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Peasant Farmers and Pandemics: The Role of Seasonality and Labour-Leisure Trade-Off Decisions[1]

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Abstract

Outbreaks of infectious diseases in developing countries deplete the primary asset of the poor – their labour – through premature deaths and increased morbidity. This study examines how peasant households may respond to the global and local effects of pandemics in economies with underdeveloped health care systems and limited social safety nets. Using data for Bhutan, the study explores some implications of different seasonal patterns of labour demand and supply and transmission peaks in a recursive-dynamic economy-wide model that includes households' labour-leisure trade-off decisions and encompasses the seasonality of the rural labour market. A global pandemic, like COVID-19, reduces household welfare, even in the absence of a local outbreak. The impacts on agricultural production and households' food security are closely linked to the timing of local infection peaks. Peasant households can mitigate the impacts of the pandemic by reallocating time from leisure to agricultural activities; this mitigation strategy is however limited in seasons when leisure is scarce. The study contributes to the understanding of how pandemics, and the timing of pandemics, impact smallholder agriculture and farm households in low income countries.

Keywords: Peasant households; Smallholder agriculture; Pandemics; COVID-19; Seasonal labour; Labour-leisure trade-off; Economy-wide impact assessment

[1] The views presented in this paper are those of the authors' and not their respective institutions.

1. Introduction

The majority of the poor reside in rural areas and are engaged in smallholder agriculture (Castañeda et al., 2018), where peasant farmers are dependent on the labour of household members. Pandemic diseases attack the primary asset (labour) of peasant households in the short- and long-term through premature deaths and morbidity, which implies a likelihood for serious adverse economic implications, over and above any social and psychological trauma. Peasants may be especially susceptible because of the seasonal pattern of labour demand driven by the biological nature of agricultural production systems. Moreover, there are limited social safety nets in developing countries: peasant farmers need to work.

Early 2020, the COVID-19 pandemic first unfolded in middle- and high-income countries causing an unprecedented slow-down in global economic activity and subsequent contraction in economic output. Following the rapid spread of COVID-19 and subsequent containment policies, global economic growth for 2020 is projected to drop by 4.9% (IMF 2020). In developing countries, the scope of containment policy responses and transfers is limited due to the high share of informal economic activities and constrained government finances. Essential economic activities, such as agriculture, have to continue, despite containment policy responses, to maintain food supplies. This requires that farmers cultivate their land during the pandemic. Unlike in developed market economies, where production systems have evolved to smooth out seasonal labour demands, smallholder agriculture systems are labour intensive and characterised by seasonality. Consequently, seasonal variations in labour demand result in periods of peak demand, e.g., planting, weeding and harvest, and periods of slack demand during which various strategies may be adopted to smooth out the demand for labour, e.g., small-scale domestic production[2] and temporary migration.

[2] Historic examples of such small-scale domestic production can be found in many countries, e.g., the production of Harris tweed by crofters in the Scottish Hebrides during the winter.

Past research on the effects of pandemics on poverty have shown that a disease outbreak during agricultural (peak) seasons can seriously disrupt agricultural supply. It has been estimated that the Spanish flu reduced the agricultural workforce in British India by 8.3% (Schultz, 1964), and that province-level reductions in land use were up to 28% (Sen, 1967). The Ebola epidemic in West Africa in 2014-15 coincided with the rice harvest season in Liberia, which increased labour shortages, through fears of contagion associated with congregating in groups. The levels of rice production were depressed and rural poverty increased sharply (La Fuente et al., 2019). Hence, the timing of disease outbreaks may be critical when analysing the economic impacts of a pandemic generally, and specifically in the context of smallholder farming.

Economy-wide simulation models have been used to study, *ex-ante*, the impacts of pandemics, e.g., social-accounting-matrix multiplier analyses or computable general equilibrium (CGE) models (Arndt et al., 2020; Breisinger et al., 2020; Laborde et al., 2020; Maliszewska et al., 2020; Zhang et al., 2020). While these methods have been applied in the context of developing countries, where a substantial share of the work force is employed in agriculture, none of the known studies account for seasonality of labour demand. Instead, they use an annual labour market specification, despite the common knowledge within agricultural disciplines that seasonality is an "inherent feature of rural livelihoods" (Ellis, 2000, p. 293). Amartya Sen (1966, p. 440) pointed out that "agriculture being a seasonal operation, it is somewhat misleading to speak in terms of a homogeneous unit of labour. A unit of labour at the time of harvesting is not replaceable by a unit of labour at a slack period". Neglecting the seasonality of rural labour markets has been shown to result in systematically biased economy-wide model results (Feuerbacher et al., 2020). Treating agricultural labour as homogenous precludes analyses of the seasonal pattern of pandemic impacts, i.e., when in the year the pandemic occurs.

This study contributes to the literature by addressing three questions:

1) What are the impacts of a global pandemic on a developing peasant economy in the absence of a local outbreak of the disease?

2) How do differences in the seasonal transmission of a local pandemic impact on the welfare of peasant households?

3) How may peasant households adjust their (short-term) seasonal labour supply decisions in response to global and local pandemics?

Five scenarios are developed to explore the global and local effects of a pandemic using data for the COVID-19 pandemic. The first scenario simulates the effects of a global pandemic, in absence of local infections. The remaining four scenarios include local outbreaks of the pandemic with different seasonal timings for peak transmissions, in addition to the global effects. The morbidity and mortality effects in case of a local outbreak are drawn from a compartmental (SIR) epidemiological model (Noll et al., 2020) to account for the typical (young) demographic of a peasant economy. The scenarios are simulated employing a recursive-dynamic CGE model. The South Asian peasant economy of Bhutan is used as an illustrative case, which allows use of a model database that incorporates seasonal labour markets (Feuerbacher et al., 2020). Other databases and models available do not incorporate seasonal labour in their data and behaviour and thus fail to capture the importance of the timing of the pandemic.

The analyses are conducted over time to distinguish between the mortality and morbidity impacts during the period of the local spread of the pandemic and the longer terms effects of premature deaths on welfare in subsequent periods, e.g., the reduction in cultivated area due to a smaller labour force. While the impacts of the current COVID-19 pandemic are simulated, the economic implications are relevant to other pandemic viral diseases with similar seasonal mortality and morbidity patterns. This study shows that accounting for the seasonality of labour has implications for how peasant households can adapt to a pandemic, e.g., through trading-off leisure with labour, and how the pandemic affects their welfare and food security. The results demonstrate that peasant household can adopt strategies that cushion the welfare implications of a pandemic by adjusting the distribution of labour services between agricultural activities and leisure.

2. Modelling Peasant Households

Peasant farm households are simultaneously households and productive activities; peasants must manage both the farm activity and the household. If peasant households are included as both activities and households the underlying model should embody properties found in the models developed by Chayanov (1986), Sen (1966), Mellor (1963), Lipton (1968), Barnum and Squire (1979), Becker (1965), Lopez (1986) and Löfgren and Robinson (1999). In such models peasant households can optimize one, or more, household objectives, i.e., act as rational economic agents (Lipton, 1968), while not being simple (separable) profit and utility maximisers. This is consistent with empirical evidence that peasants are responsive to market signals, changes in market arrangements, e.g., reductions in trade and transport costs, and changes in technology. Similarly, peasant households are not isolated from labour markets and can interact with markets to supply labour to activities other than their own productive activities, and to demand labour in peak seasons. Peasant households must also adjust to the biological nature of agricultural production and seasonal fluctuations in demand for labour; thereby reflecting that agriculture labour cannot be modelled as a homogenous unit (Sen, 1966, p. 440). This is of relevance when shocks, such as a pandemic, arise during seasons with particularly high (or low) demands for labour.

3. Global and local effects of COVID-19 pandemic scenarios

Historical records indicate the periodic occurrence of pandemics from the ancient world and Middle Ages (Huff et al., 2015). Reductions in populations due to the Black Death (1347 to 1353) were arguably the largest demographic shock experienced by Europe: the death of between 17 and 28 million people led to farmland abandonment and declines in cereal production in many parts of medieval Europe (Yeloff & van Geel, 2007). The Spanish flu (H1N1) was so far the deadliest viral pandemic in modern history killing an estimated 50 to 100 million people in the 1920s (Morens & Fauci, 2007).

Pandemics increase mortality and morbidity and require diverting resources to public health interventions from other economic activities. For example, in Bhutan, a small country situated in the Eastern Himalayas, the government has undertaken multiple and comprehensive responses to counter the spread of COVID-19 comprising random testing and rigorous screening of persons entering the country.[3] While this study uses Bhutan as an illustrative case the scenarios deliberately abstract from the actual situation in Bhutan, to derive some general implications.

Table 1 presents the five core scenarios used to address the study's main research questions. All scenarios are compared against a "Business-as-usual" (BaU) scenario, which is based on a counterfactual growth trajectory in the absence of a global and local outbreak of a pandemic. The first scenario (*Global_exBHT)* assumes that a pandemic will not spread into Bhutan, but will reduce tourism receipts, increase trade costs and affect global commodity prices (see below). The remaining four scenarios assume that there is also an (local) outbreak

[3] Yet, on August 11th, 2020, Bhutan imposed the first nationwide lockdown after infection events occurred within the country. By August 29th, 2020, the country had a total of 195 COVID-19 infections. The long-term effectiveness of such stringent containment policies remains to be seen, particularly given the porous land border with India, where COVID-19 infections are high

of the pandemic in Bhutan. These scenarios are characterized by different timings of the outbreak, i.e., whether the local infections peak during the off-season (winter), during seasons of peak labour demand (rice planting or harvesting seasons) or in middle of the rice growing season (when rice is weeded). The mortality and morbidity effects and the speed and scope of spread of the infection transmission within Bhutan are estimated using a generalized compartmental SIR (Susceptible-Infected-Recovered) model.[4]

Table 1 – Core model scenarios

Scen #	Scenario name	Scope of disease spread	Peak of local infections
1	Global_exBHT	Outbreak of COVID-19 globally, except for Bhutan	No local outbreak
2	Winter_R2.0	Global outbreak of COVID-19 with transmission inside Bhutan	Winter season
3	Plant_R2.0		Rice planting season
4	Weed_R2.0		Rice weeding season
5	Harvest_R2.0		Rice harvesting season

In all scenarios, the global outbreak occurs in 2020 (year 1) and the local outbreak is assumed to peak in different seasons within that year. The pandemic is assumed to continue through 2022, but the intensity (or magnitude) of shocks is reduced by 50% each year. The following subsections describe the detailed scenario components and calibration of shocks. An illustration of the different impact channels is presented in Figure 1. The shocks and impact channels are captured in a stylized manner, although *a priori* the magnitudes of effects of a pandemic are uncertain.

