially more time and effort could be spent refining them and exploring alternative underlying economic structures, we believe they are robust. In the Appendix, we 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. Moreover, we analyze the effects of altering the assumptions about the Covid-19 shock.

5 Welfare Analysis

We conclude the analysis by providing a summary of the welfare implications of the runs. While the model used here does not allow for a detailed household disaggregation, a natural way to reflect the welfare effects of alternative responses to the pandemic is to define a social welfare function that can give weight to the consumption of the *ex ante* poor:

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

where c_t is aggregate consumption, β_s is the *social* discount factor, c_t^p is the consumption of the *ex ante* poor and ζ is a measure of the relative weight placed on the consumption of the *ex ante* poor.

We do not measure the *consumption* of the poor directly but we can get a close approximation by computing the net income of this group and recognizing that the poor are hand-to-mouth consumers. Our definition of the *ex ante* poor allows us to reflect impacts on welfare arising from the dynamics of the labor market. This group consists of those continuously employed at low-skill in the informal and agricultural sectors plus those who are initially unemployed and those who *ex post* secure low-skilled jobs in the formal sector and those that become skilled.[27] If our income measure tracked the consumption of the ex ante poor perfectly, $1 + \zeta$ would measure the marginal rate of substitution between consumption of the ex ante poor and the consumption of the non-poor in social welfare. The second key choice concerns the social discount factor. 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.[28] The results summarized in Figures 5 and 6 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 (Figure 5, 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 and rather obviously, 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 Figure 6 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 Figure 6).

[27] The relevant transition parameters are Δ_{ij} and ξ in the model presented in the Appendix.

[28] For example the UK Treasury *Green Book: Guidance on Appraisal and Evaluation*, (2018) recommends $\beta_s = 0.966 - 0.0979$ and substantially higher $\beta_s = 0.993$ for health-related projects.

6 Conclusions and Policy Implications

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

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, notable the IMF and IDA, 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 12 percent of initial GDP over the short/medium run does not return the economy to its pre-pandemic trend line until twelve years have 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. 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 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 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.

Appendix

A The DIG-Labor-Covid-19 Model

The model has four sectors, multiple types of public sector debt, and a wide array of tax and spending variables. The economy produces two traded goods and two non-traded 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 $(1+\mathfrak{g})^t$, where $\mathfrak{g}$ is the exogenous long-run growth rate of per capita income. To fix ideas, we refer to sector x as agriculture.

Technology

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

$$\begin{aligned}
q_{x,t} &= a_x z_{t-1}^{\psi_x} k_{x,t-1}^{\alpha_x} S_{x,t}^{\theta_x} H_t^{\chi} (e_{b,t} L_{x,t})^{1-\alpha_x-\theta_x-\chi}, && (9)\\
q_{n,t} &= a_n z_{t-1}^{\psi_n} k_{n,t-1}^{\alpha_n} S_{n,t}^{\theta_n} (e_{n,t} e_{b,t} L_{n,t})^{(1-\alpha_n-\theta_n)}, && (10)\\
q_{b,t} &= a_b z_{t-1}^{\psi_b} (k_{b,t-1} + k_{f,t-1})^{\alpha_b} S_{bb,t}^{\theta_b} A_t^{\theta_a} (e_{n,t} e_{b,t} L_{n,t})^{(1-\alpha_b-\theta_b-\theta_a)}, && (11)\\
q_{j,t} &= a_j z_{t-1}^{\psi_j} k_{j,t-1}^{\alpha_j} S_{j,t}^{\theta_j} (e_{b,t} L_{j,t})^{(1-\alpha_j-\theta_j)}. && (12)
\end{aligned}$$

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, k_f is foreign owned capital in the tourism sector, and H and A are sector-specific inputs in sectors x and b (land, some natural resource, beaches, lions, etc.) 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 + lower secondary) and S_u for upper-level education (upper secondary + tertiary). Factories, infrastructure, healthcare capital, G, and education capital are built by combining a_{im} imported machines 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 k, z, G, and S_u/S_b are thus

$$\begin{aligned}
P_{k,t} &= 1 + a_{kn}(P_{n,t} - 1) + a_{kj}(P_{j,t} - 1), && (13)\\
P_{z,t} &= 1 + a_{zn}(P_{n,t} - 1) + a_{zj}(P_{j,t} - 1), && (14)\\
P_{s,t} &= 1 + a_{sn}(P_{n,t} - 1) + a_{sj}(P_{j,t} - 1). && (15)\\
P_{g,t} &= 1 + a_{gn}(P_{n,t} - 1) + a_{gj}(P_{j,t} - 1). && (16)
\end{aligned}$$

Factor Demands

Competitive firms maximize profits by hiring each input up to the point at which its MVP

equals its price:

$$P_{n,t}(1-\alpha_n-\theta_n)\frac{q_{n,t}}{L_{n,t}} = w_{n,t}, \tag{17}$$

$$(1-\alpha_b-\theta_b-\theta_a)\frac{q_{b,t}}{L_{b,t}} = w_{n,t}, \tag{18}$$

$$P_{x,t}(1-\alpha_x-\theta_x-\chi)\frac{q_{x,t}}{L_{x,t}} = w_{x,t}, \tag{19}$$

$$P_{j,t}(1-\alpha_n-\theta_n)\frac{q_{j,t}}{L_{j,t}} = w_{j,t}, \tag{20}$$

$$P_{x,t}\theta_x\frac{q_{x,t}}{S_{x,t}} = w_{s,t}, \tag{21}$$

$$P_{n,t}\theta_n\frac{q_{n,t}}{S_{n,t}} = w_{s,t}, \tag{22}$$

$$\theta_b\frac{q_{b,t}}{S_{bb,t}} = w_{s,t}, \tag{23}$$

$$P_{j,t}\theta_j\frac{q_{j,t}}{S_{j,t}} = w_{s,t}, \tag{24}$$

$$P_{n,t}\alpha_n\frac{q_{n,t}}{k_{n,t-1}} = r_{n,t}, \tag{25}$$

$$P_{x,t}\alpha_x\frac{q_{x,t}}{k_{x,t-1}} = r_{x,t}, \tag{26}$$

$$P_{j,t}\alpha_j\frac{q_{j,t}}{k_{j,t-1}} = r_{j,t}, \tag{27}$$

$$\alpha_b\frac{q_{b,t}}{(k_{b,t-1}+k_{f,t-1})} = r_{b,t}, \tag{28}$$

$$P_{x,t}\chi\frac{q_{x,t}}{H_t} = r_{h,t}, \tag{29}$$

$$\theta_a\frac{q_{b,t}}{A_t} = r_{a,t}, \tag{30}$$

where w_s is the skilled wage, r_h and r_a are land and natural amenity rents, and w_i and r_i are the low-skill wage and the capital rental in sector i. Skilled labor is intersectorally mobile, so the same wage appears in (21) - (24). Capital is sector specific, but the capital rentals differ only on the transition path. In the long run, after adjustment is complete, $r_x = r_n = r_j = r_b$.

A detailed discussion of the low-skill labor market follows in a couple of pages. For now, we note two points in connection with (17) - (20). First, the market is segmented, with $w_n > w_j \geq w_x$ and rationing of jobs in the high-wage formal sector 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.

Private Sector Optimization Problems

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

$$
\begin{aligned}
c &= \left[(1-\kappa_1)^{1/\epsilon_1} c_{fj}^{(\epsilon_1-1)/\epsilon_1} + \kappa_1^{1/\epsilon_1} c_x^{(\epsilon_1-1)/\epsilon_1}\right]^{\epsilon_1/(\epsilon_1-1)}, && (31)\\
c_{fj} &= \left[(1-\kappa_2)^{1/\epsilon_2} c_j^{(\epsilon_2-1)/\epsilon_2} + \kappa_2^{1/\epsilon_2} c_{nm}^{(\epsilon_2-1)/\epsilon_2}\right]^{\epsilon_2/(\epsilon_2-1)}, && (32)\\
c_{nm} &= \left[(1-\kappa_3)^{1/\epsilon_3} c_m^{(\epsilon_3-1)/\epsilon_3} + \kappa_3^{1/\epsilon_3} c_n^{(\epsilon_3-1)/\epsilon_3}\right]^{\epsilon_3/(\epsilon_3-1)}, && (33)
\end{aligned}
$$

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.

Three-tiered CES utility functions are not seen every day in macroeconomic models. The importance of working with a flexible, general specification of preferences will become clear in due course.

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

$$
\begin{aligned}
c_{n,t} &= \kappa_3 \left[\frac{(1+h_t)P_{n,t}}{P_{nm,t}}\right]^{-\epsilon_3} \kappa_2 \left[\frac{P_{nm,t}}{P_{fj,t}}\right]^{-\epsilon_2} (1-\kappa_1)\left(\frac{P_{fj,t}}{P_{c,t}}\right)^{-\epsilon_1} (c_{1,t}+c_{2,t}), && (34)\\
c_{j,t} &= (1-\kappa_2)\left[\frac{(1+g_jh_t)P_{j,t}}{P_{fj,t}}\right]^{-\epsilon_2} (1-\kappa_1)\left(\frac{P_{fj,t}}{P_{c,t}}\right)^{-\epsilon_1} (c_{1,t}+c_{2,t}), \quad g_j \leq 1, && (35)\\
c_{x,t} &= \kappa_1 \left(\frac{1+g_xh_t}{P_{c,t}}\right)^{-\epsilon_1} (c_{1,t}+c_{2,t}), \quad g_x \leq 1, && (36)\\
c_{m,t} &= (1-\kappa_3)\left[\frac{1+g_mh_t}{P_{nm,t}}\right]^{-\epsilon_3} \kappa_2 \left[\frac{P_{nm,t}}{P_{fj,t}}\right]^{-\epsilon_2} (1-\kappa_1)\left(\frac{P_{fj,t}}{P_{c,t}}\right)^{-\epsilon_1} (c_{1,t}+c_{2,t}), && (37)
\end{aligned}
$$

and the associated price indices

$$
\begin{aligned}
P_{c,t} &= \left[\kappa_1(1+g_xh_t)^{1-\epsilon_1} + (1-\kappa_1)P_{fj,t}^{1-\epsilon_1}\right]^{1/(1-\epsilon_1)}, && (38)\\
P_{fj,t} &= \left\{\kappa_2 P_{nm,t}^{1-\epsilon_2} + (1-\kappa_2)[(1+g_jh_t)P_{j,t}]^{1-\epsilon_2}\right\}^{1/(1-\epsilon_2)}, && (39)\\
P_{nm,t} &= \left\{(1-\kappa_3)(1+g_mh_t)^{1-\epsilon_3} + \kappa_3[(1+h_t)P_{n,t}]^{1-\epsilon_3}\right\}^{1/(1-\epsilon_3)}, && (40)\\
P_t &= \left[\kappa_1 + (1-\kappa_1)\mathbb{P}_{fj,t}^{1-\epsilon_1}\right]^{1/(1-\epsilon_1)}, && (41)\\
\mathbb{P}_{fj,t} &= \left[\kappa_2 {\mathbb{P}_{nm,t}}^{1-\epsilon_2} + (1-\kappa_2)P_{j,t}^{1-\epsilon_2}\right]^{1/(1-\epsilon_2)}, && (42)\\
\mathbb{P}_{nm,t} &= \left[\kappa_3 {P_{n,t}}^{1-\epsilon_3} + 1-\kappa_3\right]^{1/(1-\epsilon_3)}. && (43)
\end{aligned}
$$