[4] The SIR model is based on a conservative reproductive number, R0, of 2.0 (see also the suffix "R2.0"). Sensitivity analyses varying R0 between 1.5 and 3.0 show that the main findings and conclusions are robust towards higher or lower choices of R0.

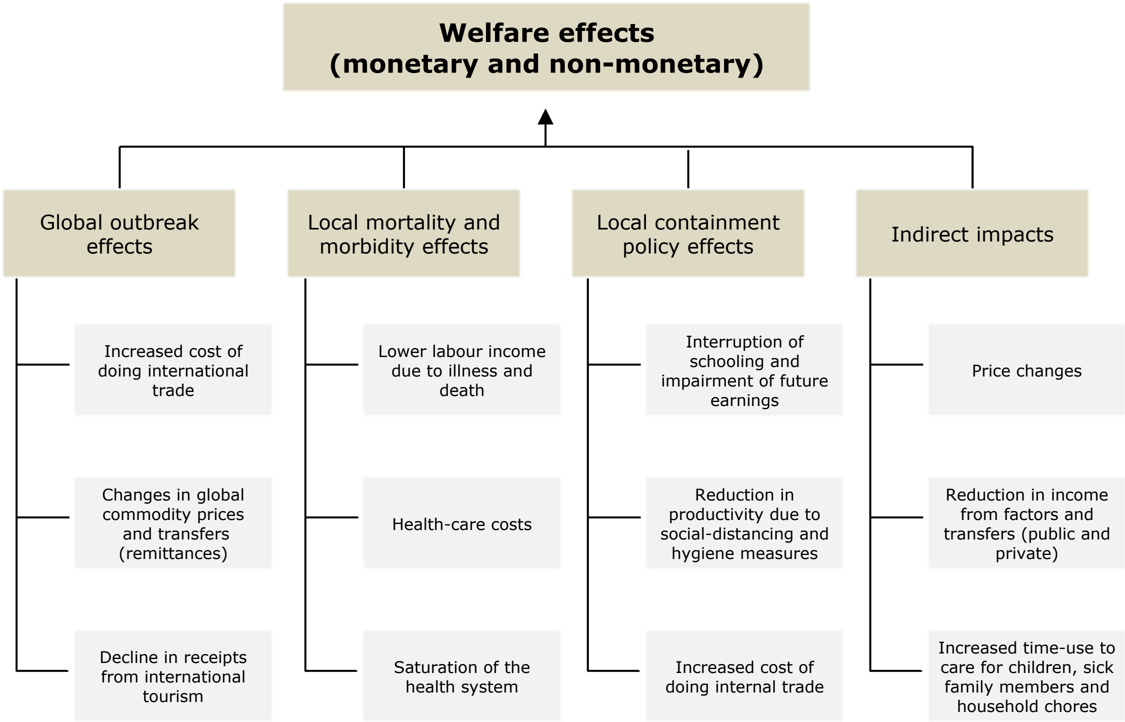

Figure 1 – The main impact channels affecting household welfare
Source: The authors' development with partial adaptations from World Bank, 2020

3.1. Impacts from a Global COVID-19 Outbreak

The effects of a global outbreak of COVID-19 on the Bhutanese economy in the absence of a local outbreak can be split into three main impact channels (Figure 1). On the import side, it is assumed that international carriage, insurance and freight (*cif*) margins increase by 15%. Presuming that international margins on average comprise 20% of world market prices, import prices increase by 3%. This magnitude is comparable to shocks on trade costs implemented by other global analyses on COVID-19 (Labourde et al., 2020; Maliszewska et al., 2020). At the export side, domestic export margins are increased by 10%.

It has been estimated that between 2020 and 2023 the world price of crude oil will remain 25% below the 2019 average price (IMF, 2020). It is assumed that this lowers global prices of refined petroleum products and other oil derivatives by 12.5%. The world market price for fertilizer is shocked to decline by 10%, following the forecast of World Bank staff (Baffes

& Koh, 2020). Possible impacts via international transfers (remittances) and changes in other global commodity prices, e.g., grain prices, were not included due to inconclusive evidence.[5]

The COVID-19 crisis has led to a collapse in global tourism. Receipts from international tourism comprise a non-trivial share of GDP in many low-income countries (United Nations, 2020). In Bhutan, borders were closed for international arrivals at the end of March 2020. As the situation is unlikely to be reversed in 2020, receipts from international tourism are expected to decline by a 90% (see Figure A1 in the appendix). The database was extended to include international tourism as an activity that uses various intermediate inputs, e.g., lodging, air and land transportation, other services such as tourist guides, and pays a production tax to reflect the tourism royalty and visa fees levied by the Bhutanese government. There is no domestic consumption and an export demand function (Appendix A2) is used to simulate the income from international tourism, which captures a reduction in the export of tourism services.

3.2. Impacts from a Local COVID-19 Outbreak

Once the disease spreads locally, the impacts of a pandemic on an economy can be separated into local mortality and morbidity effects and containment policy effects (see Figure 1). These impacts occur in addition to the above-mentioned effects from a global outbreak.

Local mortality and morbidity effects

In the short-term, the temporary reductions in labour supply due to illness dominate the mortality effects due to the low fatality rate of COVID-19. In the long-term, once the pandemic has ended, the mortality effects dominate because the pandemic permanently reduces the workforce (see below). At a reproductive number of 2.0, within 12 months after the beginning

[5] In Bhutan, remittances have increased in the first quarter of 2020 probably due to the government initiated return of migrant workers from the middle east Royal Monetary Authority of Bhutan (2020). Other studies on developing economies (e.g., Breisinger et al. (2020)) model a reduction in remittances.

of the disease spread, the supply of skilled and unskilled labour drops by 1.5% and 1.6%, respectively. In the economy-wide model, these two labour types are assumed to be permanently employed, while farm labour is subject to seasonality and divided in monthly seasonal labour accounts. Within 12 months after the beginning of the disease spread, the annual farm labour supply drops by about 1.9%, but in the month in which most infected persons suffer severe symptoms from the pandemic, the seasonal availability of farm labour is reduced by up to 10.2%.

Figure 2 illustrates the changes in monthly farm labour supply and the daily number of infections for the four local outbreak scenarios. The annual reductions in seasonal farm labour are not identical across the scenarios: when the local outbreak is during the harvest season, i.e., late in the year, there are no COVID-19 mortality and morbidity effects during the beginning of the year, but the effects drag on into the beginning of the following year. This is not the case for skilled and unskilled labour, for which the reductions in supply are assumed to be always equal across all four scenarios.[6] This assumption eases the later interpretation of results during the year of the outbreak.

[6] Roughly speaking, this reflects a situation in which COVID-19 first spreads among the urban population and then, at the different timings, to the rural population.

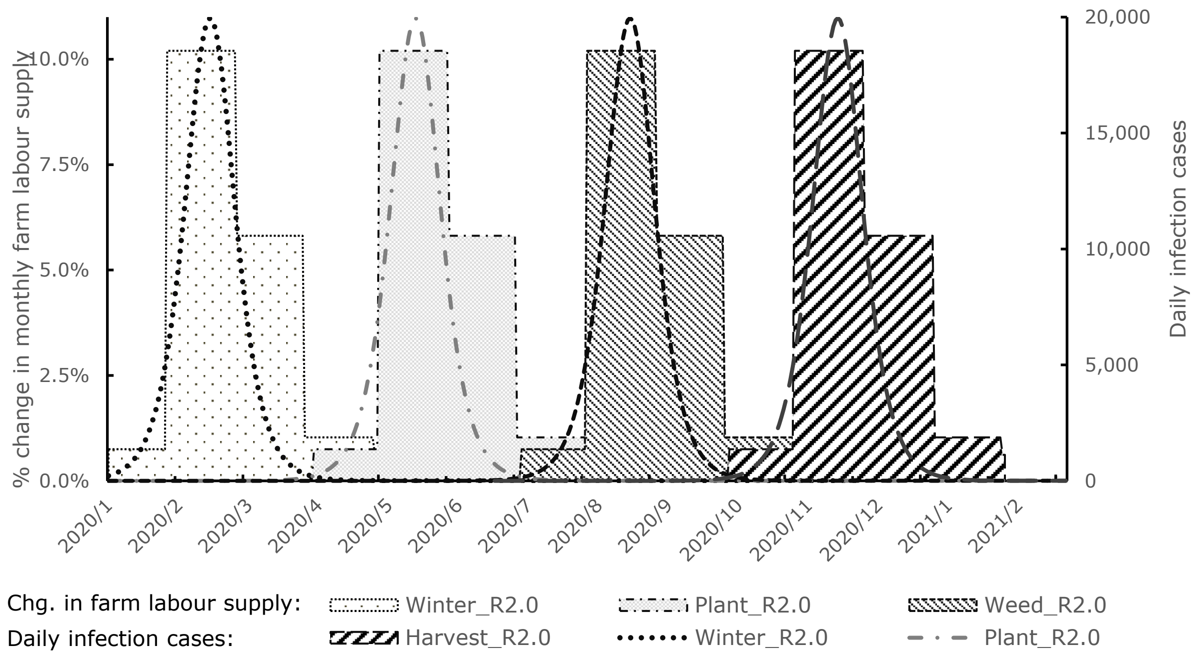

Figure 2 - Change in Farm Labour Supply (Area and left axis) and Daily Number of Infections (Lines and right axis)

Source: Authors estimates based on the SIR model (Noll et al., 2020)

The mortality and morbidity effects also increase health care costs, which in Bhutan are covered by the government.[7] The estimation of the respective increase in healthcare cost is documented in Table A3 in the appendix. During the year of the outbreak, the volumes of government health services are expanded by 14.6% to reflect increased need for healthcare. The risk of a saturation of the health system is accounted for in the SIR model, where an increased fatality rate is assumed for persons with critical conditions, but without access to intensive care unit (ICU) treatment.

Local containment policy effects

The effects stemming from containment policies depend on the stringency of the policies implemented. The scope of containment is limited in low-income countries, due to low levels

[7] Of course, wealthier households could afford private health treatment. Yet, this would require open borders, as Bhutanese usually travel to Thailand for private healthcare.

of social protection and government finances, at least in the middle- to long-term. Containment policies often entail interruption of schooling, which has impacts on students' future earning potential. In many low-income countries, school feeding is a vital intervention to ensure food security among vulnerable children. From March 2020 onwards schooling in Bhutan was interrupted. The effects are modelled as a 1% decline in the factor productivity of skilled labour from 2021 to 2030, although this may underestimate the long-term effects of the pandemic on future earnings. Social-distancing and hygiene measures will impact on economic activities such as lodging, retail trade, transportation and other services which are considered non-essential and characterized by high risks of transmitting the disease. The effects on these high-risk sectors is accounted for by reducing their total factor productivity by 10% during the pandemic.

The general rise in transaction costs and cost of doing business within the country is modelled by increasing the domestic trade and transportation margins by 10% during the pandemic. Moreover, it is reasonable to expect a disruption of domestic services, for instance public services required for investments, e.g., permits, and delays in inspections. However, these effects are difficult to quantify and cannot be incorporated in the model in a straightforward manner. Changes in government borrowings as a result of the pandemic are documented in the model closure section.

<u>Indirect impacts and the role of social reproduction</u>

Over and above the direct effects of a global and local outbreak, there are numerous indirect impacts such as price changes and reductions in income from either factors or transfers. These second-round effects are endogenously captured within the economy-wide model. Allowances could be made for idle capital and unemployment, but would require further, and restrictive, assumptions.

The model includes the trade-off between labour and leisure by households, where leisure is defined to include social reproduction[8] activities. Social reproduction comprises time-use for economic activities such as caring for family members, cooking and other household chores, that are performed outside of the production boundary of the System of National Accounts (SNA) and therefore do not contribute to the gross domestic product. In case of a local outbreak pandemic households will need to spend more time caring for sick family members and children (due to school closings). Also, while less relevant in low-income countries, time-use for household chores increase as outside dining and domestic services (such as hiring cleaning workers or nannies) become unavailable due to social-distancing and hygiene measures. To reflect the increased need for care giver services within households, the elasticities of substitutions between 'leisure' and aggregate commodities are halved – from elastic to inelastic – during the pandemic.

3.3. Estimation of mortality and morbidity effects

A generalized compartmental SIR (Susceptible-Infected-Recovered) model (Noll et al., 2020) is used to estimate the mortality and morbidity effects of different COVD-19 outbreak scenarios for Bhutan. Compartmental models have long been used in epidemiology (Kermack & McKendrick, 1927), and while they may abstract from the full complexity and heterogeneity of a pandemic they provide a systematic, and well understood method to estimate the dynamics and severity of outbreaks at the national level.

The model has a browser-based user interface and the pre-set parameters are estimated from empirical data. All model parameters (latency, infectious period, the reproductive number) and the country specific data (demographics and age profile) can be specified by the user. Table 2 reports the model parameters for the core scenario, which is based on a conservative R0 of 2

[8] Social reproduction is a theory that has its roots in Marxist feminism. It expands beyond the more common concept of household production within the economic literature (see Apps and Rees (2001); Becker (1965)).

reflecting the rural and scattered settlements in Bhutan and also its fairly young demographic (Hilton & Keeling, 2020). More details on the estimation of the mortality and morbidity effects are provided in the appendix A4.

Table 2 - Model parameters used to estimate the morbidity and mortality effects in the local outbreak scenarios

Model parameter	Value	Unit / Description
Initial number of cases	10	Persons
Imports per day	1	Daily number of infected persons entering the country from outside
Annual average R0	2.0	Average number of secondary infections per case.
Latency period	3	Days
Infectious period	3	Days
ICU capacity	96	Beds
Hospital stay	3	Days
ICU stay	14	Days
Severity of ICU overflow	3	Multiplicative factor to fatality rate of persons with critical status but without ICU access

Source: Authors' assumptions and Bhutanese news reports (The Bhutanese, 2020)

4. Data and Model

4.1. Model

The computable general equilibrium (CGE) model (Feuerbacher, 2019; Feuerbacher et al., 2020) is a variant of the STAGE model (Aragie et al., 2016; McDonald & Thierfelder, 2015) implemented in a recursive dynamic mode (McDonald & Thierfelder, 2020). There are three model features that make the model suitable to study the impacts of a pandemic on peasant households. First, the model incorporates both seasonal demand for labour and leisure supplied by rural households. Second, the time use for social reproduction activities outside the production boundary (which is included as a part of leisure) is accounted for via a labour-leisure trade-off. Third, the factor market clearing is modelled at the level of the household and (incorporated business) enterprises to account for the factor supply by institutions.

Production is modelled as a five-level system of nested CES and Leontief production functions (see Figure 3 where 0 (zero) in an arc indicates a Leontief function and σ a CES function). Land inputs are modelled as CES aggregates of land, chemical fertilizers and manure.

Capital inputs are modelled as CES aggregates of the different type of capital, and aggregate capital-labour is defined as a CES aggregate of capital and aggregate labour. Aggregate labour is a CES composite of seasonal (shaded) and permanent (non-seasonal) labour, which is a CES aggregate of skilled and unskilled labour. This is a novel formulation for a production system in a CGE model (Feuerbacher et al., 2020). Seasonal labour is only used by agricultural activities and the monthly demand for labour by agricultural activities is defined. There are no direct substitution possibilities for labour supplied in different seasons; but there are indirect substitution possibilities through labour leisure trade-offs.

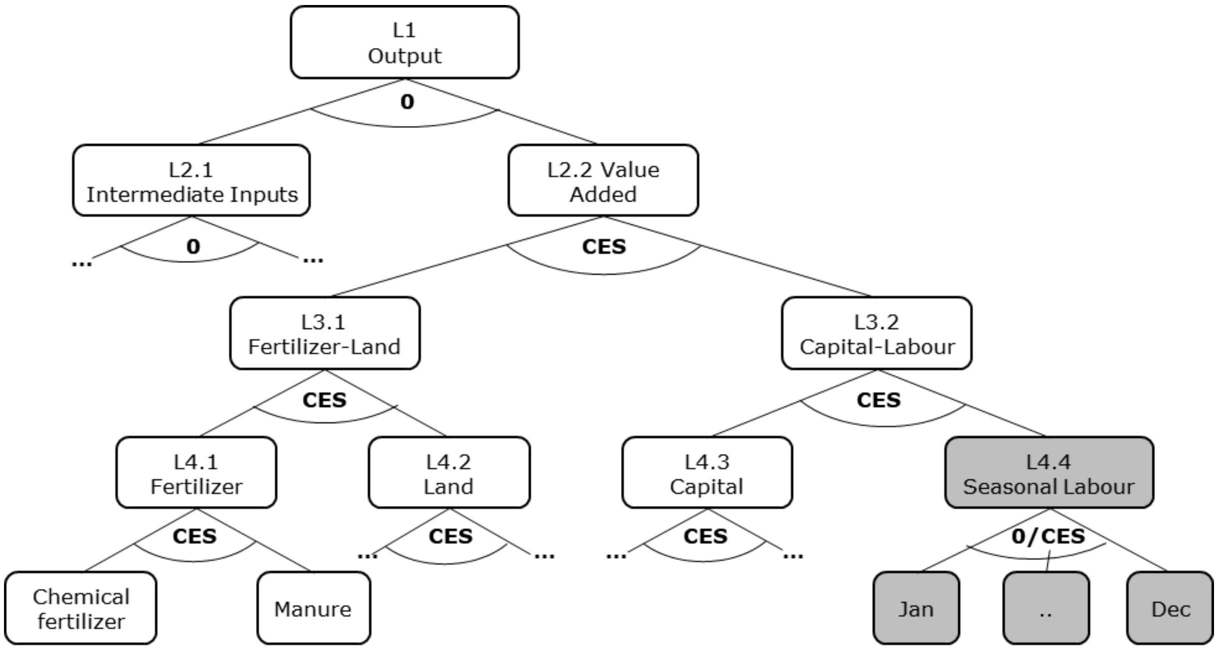

Figure 3 - Production System of Seasonal Activities

Source: Authors' modified from Feuerbacher et al., 2020
Note: For non-seasonal activities, the nest L4.4 represents permanent labour demand

Each household has a paired activity that produces household specific social reproduction and leisure, using labour services owned by the household. The production functions are CES aggregates of permanent and seasonal labour, i.e., there are labour substitution possibilities. By defining activities that produce commodities outside the production boundary as household specific, i.e., they can only be produced and consumed by the household, there are uniquely defined prices for commodities and services produced inside and outside the boundary. This approach ensures unique prices, in accord with the SNA. It is a generalization of a method used by Fontana and Wood (2000).

Labour market clearing, in quantities, is defined as $\sum_{a} FD_{f,a} \leq \sum_{ins} FSI_{ins,f}$ where $FD_{f,a}$ is the factor, *f*, demanded by activity, *a*, and $FSI_{ins,f}$ is the factor supplied by institution, *ins*, including households, which endogenizes the distribution of income (Aragie et al., 2016). This means that each household can supply its labour to its own agricultural and social reproduction/leisure activities and the labour market. Labour market clearing at the household level ensures that labour services used by activities within the SNA production boundary, and outside the production boundary for social reproduction and leisure, cannot exceed those available to the household. This formulation endogenizes the distribution of income, i.e., the distribution of earned income among households is a variable dependent on the quantities of labour each household sells to activities.

The demand system is a nested three level CES-LES[9]-CES utility function whereby households choose optimum mixes of commodities and social reproduction/leisure subject to prices and the constraints of preferences, income and labour resources. In the first (CES) level each household trades-off aggregate leisure/social reproduction services and aggregate consumption. At the second (LES) level households determine the optimum consumption levels of aggregate commodities, e.g., processed food, services, other goods, subject to minimum (subsistence) levels of consumption. At the third (CES) level households choose optimum mixes of 'natural' commodities in the aggregate commodities. The income elasticities of demand for commodity groups at the LES level were estimated using cross-sectional household data from the 2012 Bhutan Living Standard Survey (Feuerbacher, 2019). The parameters

[9] LES is a Linear Expenditure System.

needed for the labour-leisure trade-off are based on econometrically estimated wage elasticities and income elasticities of labour supply (see details in the model calibration section).