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, and transfer payments $\mathcal{T}$ handed out by the government; $\mathfrak{r}$ 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

$$P_{c,t}c_{1,t} = (1 - f_{wx})(w_{x,t}L_{x,t} + \sigma r_{h,t}H) + (1 - f_{wj})w_{j,t}L_{j,t} + a_t\mathcal{T}_t + \mathfrak{r}(1 - f_{\mathcal{R}})\mathcal{R}_t, \quad (44)$$

where

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

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.[29]

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

$$V = \sum_{t=0}^{\infty} \beta^t \left[\frac{(c_{2,t})^{1-1/\tau}}{1 - 1/\tau} \right], \quad (45)$$

subject to

$$\begin{aligned} P_t b_t - b_{f,t} \quad = \quad & \frac{1 + r_{t-1}}{1 + \mathfrak{g}} P_t b_{t-1} - \frac{1 + r_f}{1 + \mathfrak{g}} b_{f,t-1} - \frac{\eta}{2}(b_{f,t} - \bar{b}_f)^2 + (1 - f_n)r_{a,t}A \\ & +(1 - f_w)[w_{n,t}(L_{n,t} + L_{b,t}) + w_{s,t}S_{t-1}] + (1 - \mathfrak{r})(1 - f_{\mathcal{R}})\mathcal{R}_t \\ & + \sum_{\mathfrak{q}=j,n,x,b} [r_{\mathfrak{q},t} - f_{\mathfrak{q}}(r_{\mathfrak{q},t} - \delta P_{\mathfrak{q},t})]k_{\mathfrak{q},t-1} + (1 - f_h)(1 - \sigma)r_{h,t}H \\ & +(1 - a_t)\mathcal{T}_t - P_{c,t}c_{2,t} - \mu_t z_{t-1} - P_{k,t} \sum_{\mathfrak{q}=j,n,x,b} (i_{\mathfrak{q},t} + \mathbb{AC}_{\mathfrak{q},t}), \end{aligned} \quad (46)$$

and, for each sector $\mathfrak{q}$ with $\mathfrak{q} = j, n, x, b$,

$$(1 + \mathfrak{g})k_{\mathfrak{q},t} = i_{\mathfrak{q},t} + (1 - \delta)k_{\mathfrak{q},t-1}, \quad (47)$$

where β is the discount factor;[30] τ is the intertemporal elasticity of substitution; η is a positive constant; 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; and $f_{\mathfrak{q}}$, f_h, and f_w are tax rates on capital income (net of depreciation) in sector $\mathfrak{q}$, land and natural resource rents, and wage income in the formal sector.

In the budget constraint (46), $\mathbb{AC}_{\mathfrak{q},t} = \frac{v}{2}\left(\frac{i_{\mathfrak{q},t}}{k_{\mathfrak{q},t-1}} - \delta - \mathfrak{g}\right)^2 k_{\mathfrak{q},t-1}$ captures adjustment costs incurred in changing the capital stock in sector $\mathfrak{q}$, with $\mathfrak{q} = j, n, x, b$ and parameter v.[31]

[29] $0 < \sigma < 1$ when sector x comprises smallholder agriculture and other sectors (e.g., estate agriculture, mining, sharecroppers).

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

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

The term $\frac{\eta}{2}(b_{f,t} - \bar{b}_f)^2$ 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.[32] Observe also that the trend growth rate appears in several places in (46) and (47), reflecting the fact that some variables are dated at t and others at t-1. Note that the convention for detrending the capital stocks differs from that for other variables. We define $k_{\mathfrak{q},t-1} \equiv \frac{K_{\mathfrak{q},t-1}}{(1+\mathfrak{g})^t}$ for $\mathfrak{q} = j, n, x, b$. Under this convention, $i_{\mathfrak{q}} = (\delta + \mathfrak{g})k_{\mathfrak{q}}$ in the long run — as required for the capital stocks to grow at the trend growth rate $\mathfrak{g}$.

On an optimal path,

$$c_{2,t} = c_{2,t+1}\left[\beta\left(\frac{1+r_t}{1+\mathfrak{g}}\right)\frac{P_{t+1}}{P_t}\left(\frac{P_{c,t}}{P_{c,t+1}}\right)\right]^{-\tau}, \tag{48}$$

for each sector $\mathfrak{q}$, with $\mathfrak{q} = j, n, x, b$,

$$\frac{\left(\frac{r_{\mathfrak{q},t+1}}{P_{k,t+1}} - \delta\right)(1 - f_{\mathfrak{q},t+1}) + 1 + \mathbb{D}_{\mathfrak{q},t+1}\left(\frac{i_{\mathfrak{q},t+1}}{k_{\mathfrak{q},t}} + 1 - \delta\right) - \frac{1}{2}\mathbb{D}^2_{\mathfrak{q},t+1}}{1 + \mathbb{D}_{\mathfrak{q},t}} = (1+r_t)\frac{P_{t+1}}{P_t}\left(\frac{P_{k,t}}{P_{k,t+1}}\right) \tag{49}$$

where $\mathbb{D}_{\mathfrak{q},t} = v\left(\frac{i_{\mathfrak{q},t}}{k_{\mathfrak{q},t-1}} - \delta - \mathfrak{g}\right)$, and

$$\eta(b_{f,t} - \bar{b}_f) = 1 - \left(\frac{1+r_f}{1+r_t}\right)\frac{P_t}{P_{t+1}}. \tag{50}$$

Each of these equations admits a straightforward intuitive interpretation. Equation (48) 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 equations represented by (49) — one equation for each sector $\mathfrak{q}$, with $\mathfrak{q} = j, n, x, b$ — are non-arbitrage conditions. They require the return on capital, net of marginal adjustment costs, to equal the real interest rate. Similarly, equation (50) says that marginal transactions costs offset the interest differential between domestic bonds and foreign loans.

The Effort Function

Work effort of low-skill labor in the formal sector depends on their own wage, the wage in the informal sector, and the unemployment rate $\mathfrak{u}$:

$$e_{n,t} = g_o + g_1 \ln\left(\frac{w_{n,t}}{P_t}\right) - g_2 \ln\left(\frac{w_{j,t}}{P_t}\right) + g_3 \ln \mathfrak{u}_t, \tag{51}$$

where

$$\mathfrak{u}_t = \frac{\bar{L}_t - L_{n,t} - L_{j,t} - L_{b,t} - L_{x,t}}{\bar{L}_t}. \tag{52}$$

growth.

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

Naturally, workers exert more effort when they are paid a higher real wage and when low pay in the informal sector and high unemployment increase their gratitude for having a job.

The effort function in (51) may be derived from a 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. It can be also derived by appending a separable term in the utility function (45), capturing the non-pecuniary loss from effort at the job, as in Dantine and Kurmann (2010), for instance.[33]

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

$$\frac{\partial e_n}{\partial (w_{n,t}/P_t)}\left(\frac{w_{n,t}/P_t}{e_{n,t}}\right) = 1. \tag{53}$$

Equations (51) and (53) imply

$$e_{n,t} = g_1. \tag{54}$$

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 (51) and (54) then reads

$$\ln\left(\frac{w_{n,t}}{P_t}\right) = 1 - g_o + g_2 \ln\left(\frac{w_{j,t}}{P_t}\right) - g_3 \ln \mathfrak{u}_t. \tag{55}$$

Equation (55) 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 the wage curve with

$$\ln\left(\frac{w_{n,t}}{P_t}\right) - \ln\left(\frac{w_{n,o}}{P_o}\right) = (1-\mathfrak{z})\left\{g_2\left[\ln\left(\frac{w_{j,t}}{P_t}\right) - \ln\left(\frac{w_{j,o}}{P_o}\right)\right] - g_3(\ln \mathfrak{u}_t - \ln \mathfrak{u}_o)\right\}. \tag{56}$$

During the crisis, $0 < \mathfrak{z} < 1$ if social norms constraint wage cuts. After the crisis has passed, $\mathfrak{z} = 0$ re-activates the normal wage curve.

Efficiency wage considerations do not apply in the informal sector and agriculture, where self-employment and family-run farms predominate. These two sectors 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, friction-less 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 $j - x$ labor market ensures only

[33] In the model where effort is either zero or one, the informal wage and the unemployment rate will enter the no-shirking condition.

that

$$(1 - f_{wj})w_{j,t} = (1 - f_{wx})\left(w_{x,t} + \sigma r_{h,t}\frac{H}{L_{x,t}}\right),$$

which implies

$$\frac{1 - f_{wj}}{1 - f_{wx}}w_{j,t} = w_{x,t}\left(1 + \frac{\sigma\chi}{1 - \alpha_x - \theta_x - \chi}\right), \tag{57}$$

with $0 \leq \sigma \leq 1$. 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.[34] 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:

$$\bar{L}_{xj,t} = L_{x,o} + L_{jo} - \Delta_{xj}(S_t - S_o) - \xi(L_{n,t} + L_{b,t} - L_{no} - L_{bo}), \tag{58}$$

$$\bar{L}_t = \bar{L}_o - (S_t - S_o). \tag{59}$$

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 sector $x - j$ 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, through which employers put out the word that they are hiring and rely on referrals from existing employees to fill the jobs. We do not attempt to model the role played by friend-family-kinship networks in the labor market. Equation (58) simply assumes that workers previously employed in sector $x - j$ obtain ξ percent of newly created jobs in the formal sector.