4.2. Data

The model database is a Social Accounting Matrix (SAM), with satellite accounts for labour quantities, for Bhutan in 2012 (Feuerbacher et al., 2017). The main body of the transactions matrix follows standard national accounting price conventions (valuations are in basic and purchaser prices) with inter-industry accounts recorded in supply and use format for all transactions within the SNA production boundary. Distinctive features of the SAM include detailed accounts for agriculture by three agroecological zones[10] (AEZs) reflecting variations in climate and altitude and differences in growing conditions, the monthly demand for farm labour types by activities and the recording of activities for social reproduction/leisure that are outside the SNA production boundary. Due to data limitations, the accounts for social reproduction and leisure cannot be separated in the source data, therefore they are recorded as a single account – ‘leisure’.

The rural labour market is dominated by seasonal farm labour types segmented by the three AEZs. In total, there are 37.9 million person-days provided by some 170,000 farmers, i.e., an average of 225 working days per person; this excludes labour used for social reproduction and leisure. Overall, employment in seasonal activities accounts for 48% of Bhutan’s labour days. The use of person-days for seasonal labour and leisure for the three AEZs are reported in Figure A5 in the appendix, with the number of person-days absorbed by cropping, livestock, non-farm and leisure activities summarized for each month. The patterns of demand differ markedly across activities, particularly for cropping activities with rigid demand. The potential

[10] AEZ1 is the humid subtropical zone below 1,200m; AEZ2 is the dry subtropical zone between 1,200 and 1,800m; AEZ3 is the temperate zone above 1,800m

seasonal labour bottlenecks are driven by the paddy transplanting and harvesting seasons, which vary by AEZ, e.g., in AEZ1 transplanting is in June-July and harvesting in November-December. The seasonal activities in the model database, their share in total output and demand for seasonal labour and their respective seasonal labour substitution elasticities are reported in appendix A6.

Non-farm labour is classified as unskilled and skilled (permanent) labour, which is demanded by agricultural, food processing, manufacturing and service activities and social reproduction. There are five land accounts (rainfed, irrigated, orchard, pasture and forestland) each sub-divided by AEZ. There are five capital factors: two livestock capital accounts (cattle and other animals), and three physical capital factors (private capital, hydroelectric and informal capital). There are unique 'production functions' for the generation of new capital by each type of capital. Ownership of factors by institutions (agricultural household and incorporated business enterprise) is identified. Households are classified as agricultural if at least one household member is reported to work within agriculture. Agricultural households are sub-divided by AEZs and access to land, i.e., farm and landless households.

4.3. Model Calibration

The model requires exogenous parameters that govern the responsiveness of agents to changes in (endogenous) model variables and exogenous shocks. Given the nature of the shocks simulated – short term reductions in labour – the abilities of smallholder households to transfer labour from leisure/social reproduction (leisure) to agricultural production (work) are critical. This section emphasizes the parameters that control this labour transfer.

The number of days worked (H) is imputed as 225 days per year from the total days worked by agricultural workers in Bhutan. The annual disposable time-endowment for households (T) is set at 312 days per year;[11] the amount of 'leisure' time (F) is the difference. A plausible income elasticity of labour supply, $\varepsilon_{H,Y}$, is given by $\varepsilon_{H,Y} = H/T - 1$ (Boeters & Savard, 2013). The substitution elasticity for the labour-leisure trade-off, $\sigma_{lei,X}$, can be defined as $\sigma_{lei,X} = 1 - \varepsilon_{H,w}/\varepsilon_{H,Y}$, where $\varepsilon_{H,w}$ is the (unknown) wage elasticity of labour supply $\varepsilon_{H,Y} = H/T - 1$ (Boeters & Savard, 2013). Setting the wage elasticity of labour supply to 0.15 (Goldberg, 2016) gives elasticities of labour-leisure substitution of 1.54 for agricultural and 2.00 for non-agricultural households. Sensitivity analysis demonstrates the robustness of model results across a range of elasticities. The implicit income elasticity of labour supply for agricultural households is -0.28 ($\varepsilon_{H,Y} = 225/312 - 1$) and -0.15 for non-agricultural households. The calibrated values for $\varepsilon_{H,Y}$ are within the range reported by Bargain and Peichl (2016), while estimates based on shadow-wage data for low-income countries are higher (Barrett et al., 2008; Jacoby, 1993), i.e., they would result in lower quantities of leisure.[12] The substitution elasticities for different labour types (skilled, unskilled or seasonal) in the production of leisure are set at 1.50. The intra-seasonal substitution of leisure is set to 0.30, in recognition of leisure being inclusive of social reproduction, which is within the range of empirical estimates between 0.01 – 1.20 (Feuerbacher et al., 2020).

4.4. Model Closure and Business-As-Usual Assumptions

The macroeconomic closure and factor market clearing conditions for the model are:

1. Trade: the small country trade assumption (fixed world prices) is adopted except for a downward sloping export demand function for tourism services (Appendix A2). It is

[11] Defining the lower bound for T when there is zero leisure at peak labour demand gives range from 262 (in AEZ3) to 298 days (in AEZ1). 312 days allows for a minimum amount of 'leisure' for social reproduction.

[12] Lower quantities of leisure will magnify the effects of labour supply shocks.

assumed that the rest of the world does not change its lending to Bhutan in response to the pandemic; hence the current account balance is fixed as a share of GDP. The exchange rate is flexible.

2. Savings-Investment: investment is savings-driven. In the BaU scenario, savings rates are fixed at values that increase annual savings by 2% per year; the estimated savings rates are fixed in all disease outbreak scenarios.
3. Government: the government account is cleared by flexible income tax rates. In the BaU scenario, the government expenditures and borrowings are fixed as a share of GDP. In all disease outbreak scenarios, the government is allowed to increase government borrowing by 5% against the BaU, which is offset by respective reductions in borrowing in the three years after the outbreak, i.e., total borrowing over the model horizon is equal in the BaU and simulated scenarios. Government expenditure increases in the outbreak years by the amount of the increase in health care cost.
4. Factors: labour is fully employed by activities within the SNA boundary or in leisure/social reproduction but free to move between activities; three types of fixed capital (private capital, hydroelectric and informal capital) are fixed within each period; other flexible capital types (livestock) are fully employed and mobile; and land use is flexible within each period, i.e., farmers can adjust the area cultivated.
5. Technology: technology, at the aggregate value-added level, is fixed within each time period but improves over time.

The recursive dynamic settings assume that investment decisions for new capital goods for period t are made at the end of period (t-1) and then allocated to activities for period (t+1). Each type of capital has a unique (Leontief) cost/production function and the volume of production for each capital type changes in response to the (relative) rates of return to each type of capital. For types of capital that are activity specific, the allocation of new capital to each activity is determined by the (relative) rates of return to each type capital in each activity and is then fixed for that period. The same initial allocation is implemented for flexible types of capital, but they are then mobile between activities in the solution period.

Labour supplies for each labour type are assumed to grow exogenously at the same rate[13] for all households: skilled labour grew by 1.5% per annum, unskilled labour by 3.5% and agricultural labour by 0.6%. Thus, the shares of each type of labour change over time. The total-factor-productivity is assumed to grow exogenously at 4% per annum, reflecting the strong growth rates of the Bhutanese economy.

The model is run for 10 years; 'Year 0' is the base year and the pandemic impacts on the economy in 'Year 1'. The simulations used to inform the analyses include four pandemic 'intensities', based on R0 values, with the outbreaks in four different seasons and a 'Business as Usual' (BaU) scenario for which there is no outbreak of the disease.

5. Analyses and results

The analyses begin with the results of the global outbreak scenario, focusing on macro-level results. Then, more detailed results and analyses are presented to investigate how the different local outbreak scenarios impact households and how responses differ according to the season in which the pandemic arises.

5.1. A global outbreak of a COVID-19 type pandemic with no local outbreak

The effects of a global outbreak of the pandemic lead to a reduction in real GDP by 1.4% and household welfare by 1.7% in the year of the outbreak (Table 3). Tourism services are one of Bhutan's main exports, accounting for 5.4% of GDP and 15.8% of export volume; the 90% decline in export of tourism services results in a reduction of total exports by 9.7%. The real

[13] The rates were in line with past rates of labour growth, based on population projections (NSB, 2019).

exchange rate depreciates, and the volume of non-tourism exports increases by 4%, despite the simulated 10% increase in domestic export margins. The tertiary sector's output declines, depressing factor incomes from skilled and unskilled labour and incorporated capital. This primarily impacts non-agricultural households, the main beneficiaries from tourism and non-agricultural income, whose incomes decline by 3.3%. The overall decline in household incomes explains the reductions in consumption and investment (savings rates are fixed). Government expenditure in real terms increases as the price of government services decline, given the drop in skilled and unskilled wages.

Import prices increase due to higher international margins resulting in a 6.7% decline in imports (Table 3). The production of import substitutes is stimulated, particularly in the primary and secondary sectors. Agricultural households benefit from increasing producer prices, especially for cereals, which are characterized by a high import intensity. Factor incomes from farm labour, capital and land increase, which explains the smaller decline in agricultural households' income and welfare.