Public Investment in Infrastructure

Casual observation and indirect empirical evidence suggest that all too often high returns on infrastructure capital do not translate into equally high returns on public investment either because of inadequate expenditure on maintenance or because a large fraction of public investment *spending* does not increase the stock of productive infrastructure (Hulten (1996); Pritchett (2000)). The model allows for both types of inefficiency. Public in-

[34] 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.

vestment i_z increases the stock of physical infrastructure $\tilde{z}$:

$$(1+\mathfrak{g})\tilde{z}_t = i_{z,t} + (1-\delta)\tilde{z}_{t-1}. \tag{60}$$

Some of the newly built infrastructure, however, may not be economically valuable, productive infrastructure:[35]

$$z_t = z_o + s(\tilde{z}_t - \tilde{z}_o), \quad s \leq 1. \tag{61}$$

Spending on maintenance $\mathfrak{m}$ extends the service life of infrastructure by reducing the depreciation rate:

$$\delta_{z,t} = \delta_o e^{-\Lambda \mathfrak{m}_t / \tilde{z}_{t-1}}, \tag{62}$$

with $\Lambda > 1/\delta_o$. Maintenance is underfunded relative to new investment when $\Lambda > 1/\delta_z$. In too many countries this condition holds with margin to spare.

Public Investment in Human Capital

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:[36]

$$S_{u,t} = i_{u.t-8} + (1-\delta_u)S_{u,t-1}, \tag{63}$$
$$S_{b,t} = i_{b,t-6} + (1-\delta_b)S_{b,t-1}, \tag{64}$$
$$G_t = i_{g,t-3} + (1-\delta_g)G_{t-1}. \tag{65}$$

Fixed input-output coefficients connect increases in education capital and health capital to the supply of high-skill labor and the productivity of low-skill labor:

$$S_t = S_o + \phi_1(S_{u,t-1} - S_{uo}), \tag{66}$$
$$e_{b,t} = [1 - ES_t + \phi_2(S_{b,t-1} - S_{bo})][1 - HS_t + \phi_3(G_{t-1} - G_o)], \tag{67}$$

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.

Fiscal Adjustment and the Public Sector Budget Constraint

The government spends on debt service, health i_g, transfers $\mathcal{T}$, investment in infrastruc-

[35] The return on public investment is *not* necessarily lower in countries with a history of low efficiency of public investment. Low values of s in equation (60) are counterbalanced by lower values of z_o and a higher marginal product of infrastructure. In an apple-to-apple comparison of otherwise structurally identical countries, the return to investment may be *higher* in the low-efficiency country (Berg et al. (2019)).

[36] 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 (65) depends on the age at which children start work and on the share of healthcare spending allocated to adults vs. children.

ture $\mathbb{I}_z$ (including costs overruns), investment in education $i_s \equiv i_b + i_u$, and maintenance $\mathfrak{m}$. It collects revenue from user fees for infrastructure services, taxes on wages, profits from each sector $\mathfrak{q} = j, n, x, b$, and remittances as well as from the consumption VAT. When revenues fall short of expenditures, the resulting deficit is financed through domestic and external borrowing, viz.:

$$\begin{aligned} P_t \Delta b_t + \Delta d_{c,t} + \Delta d_t &= \frac{r_d - \mathfrak{g}}{1+\mathfrak{g}} d_{t-1} + \frac{\mathfrak{d} r_{dc} - \mathfrak{g}}{1+\mathfrak{g}} dc_{t-1} + \frac{r_{t-1} - \mathfrak{g}}{1+\mathfrak{g}} P_t b_{t-1} + P_{g,t} i_{g,t} + \mathcal{T}_t \\ &+ P_{z,t} \mathbb{I}_{z,t} + P_{z,t} \mathfrak{m}_t + P_{s,t} i_{s,t} - \mu_t z_{t-1} - f_h r_{h,t} H \\ &- f_w w_{s,t} S_t - f_n [(r_{b,t} - \delta P_{k,t}) k_{f,t-1} + r_{a,t} A] - f_{\mathcal{R}} \mathcal{R}_t \\ &- \sum_{\mathfrak{q}=j,n,x,b} [\, f_{\mathfrak{q}} (r_{\mathfrak{q},t} - \delta P_{k,t}) k_{\mathfrak{q},t-1} + f_{w\mathfrak{q}} w_{\mathfrak{q},t} L_{\mathfrak{q},t}] - h_t \mathfrak{pc}_t, \end{aligned} \tag{68}$$

where $\Delta b_t = b_t - b_{t-1}$, $\Delta d_{c,t} = dc_t - dc_{t-1}$, $\Delta d_t = d_t - d_{t-1}$, $f_{wn} = f_{wb} = f_w$, $w_{b,t} = w_{n,t}$, and r_d and r_{dc} are the interest rates (in dollars) on concessional debt d and commercial debt dc. In the coefficient multiplying dc_{t-1}, $\mathfrak{d}$ equals zero when creditors agree (grudgingly) to temporarily suspend interest payments on commercial/semi-concessional loans. The tax base for the VAT corresponds to $\mathfrak{pc}_t = P_{n,t} c_{n,t} + g_j P_{j,t} c_{j,t} + g_x P_{x,t} c_{x,t} + g_m c_{m,t} + g_b q_{b,t}$.

The term $P_{z,t} \mathbb{I}_{z,t}$, where $\mathbb{I}_{z,t} = \mathcal{H}_t (i_{z,t} - i_{z,o}) + i_{z,o}$, needs some explanation. Because skilled administrators are in scarce supply in low-income countries, ambitious public investment programs are often plagued by poor planning, weak oversight, and myriad coordination problems, all of which contribute to large cost overruns during the implementation phase.[37] To capture this, we multiply new investment $(i_{z,t} - i_{z,o})$ by $\mathcal{H}_t$, where $\mathcal{H}_t = \left(1 + \frac{i_{z,t}}{\tilde{z}_{t-1}} - \delta_z - \mathfrak{g}\right)^{\phi}$ and $\phi \geq 0$ determines the severity of the absorptive capacity constraint in the public sector. The constraint affects only implementation costs for new projects: at the initial steady state, $\mathcal{H} = 1$, as $i_z = (\delta + \mathfrak{g}) / \tilde{z}$, or in scenarios where a loss in revenue forces cuts in i_z ($\phi = 0$ when $i_{z,t} < i_{z,o}$).

Countries differ in their access to world capital markets. In the base case, the borrowing and amortization schedule for non-concessional loans is fixed exogenously during the Covid-19 crisis and for some years thereafter. Thus, in any given year, the *ex ante*

[37] Development agencies report that cost overruns of 35 percent and more are common for new projects in Africa. The most important factor by far is inadequate competitive bidding for tendered contracts (Brinceno-Garmendia and Foster (2010)).

financing gap ($\mathfrak{Gap}$) is

$$\begin{aligned}\mathfrak{Gap}_t &= \frac{r_d - \mathfrak{g}}{1+\mathfrak{g}} d_{t-1} + \frac{1+\eth r_{dc}}{1+\mathfrak{g}} dc_{t-1} + \frac{r_{t-1}-\mathfrak{g}}{1+\mathfrak{g}} P_t b_{t-1} + P_{g,t} i_{g,t} - dc_t \\ &+ \mathcal{T}_o + P_{z,t}\mathbb{I}_{z,t} + P_{z,t}\mathfrak{m}_t + P_{s,t} i_{s,t} - \mu_t z_{t-1} - f_h r_{h,t} H \\ &- f_w w_{s,t} S_t - \ f_n[(r_{b,t} - \delta P_{k,t}) k_{f,t-1} + r_{a,t} A] - f_{\mathcal{R}} \mathcal{R}_t \\ &- \sum_{\mathfrak{q}=j,n,x,b} [\, f_{\mathfrak{q}} (r_{\mathfrak{q},t} - \delta P_{k,t}) k_{\mathfrak{q},t-1} + f_{w\mathfrak{q}} w_{\mathfrak{q},t} L_{\mathfrak{q},t}] - h_o \mathfrak{pc}_t, \end{aligned} \tag{69}$$

That is, $\mathfrak{Gap}$ corresponds to expenditures (including interest rate payments on debt) less revenues and external non-concessional borrowing, when transfers and the VAT rate are kept at their *initial* levels $\mathcal{T}_0$ and h_0. In the short/medium run, *part* of this $\mathfrak{Gap}$ can be financed by external concessional and/or domestic borrowing, which are determined by

$$\Delta d_t = \lambda_d[\mathfrak{Gap}_t + \mathcal{T}_t - \mathcal{T}_0 - (h_t - h_0)\mathfrak{pc}_t] \tag{70}$$

and

$$P_t \Delta b_t = (1-\lambda_d)[\mathfrak{Gap}_t + \mathcal{T}_t - \mathcal{T}_0 - (h_t - h_0)\mathfrak{pc}_t], \tag{71}$$

where $\lambda_d \in [0,1]$ splits the borrowing between domestic and external concessional borrowing. 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 $\mathfrak{Gap} < 0$ between spending cuts and tax increases. The debt-stabilizing values for transfers and the VAT — their *long-run target* values — are,

$$\begin{aligned}\mathcal{T}_t^{target} &= \mathcal{T}_o - \lambda \mathfrak{Gap}_t, & (72)\\ h_t^{target} &= h_o + (1-\lambda)\frac{\mathfrak{Gap}_t}{\mathfrak{pc}_t}, & (73)\end{aligned}$$

where policy makers' preferences fix λ respecting $0 \le \lambda \le 1$.

Equations (72) and (73) are paired with targets for the long-run levels of domestic and concessional debt. The reactions functions that govern the paths of h and $\mathcal{T}$ are non-linear and incorporate these targets as well as socio-political constraints on how much and how fast fiscal policy can change:

$$h_t = Min\{h_t^r, h^{\text{cap}}\} \quad \text{and} \quad \mathcal{T}_t = Max\left\{\mathcal{T}_t^r, \mathcal{T}^{\text{floor}}\right\}, \tag{74}$$

where

$$h_t^r = h_{t-1} + \lambda_1(h_t^{target} - h_{t-1}) + \lambda_2 \frac{d_{t-1} - d^{target}}{y_t} + \lambda_5 \frac{b_{t-1} - b^{target}}{y_t}, \tag{75}$$

$$\mathcal{T}_t^r = \mathcal{T}_{t-1} + \lambda_3(\mathcal{T}_t^{target} - \mathcal{T}_{t-1}) - \lambda_4(\, d_{t-1} - d^{target}) - \lambda_6(b_{t-1} - b_{target}), \tag{76}$$

h^{cap} is an upper bound on the VAT rate, $y_t = P_{n,t}q_{n,t} + P_{j,t}q_{j,t} + P_{x,t}q_{x,t} + q_{b,t}$, and $\mathcal{T}^{\text{floor}}$ is a

lower bound on transfers.[38] Inside the bounds, the parameters λ_1- λ_6 determine whether policy adjustment is fast or slow. Under "slow" adjustment, d and/or b may rise above its target level in the time it takes h and T to reach h^{target} and $\mathcal{T}^{target}$. When this happens, the transition path includes a phase in which $\mathcal{T} < \mathcal{T}^{target}$ and $h > h^{target}$ to generate the fiscal surpluses needed to pay down the debt.