Table 3 - Summary of the model results in year 1 for all core scenarios (Source: Authors' calculations)

GDP components (valued at base prices)	Base Share of GDP (%)	Changes compared to BaU (%)				
		Global _exBHT	Winter _R2.0	Plant _R2.0	Weed _R2.0	Harvest _R2.0
GDP	100.0	-1.4	-4.7	-4.7	-4.6	-4.6
Absorption (C+I+G)	124.5	-1.6	-4.1	-4.1	-4.1	-4.1
Consumption (C) *(excl. leisure)*	44.2	-2.5	-5.6	-5.7	-5.6	-5.5
Agricultural households	16.4	-0.7	-4.6	-4.9	-4.6	-4.5
Non-agricultural households	28.2	-3.5	-6.1	-6.1	-6.1	-6.1
Investment (I)	62.2	-2.0	-4.7	-4.7	-4.7	-4.7
Government (G)	15.5	2.3	1.8	1.8	1.8	1.7
Exports (E)	36.9	-9.7	-13.9	-13.8	-13.8	-13.8
Imports (M)	61.4	-6.7	-9.1	-9.0	-9.0	-9.0
Other macro-level indicators						
Real exchange rate (*Domestic currency/ foreign currency*)		4.7	4.6	4.6	4.6	4.6
Producer price index (*PPI*)		0.0	-0.8	-0.8	-0.8	-0.8
Avg. household income *(excl. leisure)*		-2.4	-5.8	-5.9	-5.8	-5.7
Agricultural households		-0.3	-4.0	-4.3	-4.0	-4.0
Non-agricultural households		-3.3	-6.6	-6.5	-6.6	-6.5
Avg. household welfare [a] *(incl. leisure)*		-1.7	-5.4	-5.4	-5.3	-5.3
Agricultural households		-0.5	-4.3	-4.4	-4.2	-4.2
Non-agricultural households		-2.4	-5.9	-5.9	-5.9	-5.9
Domestic production:		-2.4	-5.9	-5.9	-5.9	-5.9
Primary sector		1.8	-0.9	-1.3	-0.8	-0.8
Secondary sector		1.0	-2.4	-2.3	-2.3	-2.3
Tertiary sector		-7.9	-11.8	-11.8	-11.8	-11.8
Factor income:		-1.9	-5.4	-5.4	-5.3	-5.3
Skilled labour		-3.0	-4.8	-4.7	-4.7	-4.7
Unskilled labour		-3.2	-6.4	-6.4	-6.4	-6.4
Farm labour		0.8	-2.6	-2.6	-2.4	-2.7
Incorporated capital		-1.6	-6.0	-6.0	-6.0	-5.9
Agricultural capital		3.0	-2.8	-5.7	-3.5	-3.2
Arable land		1.6	-2.7	-3.4	-2.6	-2.3
Non-arable land		2.1	-3.8	-2.3	-2.7	-3.0
Wages: Skilled labour		-3.56	-3.37	-3.37	-3.36	-3.32
Unskilled labour		-3.55	-6.18	-6.16	-6.15	-6.12
Farm labour		0.76	-0.21	-0.16	-0.29	-0.61
Agriculture sector indicators						
Agricultural producer prices		1.6	0.2	0.6	0.5	0.1
Agricultural production		-0.2	-1.1	-1.9	-1.3	-1.0
Crop producer prices		1.3	0.0	0.6	0.4	-0.1
Crop production		0.4	-0.5	-1.7	-0.6	-0.4
Cereal producer prices		2.6	0.9	2.1	2.1	1.0
Cereal production		1.1	0.7	-2.6	-0.4	-0.5
Arable land supply		0.4	-0.6	-1.4	-0.9	-0.5

[a] Welfare changes are measured by the Slutsky equivalent variation incl. leisure expressed as a share of households' base expenditure

The adverse impacts from the pandemic subside gradually; GDP in years 2 and 3 also declines (Figure 4). In subsequent years the economy rebounds, reaching the BaU growth trajectory from year 4 onwards. The macro-level results (Table 3) generally indicate that poor households without agricultural income are most vulnerable to the global implications of the pandemic, particularly in terms of food security as domestic food prices increase, while incomes from non-agricultural income sources decline.

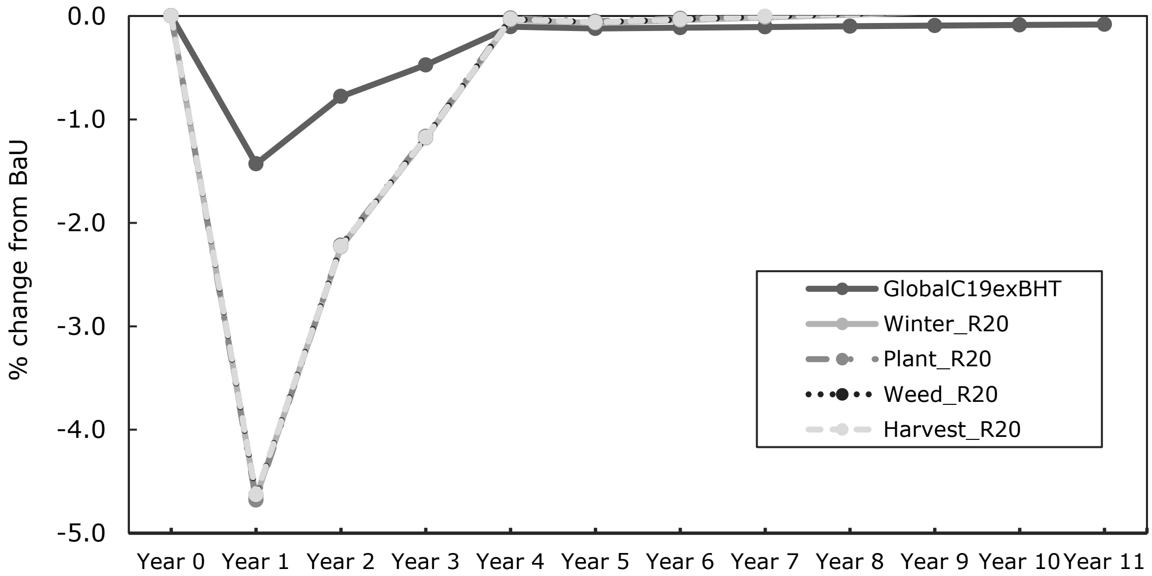

Figure 4 - Real GDP for Different Outbreak Scenarios (% change from BaU)
Source: Authors' calculations.

5.2. Analysing results from local outbreak scenarios

The combination of the global effects and local effects from an outbreak at different seasonal timings result in a greater reduction in real GDP of 4.6% in the year (Table 3). As with the global outbreak scenario, the economy rebounds after the outbreak in year 1 (Figure 4). Other summary indicators produce results that follow the same general patterns; absorption declines and then recovers, but not fully; as do export and import volumes and household consumption. The patterns of the changes are in line with expectations. In contrast to the global outbreak, for all local outbreak scenarios income and welfare decline for every household category (see below). Exports decline at a higher rate (Table 3), since non-tourism exports suffer from reduced labour availability and increased domestic cost of doing business.

Farm labour wage rates, agricultural production and food security

The pandemic attacks the main asset of peasants, their labour. Figure 5 reports the farm labour wage and supply responses upon different timings of the pandemic shocks in detail for the mid-altitude agroecological zone (AEZ2). The results are similar in the other two zones. Depending on the timing of the outbreak, farm labour supply is reduced in seasons when labour demand is at its peak, which in Bhutan is during the rice transplanting and harvesting season. When the pandemic hits peasant households in that season, farm labour (shadow) wages respond strongly with increases in seasonal wage rates of up to 53% (see panel A in Figure 5). The more the timing of the outbreak coincides with main agricultural activities, the greater the increases in (shadow) farm labour wages.

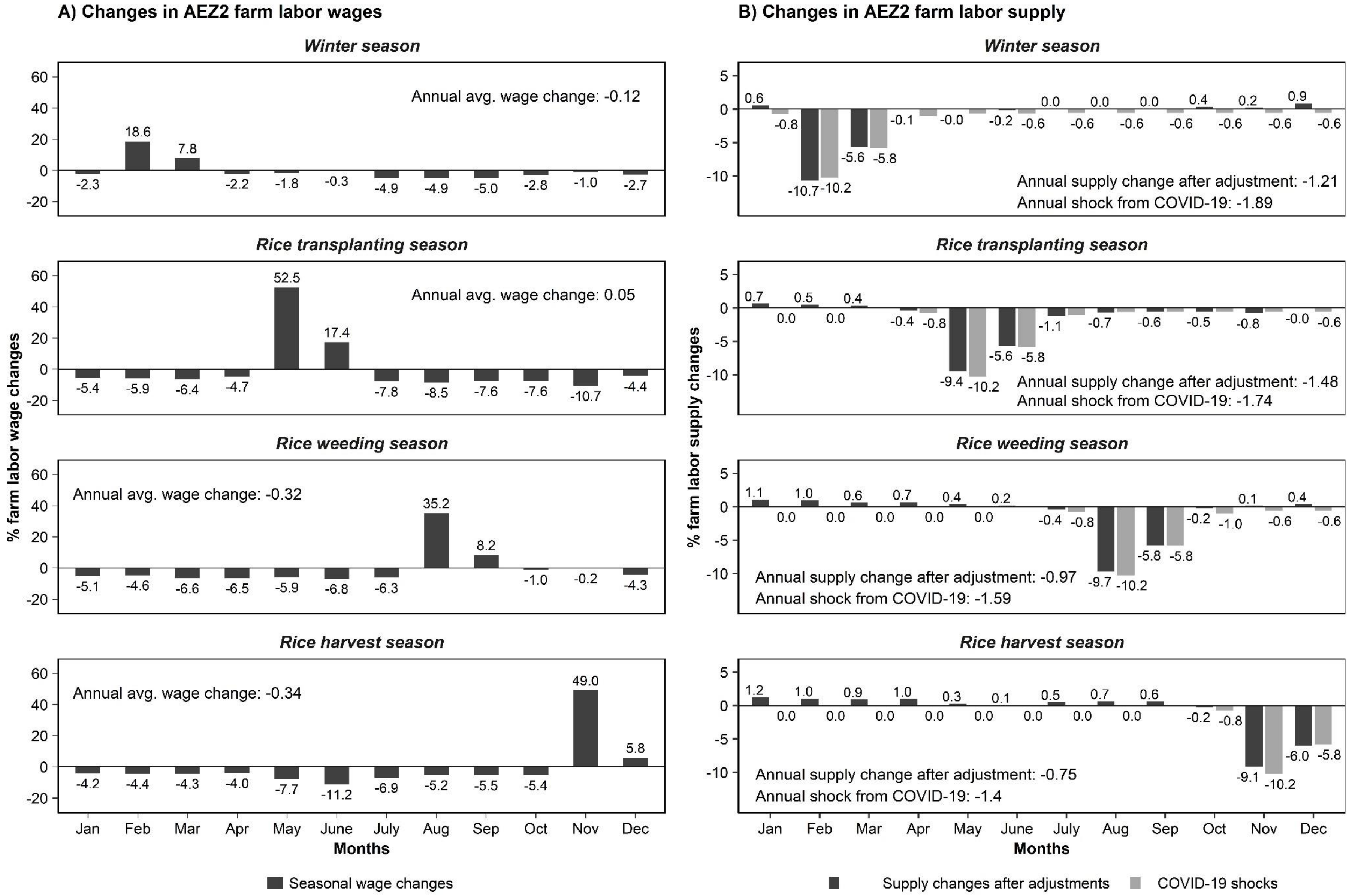

Figure 5 - Changes in farm labour wages and supply in the mid-altitude agroecological zone (AEZ2) for the four local-outbreak scenarios

The different patterns of seasonal wage changes impact directly on the supply of agricultural products, because production costs vary across the scenarios depending on the pattern of seasonal wage changes. The impacts on food security through increases in purchaser prices vary according to the timing of the local outbreaks (Figure 6): the adverse effects are greatest when the local outbreak peaks during the rice transplanting season, the season when farm labour in Bhutan is scarcest. These implications of seasonality are omitted from 'standard' economy-wide models with strong separability assumptions, which makes their results prone to biases.