The reaction functions embody the core policy dilemma. Fiscal adjustment is painful, especially when administered suddenly in large doses. The government would prefer therefore to phase-in tax increases and expenditure cuts slowly. But if it moves too slowly, or if the bounds on h and $\mathcal{T}$ constrain adjustment too much, interest payments will rise faster than revenue net of transfers, causing the debt to grow explosively. Large debt-financed increases in public investment are undeniably risky — the economy converges to a stationary equilibrium only if policy makers win the race against time.

Market-Clearing Conditions

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

$$S_t = S_{x,t} + S_{n,t} + S_{j,t} + S_{bb,t}, \qquad \bar{L}_{xj,t} = L_{x,t} + L_{j,t}, \tag{77}$$

$$q_{n,t} = c_{n,t} + a_{kn}\left[\sum_{\mathfrak{q}=j,n,x,b}(i_{\mathfrak{q},t} + \mathbb{AC}_{\mathfrak{q},t}) + (\delta + \mathfrak{g})k_{f,t-1}\right] + a_{zn}(\mathbb{I}_{z,t} + \mathfrak{m}_t) + a_{sn}i_{s,t} + a_{gn}i_{g,t}, \tag{78}$$

and

$$q_{j,t} = c_{j,t} + a_{kj}\left[\sum_{\mathfrak{q}=j,n,x,b}(i_{\mathfrak{q},t} + \mathbb{AC}_{\mathfrak{q},t}) + (\delta + \mathfrak{g})k_{f,t-1}\right] + a_{zj}(\mathbb{I}_{z,t} + \mathfrak{m}_t) + a_{sj}i_{s,t} + a_{gj}i_{g,t}, \tag{79}$$

where, to repeat, $\mathbb{AC}_{\mathfrak{q},t} = \frac{v}{2}\left(\frac{i_{\mathfrak{q},t}}{k_{\mathfrak{q},t-1}} - \delta - \mathfrak{g}\right)^2 k_{\mathfrak{q},t-1}$ in sector $\mathfrak{q}$ and $\mathbb{I}_{z,t} = \mathcal{H}_t(i_{z,t} - i_{z,o}) + i_{z,o}$.

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

[38] $\mathcal{T}^{\text{floor}}$ may be rising over time, as in the case where other cuts in non-investment expenditure do not offset growth in public sector wages.

produces

$$\begin{aligned}\Delta d_t + \Delta dc_t + \Delta b_{f,t} \quad = \quad & \frac{r_d - \mathfrak{g}}{1+\mathfrak{g}} d_{t-1} + \frac{\mathfrak{d} r_{dc} - \mathfrak{g}}{1+\mathfrak{g}} dc_{t-1} + \frac{r_f - \mathfrak{g}}{1+\mathfrak{g}} b_{f,t-1} + \frac{\eta}{2}(b_{f,t} - \bar{b}_f)^2 \\ & + P_{z,t}\mathbb{I}_{z,t} + P_{z,t}\mathfrak{m}_t + P_{s,t} i_{s,t} + P_{g,t} i_{g,t} + P_t(c_{1,t} + c_{2,t}) \\ & + P_{k,t} \sum_{\mathfrak{q}=j,n,x,b} (i_{\mathfrak{q},t} + \mathbb{AC}_{\mathfrak{q},t}) + [r_{b,t} - f_n(r_{b,t} - \delta P_{k,t}) k_{f,t-1}] \\ & - y_t - \mathcal{R}_t - h_t g_b q_{b,t}, \qquad (80)\end{aligned}$$

where, to repeat, $\Delta\mathfrak{n}_t = \mathfrak{n}_t - \mathfrak{n}_{t-1}$ for $\mathfrak{n} = d, dc, b_f$, and $y_t = P_{n,t}q_{n,t} + P_{j,t}q_{j,t} + P_{x,t}q_{x,t} + q_{b,t}$. This equation includes extra terms that reflect the impact of trend growth on real interest costs. The textbook identity emerges when $\mathfrak{g} = 0$.[39]

B Sensitivity Analysis

Although plausible and insightful, our core results are generated from a single point in the calibration space. Some elements of this calibration, particularly those defining the initial equilibrium and key behavioral parameters, are anchored in a careful and extensive reading of the literature and evidence. The calibration of the Covid-19 shock itself as well as aspects of the policy response are necessarily more tentative: as with all other researchers at present, our assumptions are founded on often highly incomplete information. This means that our results can and should be subject to detailed sensitivity testing across the range of calibration parameter values and structural characteristics. Since space and time precludes a comprehensive sensitivity analysis, in this Appendix we limit ourselves to just a couple of observations. First, we consider how the same shock and policy response are likely to play out in two groups of countries especially hard hit by the pandemic namely those that are highly dependent on international tourism and those that are highly dependent on remittances. Second, we discuss the effects of altering some of the more tentative assumptions about the specific impact of the shock.

B.1 The Tourism-Dependent Economy

For a substantial number of low-income countries, the tourism sector accounts for a large share of output, employment and export earnings. For tropical small islands blessed with warm weather and beautiful beaches, the sector may account for between 15 - 35 percent of GDP. We explore a re-calibration of our baseline model to allow for the value added share to be 25 percent. All other parameters take the same values as in Table 1.[40].

As Figure 7 shows, the Covid-19 shock for the Tourism dependent economy is quali-

[39] VAT revenues collected in the tourism sector $h_t g_b q_{b,t}$ increase national income and reduce the current account deficit because the tax falls entirely on foreign tourists.

[40] The sectoral value added shares are derived residually. The higher share for the tourism sector comes largely at the expense of agriculture's share, which decreases from 34.6 to 11.3 percent.

tatively similar to the base case, but differs substantially in terms of magnitude. The exposure of the tourism sector to the almost complete collapse of international travel and tourism precipitates a tremendous economic collapse. When the pandemic first strikes, GDP, the real high-skill wage, and formal sector employment decrease 16 - 20 percent while the unemployment rate jumps from 6 to 7.8 percent. Private investment plummets so much so fast that the aggregate capital stock decreases 10 percent in just three years. At the same time that the real economy implodes, the public debt skyrockets to 72 percent of GDP. The shock to the tourism-dependent economy is huge but temporary. Over the medium/long term, most variables get within shouting distance of their counterparts in the baseline scenario. Most, but not all. For 40+ years, the decrease in the private capital stock is more than twice as large and the increase in the public debt twenty percentage points (of GDP) higher than in the average low-income country.

Needless to say, fighting back is harder in in the tourism-dependent economy. Given the larger initial shock, the requisite investment program is bigger and more severely front-loaded to achieve recovery to the pre-pandemic trend lines for per capita income and real wages within a decade. The larger needs means aggressive fiscal reforms (or higher tax rates) are even more important to as in their absence the required volumes of external finance quickly become infeasible, even if debt dynamic remain favourable.[41]

B.2 The Remittance-Dependent Economy

As discussed in the main text, one of the biggest areas of uncertainty around the likely impact of the pandemic is the response of remittances. Much of the data is based on balance of payments data which reflects on formal money transfer operators. In many countries the volume of remittances flowing through informal channels is large and highly substitutable with official remittances. It is quite possible therefore that total remittances have declined even as official remittances have recovered to or surpassed pre-pandemic levels. Consider the data for The Gambia. In the second and third quarters of 2020, year-over-year remittances in the Balance of Payments increased a spectacular 89.3 percent. But in household surveys for March-August 2020, 84.6 percent of respondents reported a decline in international remittances while a scant 1.3 percent said they increased (Besart and M.Meyer (2021)). Regardless of what the aggregate data shows for 2020, it seems clear that remittances decreased sharply in some highly remittance-dependent low-income countries. Nepal is one such country, where remittance inflows were equivalent to 27.3 percent of GDP in 2019 and are estimated to have decreased by around 10 percent in 2020 (World Bank (2020*b*)).

We re-calibrate our model to reflect this greater exposure and examine the impact of the pandemic shock (see Figure 8). What is striking in this case is that while the remittance

[41] Absent reforms, the investment program catapults the debt to 92 percent of GDP at year ten, although with reforms that increase the collection rate for the VAT, the debt drops to 81 and 69.4 percent of GDP at the 15- and 25-year horizons, respectively.

shock is more than five times larger than the base case, the trajectory of public debt and key aggregate macroeconomic variables is only a little worse than in the base case. The reason for this is straightforward and reflects the way in which we have generated these simulations. From an aggregate perspective, remittances and concessional finance are close substitutes in the capital account; the larger the reduction in remittances, the larger the net inflow of concessional finance.

Unless external finance can substitute dollar-for-dollar for lost remittance income, or taxation can adjust quickly, the sharp loss of income in remittance-dependent economies is traumatic and potentially destabilizing. Simulations available upon request show that the severity of the remittance shock is felt, when external concessional financing is limited so that domestic tax and bond financing bears a share of cost of financing and adjustment. Indeed, in that case, it is not possible for domestic borrowing to take the full strain of financing the public investment program in the face of the shock, until tax adjustments come through. Even if tax adjustment can be implemented quickly, the pressure on both tax and domestic borrowing remains high for long.

B.3 Modifying the Covid-19 Shock

Finally, we consider the robustness of our core insights to variations in some of the more tentative assumptions about the impact of the Covid-19 outbreak and the implications of the lock-down responses. We consider two specific effects. First, we allow the adverse impact of lock-down measures to be skewed towards the informal sectors of the economy rather than the formal sector as we assume in the earlier runs. Second, we allow the loss-of-learning that is currently concentrated on the accumulation of basic education to also affect the accumulation of higher-level training. Full details of these alternative simulations are available on request but the key results contain no great surprises and indeed confirm the essential insights of our previous analysis.