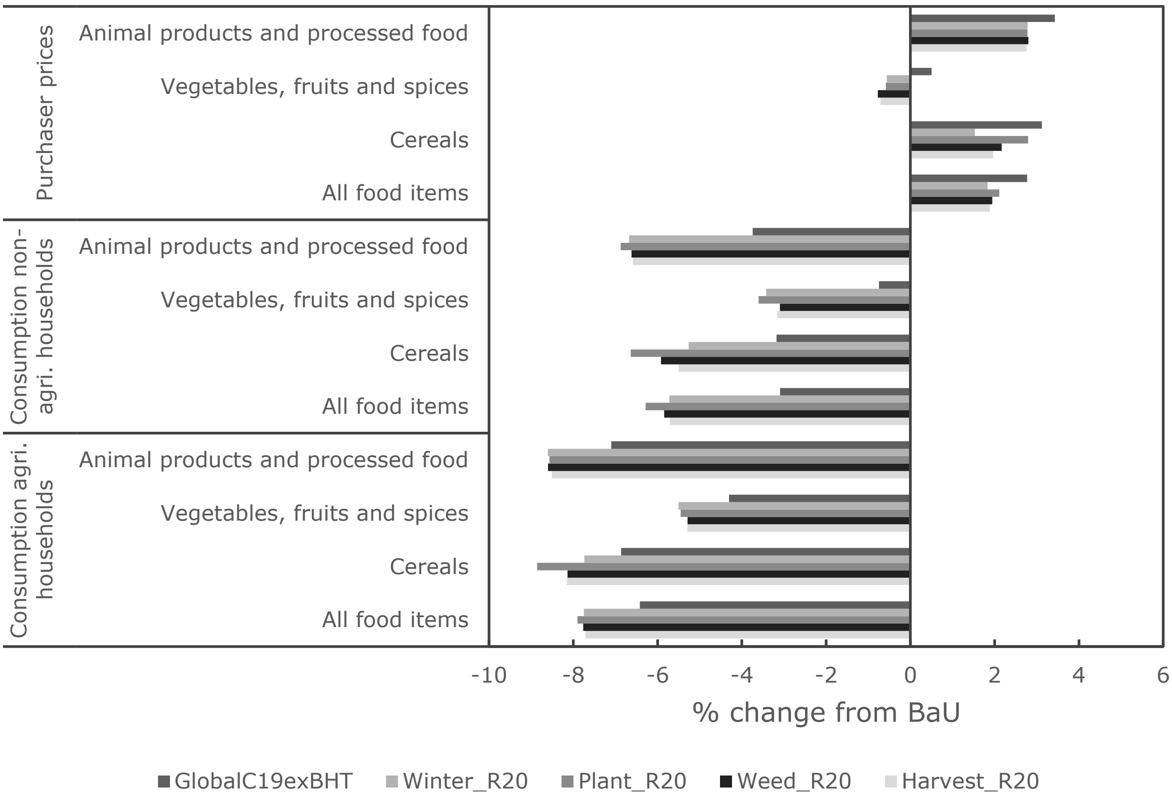

Figure 6 - Changes in purchaser prices and consumption of key food categories
Source: Authors' calculations

Mitigation responses by peasant households

Smallholder household's labour-leisure trade-off encompasses not only their farm labour supply decisions, but their overall labour supply decisions; including the time-allocation of skilled and unskilled members who work outside of agriculture. As skilled and unskilled labour wages decline at higher rates than farm labour wages, households can substitute farm labour with non-farm labour to be used for household specific leisure. Moreover, households can substitute seasonal leisure across time periods, reducing time used for leisure in a peak labour demand season, when seasonal wages are high, with leisure in periods of lower seasonal wages, i.e., intertemporal substitution.

The annual change in farm labour supply, after the economy has adjusted to the pandemic, is less than the reduction in labour availability due to the pandemic induced mortality and morbidity effects (see Figure 5, panel B). This arises because peasant households can respond to the pandemic by increasing their supply of seasonal farm labour through the year.

However, households' ability to reallocate time from leisure to activities within the production boundary varies across seasons. In the winter season, farmers allocate a higher share of their time endowment to leisure activities. The differences in labour allocation across the different local outbreaks is shown in Figure 7. When the pandemic reduces labour supply in the winter season, person-days reallocated away from leisure to other activities is the most important mitigation channel. But, labour allocated to the typical winter activities (forestry and textile weaving) still declines. When the pandemic hits during the agricultural growing season (rice transplanting, weeding or harvest season), farmers' face a shortage of labour available, particularly for the production of cereals. Labour allocated to rice production declines by 3.4% and 1.3%, when the pandemic occurs during rice transplanting or harvest season. Labour available to maize production declines throughout (whilst very slightly in the last scenario), but particularly when the agricultural sector experiences an outbreak during the rice weeding season, which is the time of maize harvest.

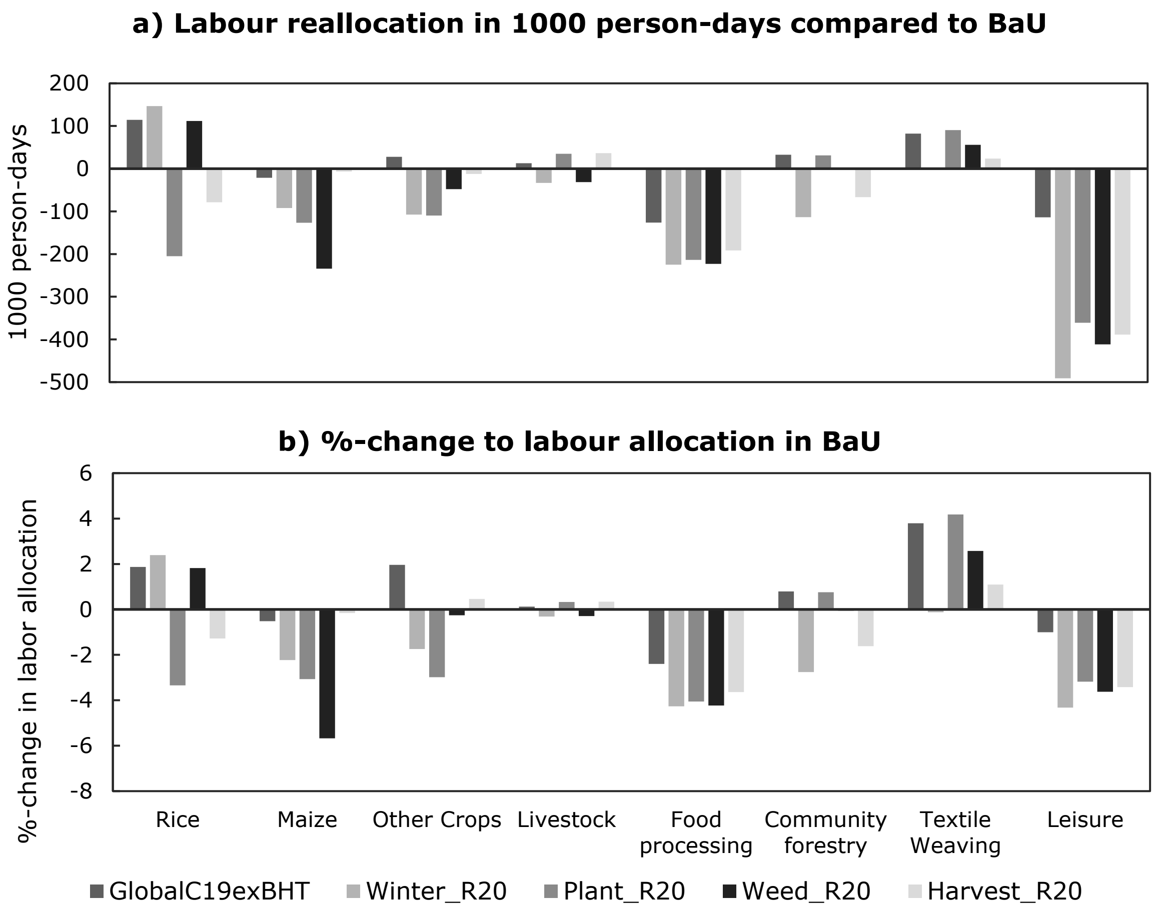

Figure 7 - Changes in labour allocation in year 1 under different outbreak scenarios
Source: Authors' calculations.

Households' labour-leisure trade-off decisions depend on changes in the relative prices of leisure and aggregate consumption, a substitution effect, and changes in household incomes, an income effect. All representative household groups (RHGs) used in the model respond by reducing leisure (generated from all labour types) to compensate for income lost (Figure 8), when the outbreak occurs both globally and locally. Their labour-leisure trade-offs are thus dominated by income effects. When the outbreak is only global, non-agricultural households decrease their leisure consumption (and thus increase their labour supply). Their response is explained by a greater decline in the composite price of leisure than that of consumption, which means the substitution effect dominates the income effect. The seasonal timing of the local outbreak clearly matters for the agricultural households in the three different agroecological zones, while its impacts on the labour supply by non-agricultural households are negligible.