Consider first the case where the productivity hit is concentrated on the informal sector. To investigate this we assume the scale of the productivity shock remains equivalent to the baseline case (as measured in units of labor input lost) but that this falls disproportionately on the rural and urban informal sectors. Given the initial relative productivity differential between formal and informal sectors, the aggregate output loss is slightly moderated 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.

A similar picture emerges in the second case, where we allow for loss-of-learning effects

to also affect those undergoing upper-level education. In contrast to the growing body of empirical work quantifying loss-of-learning effects in basic education, there is little evidence yet of the impact of the disruption to higher-level education on skills and labor productivity. Absent any stronger guidance we simply assume the same quantitative impact on higher-level education as for basic level, adjusted for the shorter gestation period involved. Given that the full effect of loss-of-learning (whether in basic- or higher-level education) impacts labor productivity with a lag of eight and six years respectively, there is no immediate impact of the wider damage to education, but even when the impacts kick in, the impact on aggregate output and incomes is relatively modest – annual output is only around 0.2 percent lower at year $t = 10$ – reflecting the relative size of the skilled and unskilled labor force. We see slightly stronger distributional effects, but these generally work *against* unskilled labor that is complementary to skilled labor and favors the (slower growing) supply of high skilled workers: the cost of the loss of learning in upper-level education worsens income distribution.

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Tables and Figures

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) 1/	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 $(\chi, \alpha_x, \theta_x)$	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 $(\mathfrak{g})$	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 $(f_{\mathcal{R}})$	0.1
Efficiency of public investment (s)	1
Absorptive capacity constraint (ϕ)	0
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 maintenance spending to GDP $(P_z m/GDP)$	0.01644
Ratio of infrastructure investment to GDP $(P_z i_z/GDP)$	0.06
Ratios of education investment to GDP $(P_s i_b/GDP, P_s i_u/GDP)$	0.028, 0.012
Ratio of public investment in health to GDP $(P_g i_g/GDP)$	0.019
Ratio of remittances to GDP (base case)	0.072

Notes: 1/ 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 substitution is low.

Table 1. Baseline Calibration (Continued)

Parameter/Variable	Value
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^{target}, d^{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 $(\mathfrak{u})$	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 pivate capital goods $(\alpha_{kj}, \alpha_{kn})$	0.35, 0.15
Non-traded cost shares in infrastructure $(\alpha_{zj}, \alpha_{zn})$	0.35, 0.15
Non-traded cost shares in education capital $(\alpha_{sj}, \alpha_{sn})$	0.2, 0.6
Non-traded cost shares in health capital $(\alpha_{gj}, \alpha_{gn})$	0.35, 0.15
Gross return to infrastructure (R_z)	0.27
Gross returns to education $(R_u, R_b)^{2/}$	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
Share of domestic capital in total capital stock in the tourism sector	1

Notes: 2/ For the assumed time lags, the internal rate of return is 12 percent for basic education and 10 percent for upper-level education.

Table 2. Baseline Economic Shocks[1/]

Shock \ Year	1	2	3	4
Lockdown and Global Supply Chain (% decrease in TFP)				
Formal Sector	8	5	2	0
Informal Sector	4	3	1	0
Agriculture	2.7	1.5	1	0
Commodity Price (% decrease)	3	2	1	0
Remittances (% decrease)	0.5	0.5	0.3	0.1
Tourism Sector (% decrease in TFP)	40	30	20	10

Notes: 1/ For year 5 and beyond, all shocks are zero.

Table 3. External Financing (in Percent of Initial GDP) and Other Responses to the Covid-19 Pandemic

Feature	Response/Assumption
Debt service on external non-concessional borrowing	As a result of the G20 Debt Service Standstill Initiative (DSSI), interest payments on external commercial debt suspended for the first three years post-pandemic.
Reserve augmentation	Countries' share of the IMF's 2021 $650 billion SDR allocation, generates 2 percent of initial GDP in 'excess of reserves'. These are drawn as grant financing in $t = 2$ and $t = 3$.
Wage curve	The wage curve is temporarily suspended ($\mathfrak{z} = 1$) during $t = 1, 2$ of the pandemic, placing a floor under cuts in formal sector wages; the wage curve partially returns ($\mathfrak{z} = 0.5$) in $t = 3$, recovering fully ($\mathfrak{z} = 0$) in $t = 4$.[1/]

Notes: 1/ See the specification of the wage curve in the online Appendix.

Table 4. Health and Education Shocks[1/]

(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

Notes: 1/ For years not shown, all shocks are assumed to be zero.

Table 5. 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

Table 6. Summary Macroeconomic Effects of Lockdown and Responses

	Year 1	Year 2	Year 5	Year 10	Year 20	Year 50
[A] Shock, Lockdowns and Global Contraction [1/]						
Fiscal Adjustment						
External concessional financing [2/]						
Aggregate Output[8/]	-7.2%	-5.4%	-1.8%	-3.1%	-3.3%	-3.0%
Aggregate Consumption[8/]	-5.0%	-4.0%	-1.9%	-2.7%	-2.9%	-2.4%
Skilled Wage[8/]	-9.1%	-7.0%	-1.8%	-2.6%	-2.8%	-2.7%
Income of ex ante poor[8/]	-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%
Domestic consumption taxation [3/]						
Aggregate Output	-7.2%	-5.4%	-1.8%	-3.2%	-3.4%	-3.2%
Aggregate Consumption	-5.8%	-4.7%	-2.4%	-3.3%	-3.5%	-3.0%
Skilled Wage	-9.4%	-7.2%	-2.0%	-2.8%	-3.1%	-3.1%
Income of ex ante poor	-5.6%	-3.9%	-1.5%	-2.8%	-3.1%	-2.8%
Domestic Debt/GDP (initial = 15%)	15.5%	15.5%	15.5%	15.5%	15.5%	15.2%
Total External Debt / GDP (initial = 38%)	39.1%	39.1%	38.1%	39.2%	39.2%	38.4%
Recurrent transfers to households [4/]						
Aggregate Output	-7.2%	-5.3%	-1.8%	-3.2%	-3.4%	-3.1%
Aggregate Consumption	-5.7%	-3.6%	-2.4%	-3.3%	-3.5%	-3.0%
Skilled Wage	-9.3%	-6.8%	-1.9%	-2.8%	-3.0%	-3.0%
Income of ex ante poor	-5.7%	-4.0%	-1.5%	-2.8%	-3.1%	-2.8%
Domestic Debt/GDP (initial = 15%)	15.6%	15.6%	15.5%	15.2%	14.7%	12.9%
Total External Debt / GDP (initial = 38%)	39.2%	39.2%	38.0%	39.2%	39.2%	38.3%
Domestic tax plus reduced public infrastructure [5/]						
Aggregate Output	-7.2%	-5.6%	-2.3%	-3.9%	-3.9%	-3.3%
Aggregate Consumption	-5.4%	-4.3%	-2.4%	-3.8%	-3.9%	-3.2%
Skilled Wage	-9.4%	-7.3%	-2.4%	-3.5%	-3.6%	-3.3%
Income of ex ante poor	-5.7%	-4.1%	-2.0%	-3.5%	-3.5%	-2.9%
Domestic Debt/GDP (initial = 15%)	15.6%	15.6%	15.6%	15.6%	15.6%	15.1%
Total External Debt / GDP (initial = 38%)	39.3%	39.3%	38.0%	39.3%	39.3%	38.2%
[B] Fighting back: health and education investment [1/]						
Pure 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 [6/]						
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%
External finance plus domestic tax and reduced O&M [7/]						
Aggregate Output	-7.2%	-5.4%	-2.6%	-2.8%	-1.2%	-0.5%
Aggregate Consumption	-5.0%	-4.1%	-2.8%	-2.8%	-1.5%	-0.6%
Skilled Wage	-9.1%	-6.5%	-2.0%	-2.9%	-1.5%	-0.8%
Income of ex ante poor	-5.7%	-4.0%	-2.2%	-2.4%	-0.8%	-0.3%
Domestic Debt/GDP (initial = 15%)	18.2%	18.0%	17.3%	16.3%	15.1%	14.9%
Total External Debt / GDP (initial = 38%)	40.1%	39.9%	37.4%	39.1%	38.6%	37.9%

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/ Domestic recurrent and investment spending and real borrowing held at baseline levels; fiscal adjustment through changing domestic consumption tax. Note: changing debt ratios reflect changes in denominator.

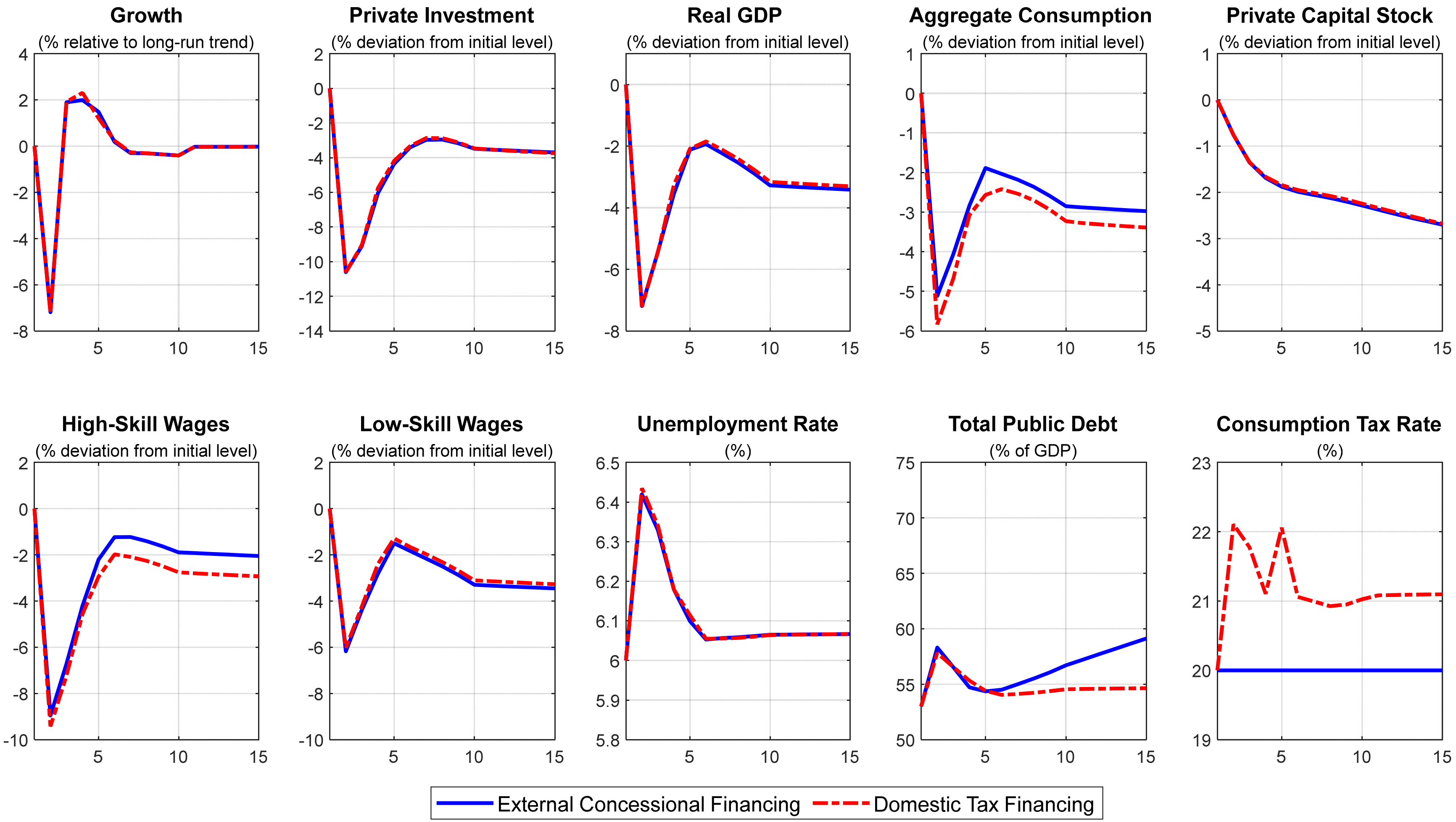
4/ Domestic tax rates, investment spending and real borrowing held at baseline levels; fiscal adjustment through changing transfers to households. Changing debt ratios reflect changes in denominator.

5/ Domestic recurrent spending and real borrowing held at baseline levels; fiscal adjustment through reduced infrastructure spending plus small adjustments to tax rate.

6/ 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.

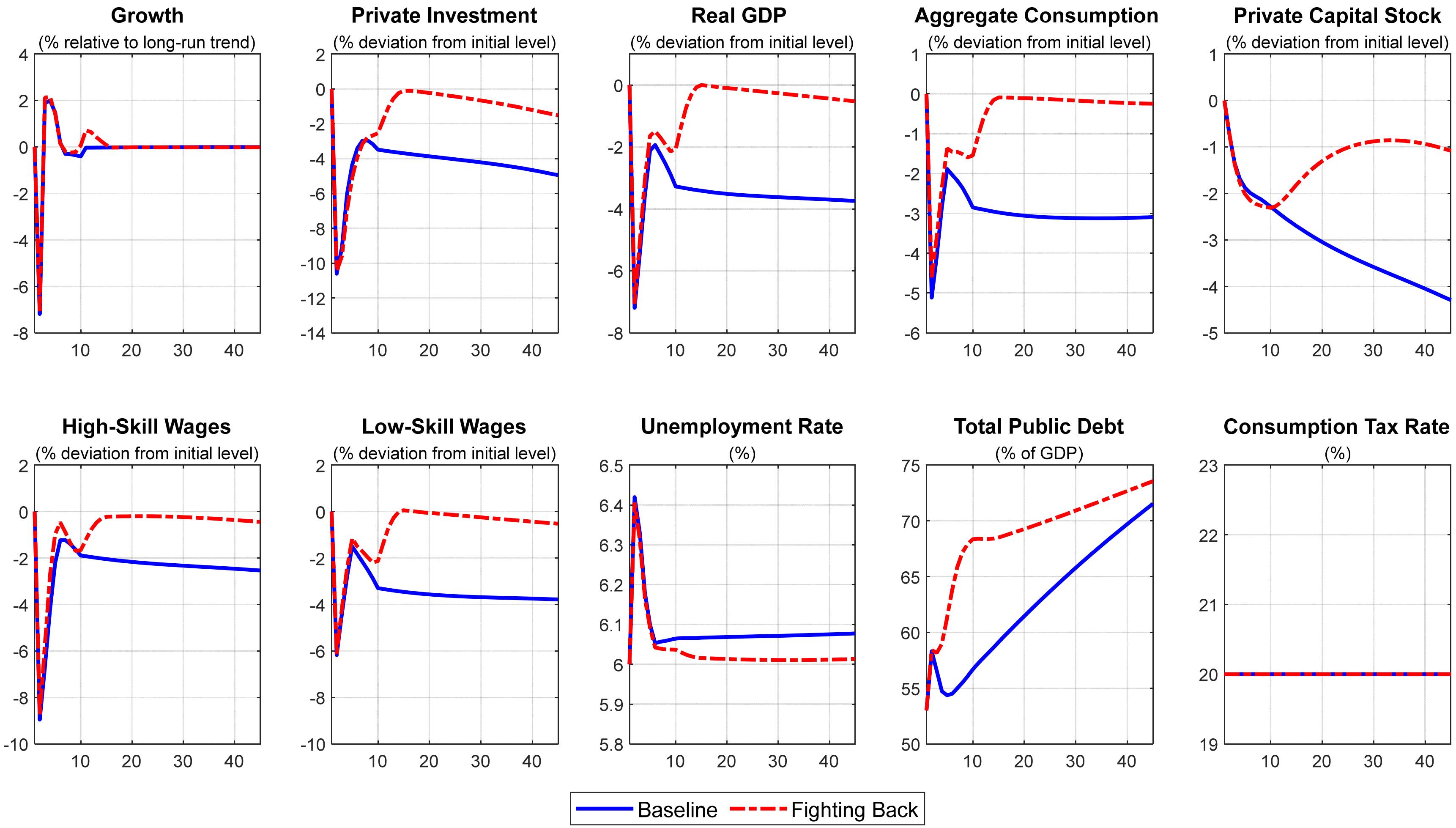
7/ As previous run but with maintenance expenditure on public infrastructure capital reduced to 75% of optimal level for t=1 to 5.

Figure 1. Baseline Shock



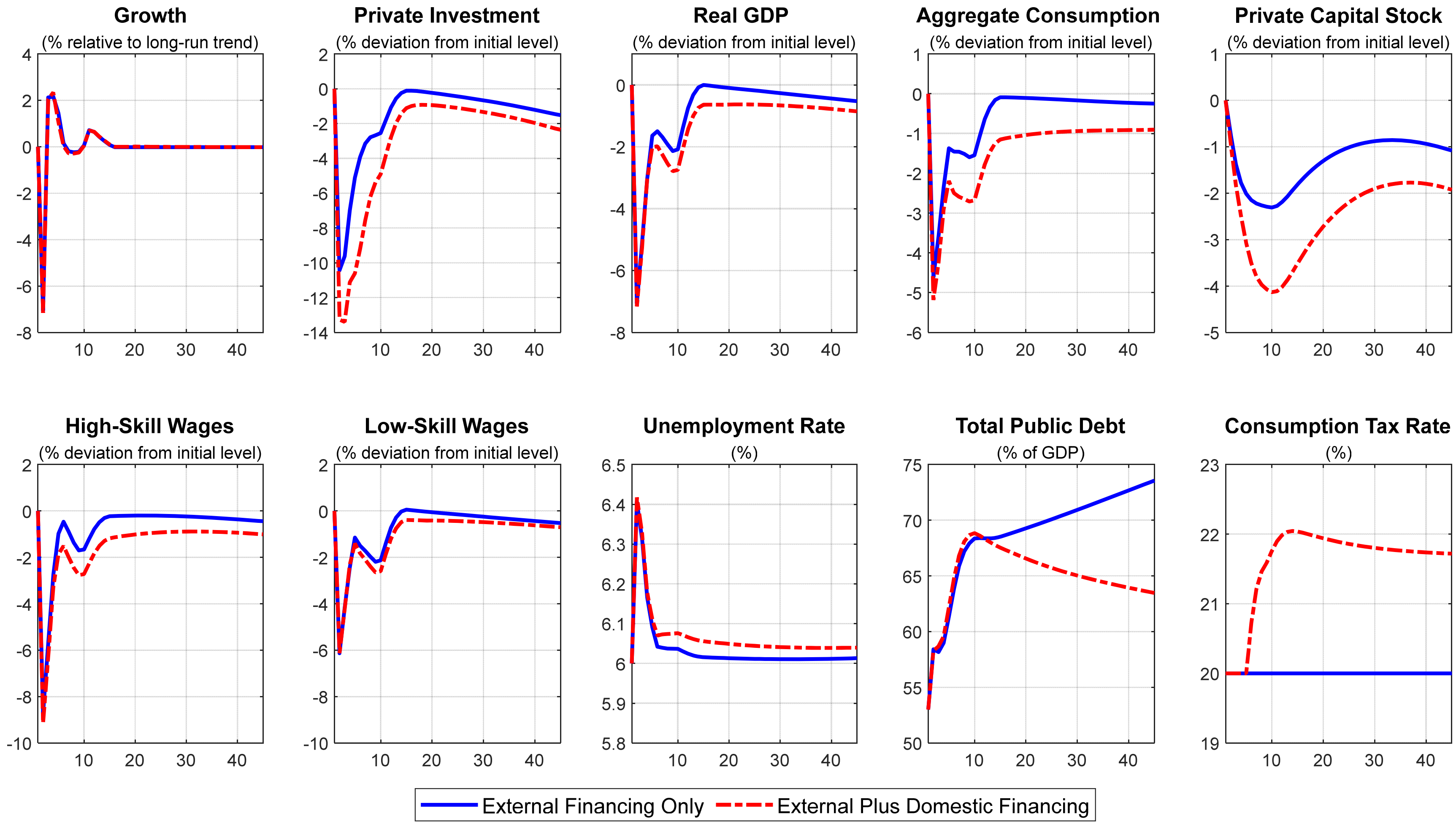
Notes: Dynamic response of baseline economy to Covid-19 shock with: (i) 'passive' domestic fiscal policy (no change in public spending or to domestic tax rates) and external concessional finance; and (ii) with domestic consumption tax adjustment.