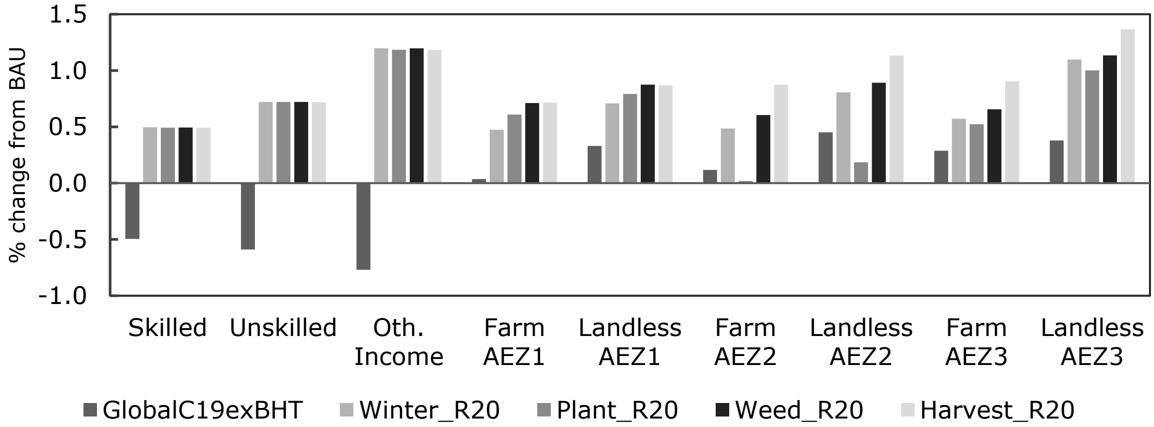

Figure 8 – Changes in the labour supply by the representative household groups (RHG) across outbreak scenarios.
Note: In case of the local outbreak scenarios, the BaU reference has been adjusted for the annual decline in labour supply due to COVID-19 induced mortality and morbidity effects.

Source: Authors' calculations

The impacts of the pandemic on household welfare

Households' lower consumption of leisure is not reflected in the reductions in real GDP, which is a measure masking substantial differences in welfare effects across the different RHGs. In the global outbreak, it is the unskilled households who suffer from the greatest reduction in welfare, whether changes in leisure consumption are included or not (Figure 9). Generally, the inclusion of leisure only slightly alters welfare results of the global outbreak scenario. Yet, in the local outbreak scenarios (Figure 9 shows only results for the outbreaks in the planting season, but results for the remaining ones are similar), the welfare effects are generally greater when leisure is included. This is explained by the general reductions in the consumption of leisure. A clear pattern emerges for all RHGs when the pandemic affects the local economy: the equivalent variation (EV) measure inclusive of leisure is always more negative than the EV measure defined over the consumption of goods and services (G&S) only, excluding leisure. This demonstrates the responses by RHGs who reduce leisure to compensate for income lost during the pandemic.

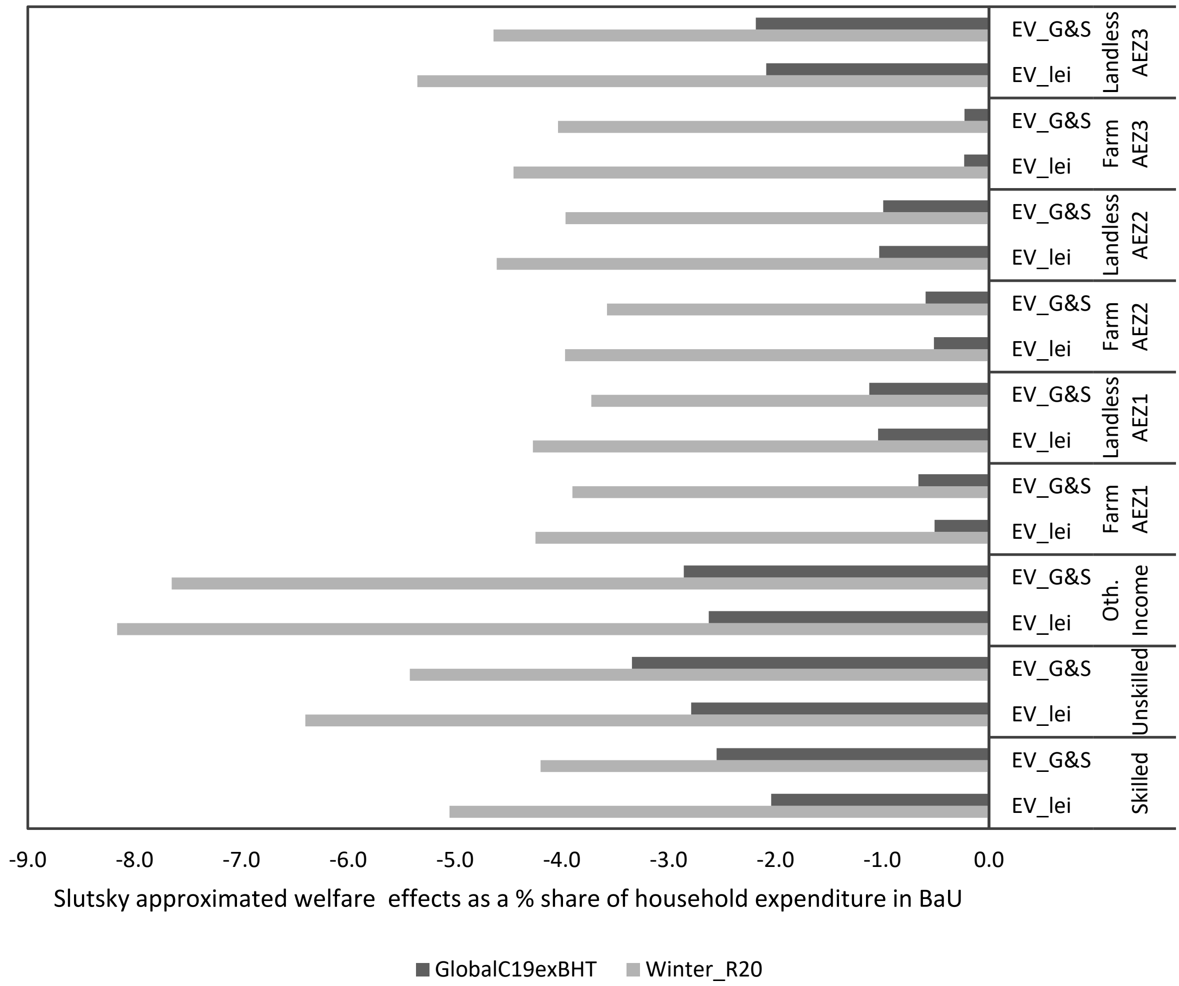

Figure 9 - Household welfare effects measured as Slutsky approximated equivalent variation (EV) either including leisure (EV_lei) or only based on goods and services (EV_G&S)
Source: Authors' calculations

6. Discussion

Modelling global as well as local outbreak scenarios with differences in timing, this study uses a differentiated approach to assess the impacts of a viral pandemic, such as COVID-19, on smallholder households. A global pandemic, without a local outbreak, predominantly reduces the welfare of non-agricultural households, who are more exposed to global value chains, especially tourism. In the absence of a local outbreak, agricultural households fare better given that they are simultaneously producers of agricultural outputs, whose output prices generally increase along with the rise in import prices of substitutes. This is also largely in agreement with anecdotal evidence from Bhutan (Rai, 2020).

In the presence of local outbreaks, resulting in a single wave of local infections, the decline in overall household welfare is more than three times as high compared to the global outbreak. Since the pandemic affects the primary asset of smallholders, their labour, welfare also decline for agricultural households. The results show that the output of agricultural production, particularly for cereals, and the mitigation responses by smallholders depend on when during the year the pandemic induced morbidity and mortality effects and subsequent labour supply shocks occur. Generally, agricultural households mitigate the shock in reduced labour availability by reducing their consumption of leisure. This, on average, allows them to reduce the decline in labour supply to economic activities by 34% (Fig. 5b). Yet, the capability to reallocate time from leisure and reproduction activities to activities within the production boundary is much more constrained in seasons of peak labour demand, e.g., in the planting season, than in slack seasons such as during wintertime. These insights are intuitive, but the seasonality of rural labour markets is not accounted for in economy-wide model studies of developing economies with a substantial proportion of peasant households. The model results highlight the importance of incorporating smallholders' labour-leisure trade-off decisions with the possibility of intertemporal substitution in both micro- and macro-level economic models. This accounts for the empirical reality of seasonal fluctuations in smallholders' consumption of leisure and time-use outside the SNA's production boundary (Blackden & Wodon, 2012; Johnston et al., 2018).

6.1. Limitations and areas for future research

With more than half of the population being dependent on farming, the role of agriculture in Bhutan is of similar importance to that in other low-income countries. The majority of farmers in Bhutan are semi-subsistence oriented, but some farmers are dependent on export markets. Farmers growing export crops suffer from lower export prices in both the global and local outbreak scenarios given the increase in export margins, which is, however, offset by the depreciation in the exchange rate. A limitation of the model is that the database does not treat export-oriented farmers as separate households, which masks differences in welfare changes across the different types of agricultural households.

The estimated burden of the pandemic on households and society as a whole is likely to be at the lower bound. The assumption of an annual average reproductive number (R0) of 2 in the core scenario is conservative given much higher estimates in the literature (Liu et al., 2020). The study also does not account for secondary morbidity effects in the aftermath of the COVID-19 pandemic, which are still not sufficiently well known and understood. Moreover, this study has avoided a discussion of the social and psychological implications of a pandemic. Premature deaths would be expected to be more traumatic than 'normal' deaths; a rise in premature death rates will therefore have adverse implications for wellbeing that this study cannot capture. The COVID-19 crisis has led to an interruption of school feeding programs (Amolegbe, 2020). This was not explicitly included in the model and the impacts on households' food security, measured as changes in food consumption, may be underestimated. This study also does not account for the fear of contagion among the population (Shultz et al., 2016), which could result in a further decline in labour availability. This "fear factor" is difficult to quantify, but could be implemented by changing agents' preferences when trading off labour with leisure. Despite these caveats, it should also be noted that the study's main contribution is to investigate how pandemics affect the livelihoods of peasants and how the impact changes with different seasonal timings.

A critical presumption for this study is that peasant households are rational agents; they respond to changes to protect the wellbeing of household members. Despite the constraints imposed on peasant households by the seasonal fluctuations in the demand for labour in agricultural activities, there is an argument that peasant households can adjust their behaviour so that, at least partially, the negative effects of a pandemic are offset. A minor response is changes in the area cultivated. More substantially however they can increase the supply of labour to agricultural activities through reductions in time allocated to leisure and social reproduction, while they can, given warning, modify their patterns of production to reduce the demand for labour. Combining this with changes in the patterns of consumption they may be able to mitigate the welfare losses so that they are less than the overall decline in economic activity; although this may not be enough to protect the least well-off peasant households.