Figure 2. Fighting Back vs. Passive Baseline Response



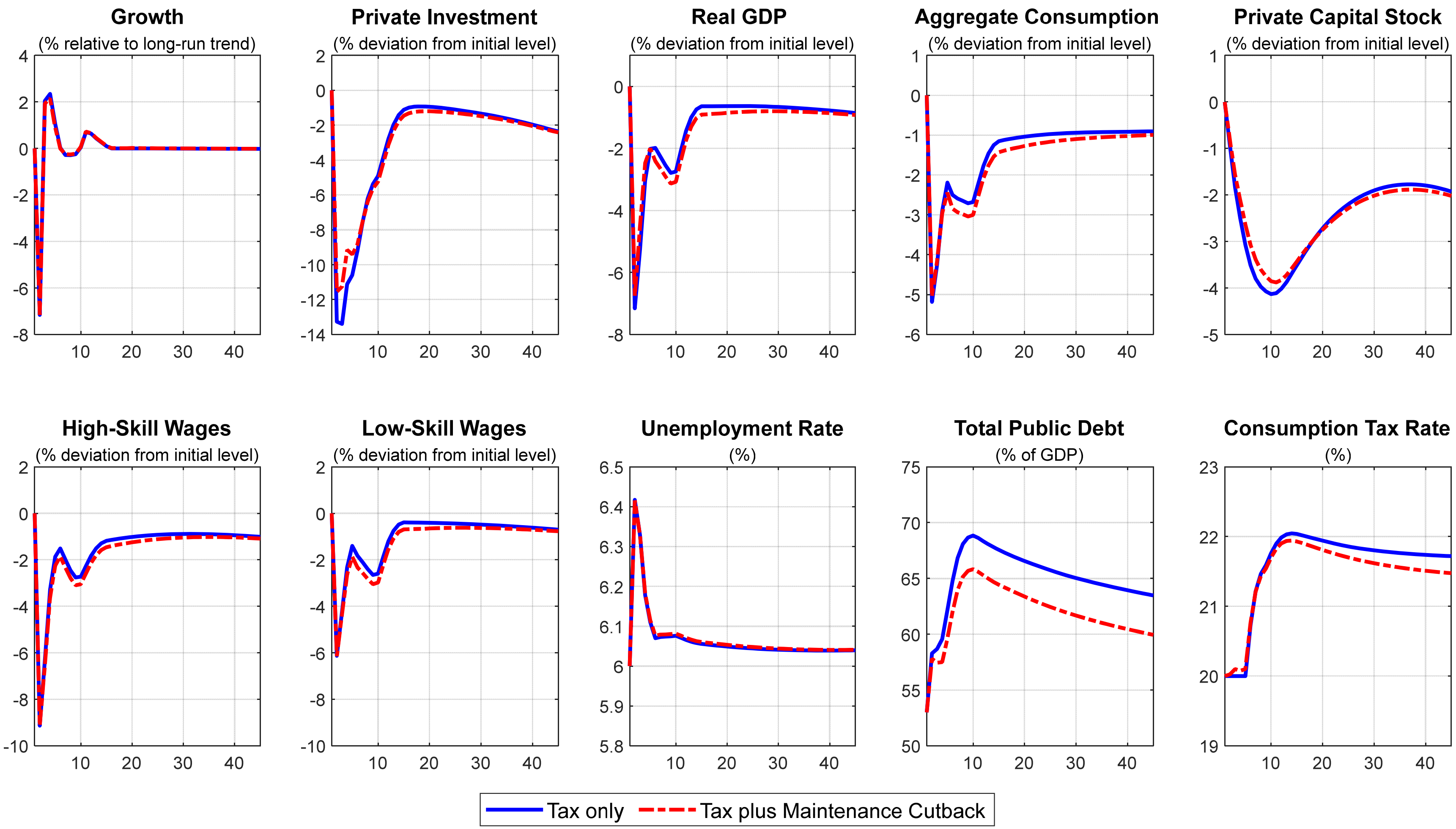
Notes: Public investment program, rises by 3 percent of initial GDP by $t = 3$, providing an additional 12.95 percent of initial GDP over first eight years. Two thirds of expenditure is allocated to supporting basic education spending. External concessional finance adjusts to satisfy external and fiscal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

Figure 3. Fighting Back with Domestic Financing



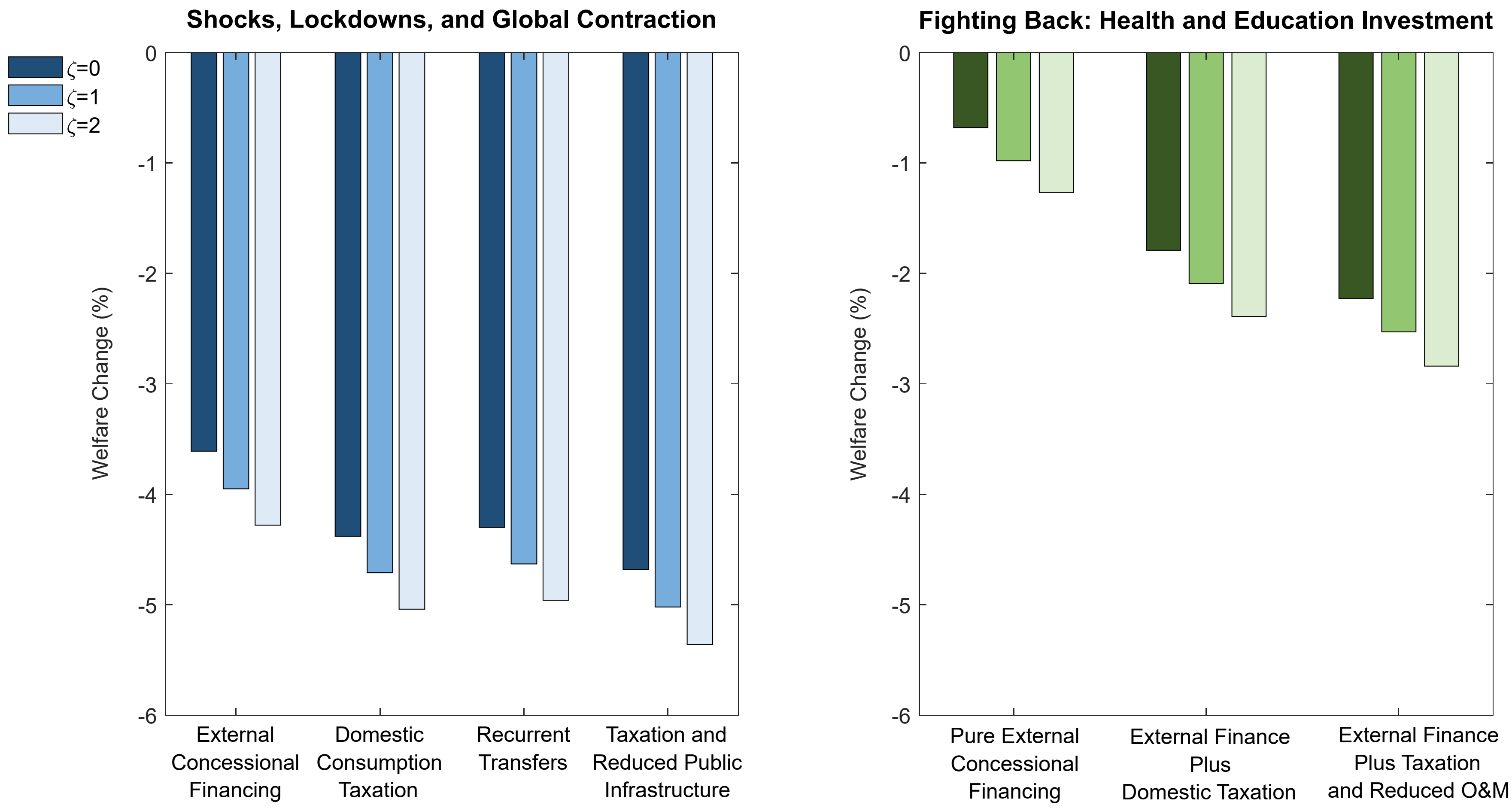
Notes: Public investment program as per Figure 2. Plot compares full external concessional finance with case where donors provide an additional 10 percentage points of initial GDP in concessional funding, which covers approximately 50 percent of the additional public investment.

Figure 4. Domestic Financing with Reduced Maintenance Spending



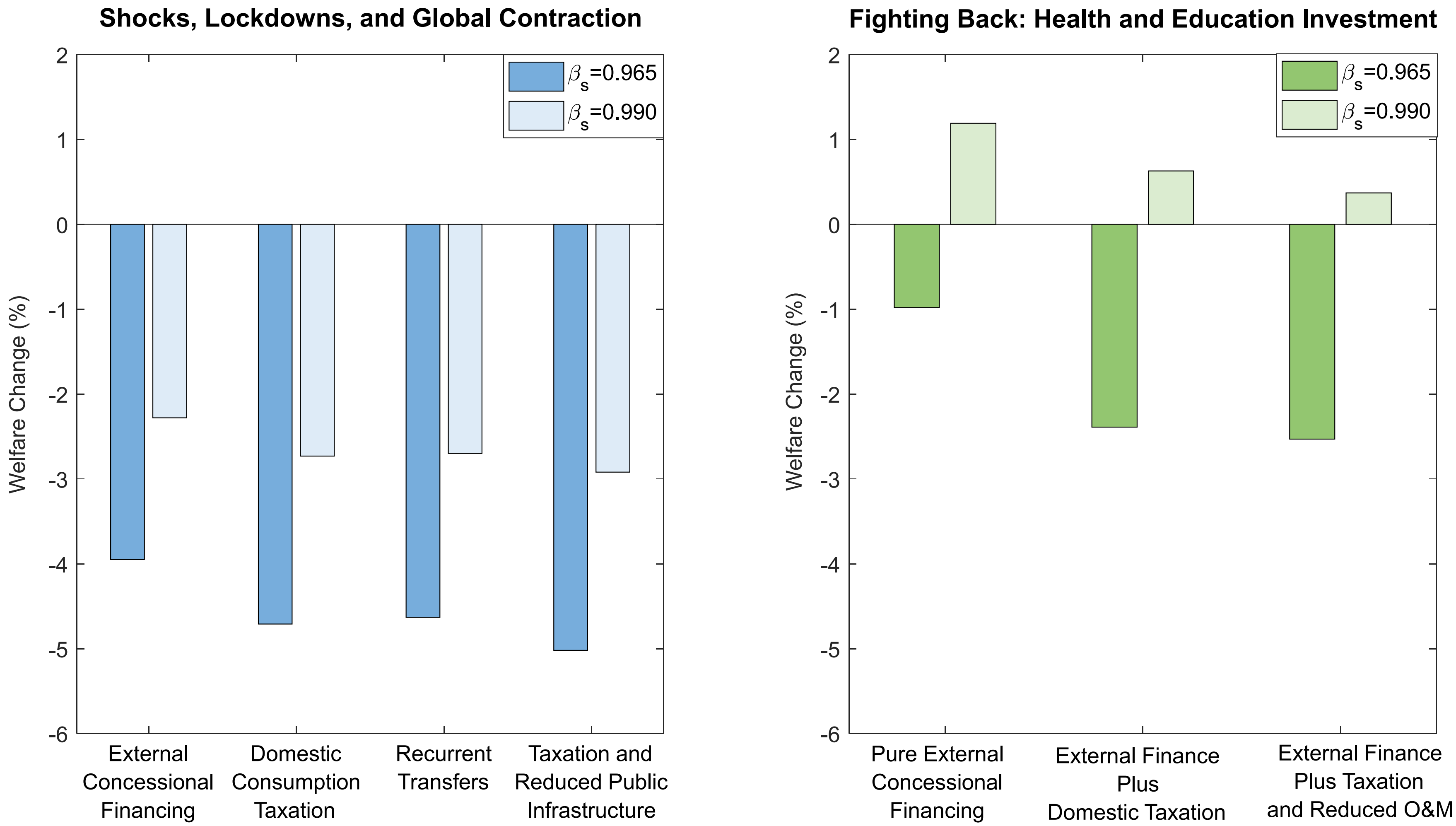
Notes: Public investment program as per Figure 3. Donors provide an additional 10 percentage points of initial GDP in concessional funding, which covers approximately 50 percent of the additional public investment. Compares all adjustment through taxation and domestic borrowing versus cases where maintenance expenditures are reduced to finance new public investment.

Figure 5. Welfare: Covid-19 Shock and Fighting Back Strategies, Varying the Distributional Weight ζ



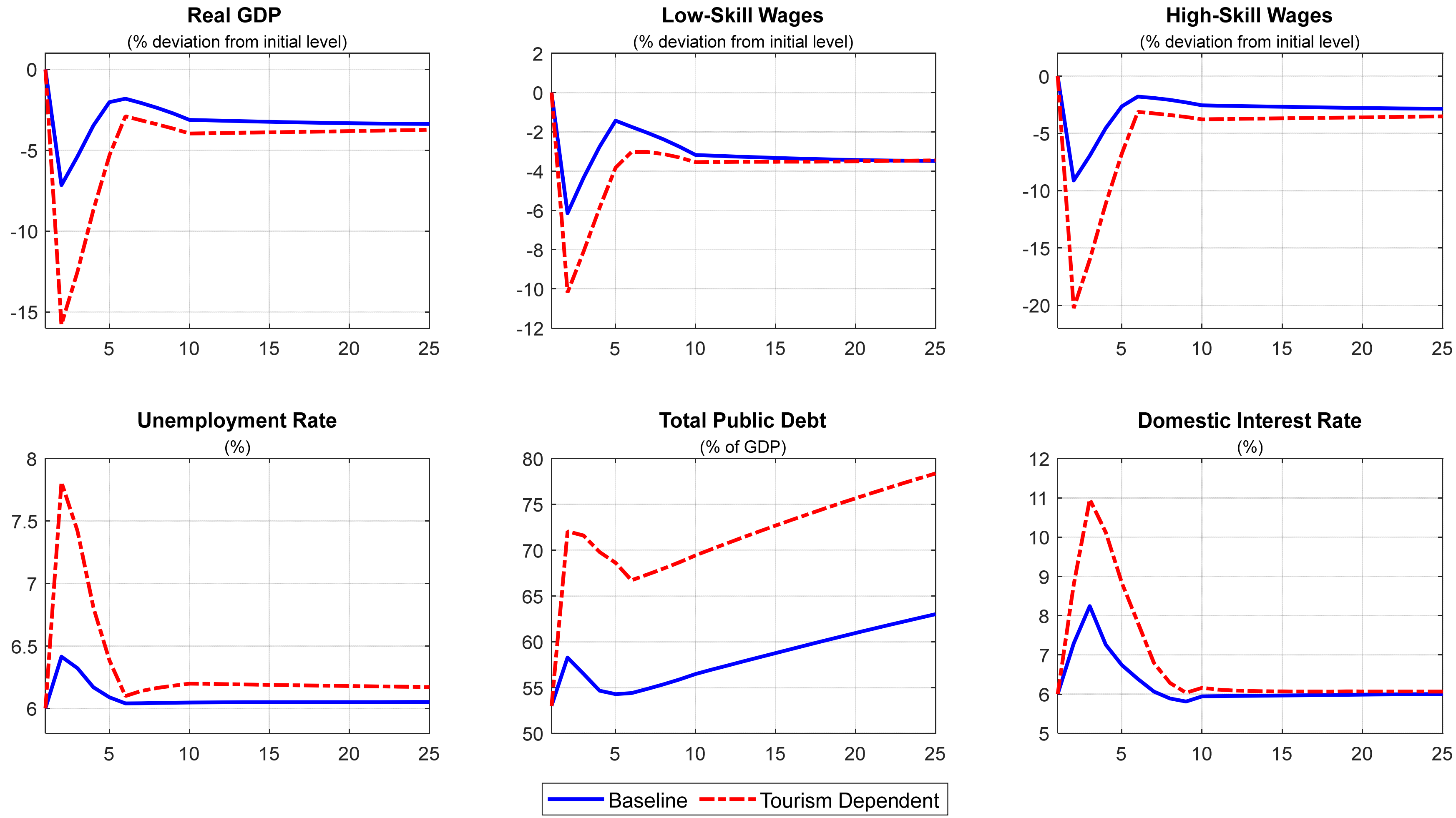
Notes: Welfare evaluated at the private discount rate under different distributional weights ζ. Runs correspond to those reported in Table 6. See notes to Table 6 for detailed description of each run.

Figure 6. Welfare: Covid-19 Shock and Fighting Back Strategies, Varying the Social Discount Factor β_s



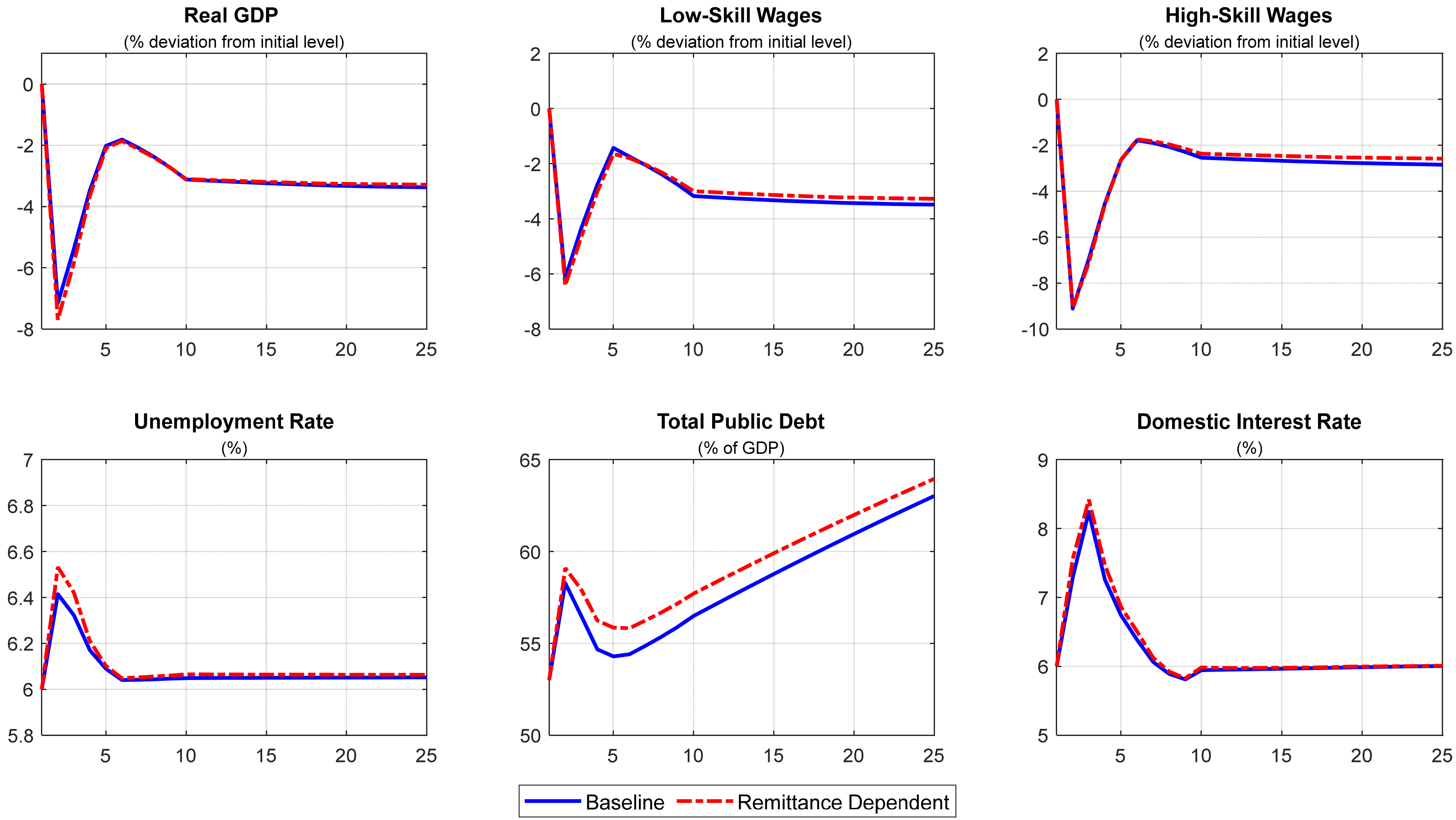
Notes: Welfare evaluated at $\zeta = 1$ under different social discount factors β_s. Runs correspond to those reported in Table 6. See notes to Table 6 for detailed description of each run.

Figure 7. The Tourism-Dependent Economy



Notes: Dynamic response of tourism-dependent economy compared to baseline economy. In both cases, we assume 'passive' domestic fiscal policy (no change in public spending or to domestic tax rates) with external concessional finance adjusting to satisfy external and fiscal balance.

Figure 8. The Remittance-Dependent Economy



Notes: Dynamic response of remittance-dependent economy compared to baseline economy. In both cases, we assume 'passive' domestic fiscal policy (no change in public spending or to domestic tax rates) with external concessional finance adjusting to satisfy external and fiscal balance.

PUBLICATIONS

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