The model used for the present analysis may be extended for future studies on the impact of pandemics. For example, the long-term impacts of the pandemic on labour markets do not adequately account for the reduced education and the long-term reductions in returns to labour. The model could be extended to include migration changes due to the pandemic, which are however difficult to parametrize. The model database does also not account for gender, particularly as regards the (often traditional) division of labour between women and men, whether in production or reproduction activities. Incorporating social and gender norms, as well as the intrahousehold allocation of labour, is at the frontier of economy-wide modelling (a recent contribution in this regard is Arora & Rada, 2020). Finally, the model does not capture a preference shift in which tastes and preferences change following a pandemic.

6.2. Concluding comments

This study explores some of the responses to a viral pandemic that may be realized in developing economies with a substantial proportion of peasant households. There are reasons to be optimistic that adjustments, particularly by peasant households, may limit the extent of the damage to the economic wellbeing in a developing country. The study provides three key findings: first, reductions in household welfare due to a global pandemic (with no local infections) are about a third as high if the pandemic would spread locally. Second, the timing of when local infections peak and thus when labour supply drops due to mortality and morbidity influence smallholders' ability to mitigate the shock and how much the pandemic impacts the agricultural sector and a country's food security. Pandemic events that coincide with peak agricultural seasons result in more adverse impacts in terms of welfare and food security than shocks occurring during the agricultural lean seasons. Third, modelling households' labour-leisure trade-offs reflecting seasonality of leisure helps to understand the mitigation responses of households, particularly peasant households. Models that do not recognize the dual role of peasant households as productive activities and households, typically by presuming that peasant households operate in the same way as farmers in developed market economies, risk failing to recognize or understand how developing economies may respond to exogenous shocks such as pandemics. Understanding households' mitigation behaviour and the role of seasonality are of importance for the design and implementation of containment policies, as a delay of an infection peak may substantially alter its impact on rural livelihoods.

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Appendix

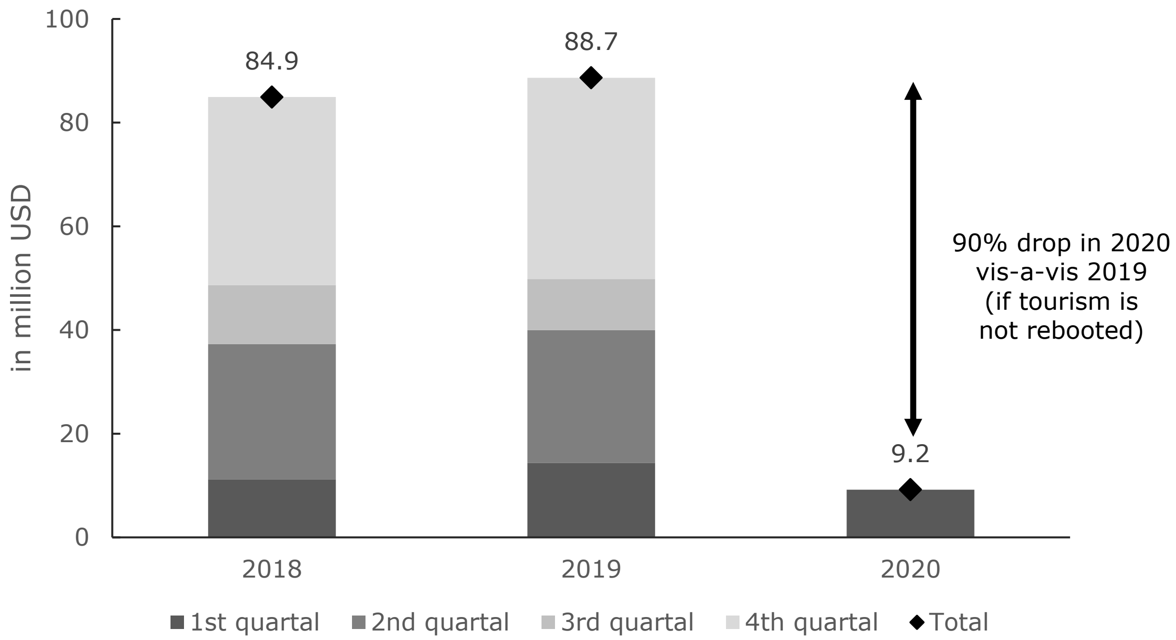

Figure A1 - International tourism receipts in million USD as of August 2020
Source: Royal Monetary Authority of Bhutan, 2020

Appendix A2 - Export demand function for tourism services

Export demand function for tourism services: $QE = econ \frac{PWE}{pwse}^{-\varepsilon}$

Where:
QE is the quantity of tourism commodities exported
econ is a scaling parameter
PWE is the endogenous world price for tourism services supplied by Bhutan
pwse is the world price charged by competitors
and
ε is the export demand elasticity

Table A3– Days of hospitalization and ICU care and the estimated associated health care cost (core scenario with R0=2.0 printed in italics) Source: Authors' calculation

COVID-19 Scenario (by reproductive number)	**Hospitalized (in bed-days)[a]**	**ICU (in days)[b]**	**Deaths**	**Treatment cost (million USD, 2012 prices)**	**% increase in government provided healthcare expenditure**
R0_1.5	13,260	4,192	2,562	3.78	10.8
R0_2.0	*18,110*	*5,682*	*3,633*	*5.13*	*14.6*
R0_2.5	20,283	6,352	4,108	5.73	16.4
R0_3.0	21,367	6,687	4,345	6.03	17.2

[a] Hospital health-care is assumed to cost 40 USD/bed-day

[b] Cost of ICU care is an average of cost estimates provided by Chatterjee S, Levin C, Laxminarayan R (2013) Unit Cost of Medical Services at Different Hospitals in India. PLoS ONE 8(7): e69728; and Ye et al. 2017 A Contemporary Assessment of Acute Mechanical Ventilation in Beijing: Description, Costs, and Outcomes https://dx.doi.org/10.1097%2FCCM.0000000000002360

Appendix A4 – Details on the estimation of the mortality and morbidity effects

The SIR (Susceptible-Infected-Recovered) model (Noll et al., 2020) model is stratified by age-groups and compartments that represent the spread and development of infections. The compartments are susceptible (S), exposed (E), infected (I), the recovered (R), hospitalized (H), and critical (C). The model is driven by a reproductive number, R0, i.e., the average number of persons infected by each infectious individual. The probabilities of transitioning between compartments are age specific and the model allows for seasonal forcing[14]. Deaths occur from the C compartment; those entering C are admitted to an Intensive Care Unit (ICU), with preference granted to younger persons, or move to an overflow (O) compartment, if ICU space is full. The severity of ICU overflow can be modelled through a multiplicative factor to the fatality rate of persons with critical conditions, but without access to ICU treatment. Persons from C critical status either recover (R) or die (D).

The morbidity and mortality effects are estimated for R0 values of 1.5, 2.0, 2.5 and 3.0, reflecting the range reported by Liu et al. (2020), and associated model parameters. The demographic data used for all scenarios are reported in Table A4.1.

[14] Seasonal forcing allows for differences in impacts due the season of infection. Given the limited understanding of COVID-19 the feature is not used for this study.

Table A4.1 – Demographics for Bhutan and age-group specific disease severity

Age group	Population (projected for 2020)[a]	Confirmed[b] % of total pop.	Severe[c] % of confirmed	Critical[d] % of severe	Fatal[d] % of critical
0-9	118,012	5	4.8	5.0	30.0
10-19	133,528	5	1.1	10.0	30.0
20-29	147,116	10	10.4	10.0	30.0
30-39	133,260	15	18.8	15.0	30.0
40-49	87,107	20	21.5	20.0	30.0
50-59	58,464	25	30.8	25.0	40.0
60-69	38,924	30	38.0	35.0	40.0
70-79	20,906	40	39.2	45.0	50.0
80+	9,368	50	34.4	55.0	50.0

Sources: [a] National Statistics Bureau of Bhutan (NSB, 2019); [b] Pre-set assumptions by the SIR model; [c] Mean of Riccardo et al. (2020) and Verity et al. (2020) adjusted for under-ascertainment; [d] Epidemiological characteristics reported by Chinese Center for Disease Control and Prevention (The Novel Coronavirus Pneumonia Emergency Response Epidemiology Team, 2020)

The SIR model reports four categories of disease severity: non-severe, severe, critical and fatal. The number of labour days lost due to the COVID-19 morbidity and mortality effects depend on the degree of disease severity. To account for the range of symptoms the non-severe category is subdivided into three categories: asymptomatic, mild and moderately severe, giving six categories of disease severity. It is assumed that 20% of infections are asymptomatic (Mizumoto et al., 2020), 60% have mild symptoms, 17% have moderately severe infections and 3% with severe infections. This reflects the large proportion of young people in Bhutan. The proportions and numbers of infections in each category and the numbers of person days lost for the 20-69 age group given an R0 of 2.0 are reported in Table A4.2. In total, there is a 1.7% reduction in person days among the working age population. Since the percent reduction is computed using the total person days in a year (365 days), it can be directly used as an estimate for the reduction labour days.

Table A4.2 - Disease Severity and Labour Days Lost (R0 = 2.0) (Source: Authors' estimates)

Disease severity	Description	% of all infection cases	Person days lost per infected person	Number of infections (20-69 years)	Person days lost – Year 1 (20-69 years)	% of total persons days lost (20-69 years)
Asymptomatic	No symptoms	19.9	0	75,182	0	0.0
Mild	No hospitalization	59.6	5	225,546	1,127,732	37.3
Moderately severe		16.8	14	63,749	892,486	29.5
Severe	Hospitalized	2.8	30	10,482	314,457	10.4
Critical	ICU treatment needed	0.4	60	1,495	89,700	3.0
Fatal		0.6	∞	2,082	596,519	19.7
TOTAL		100.0		378,537	3,020,893	100.0
% of total population				81.4%		
% of total person days					1.7%	

Note: The percentage of person days lost is computed dividing total person days lost by the total annual person days (number of persons * 365 days/year)

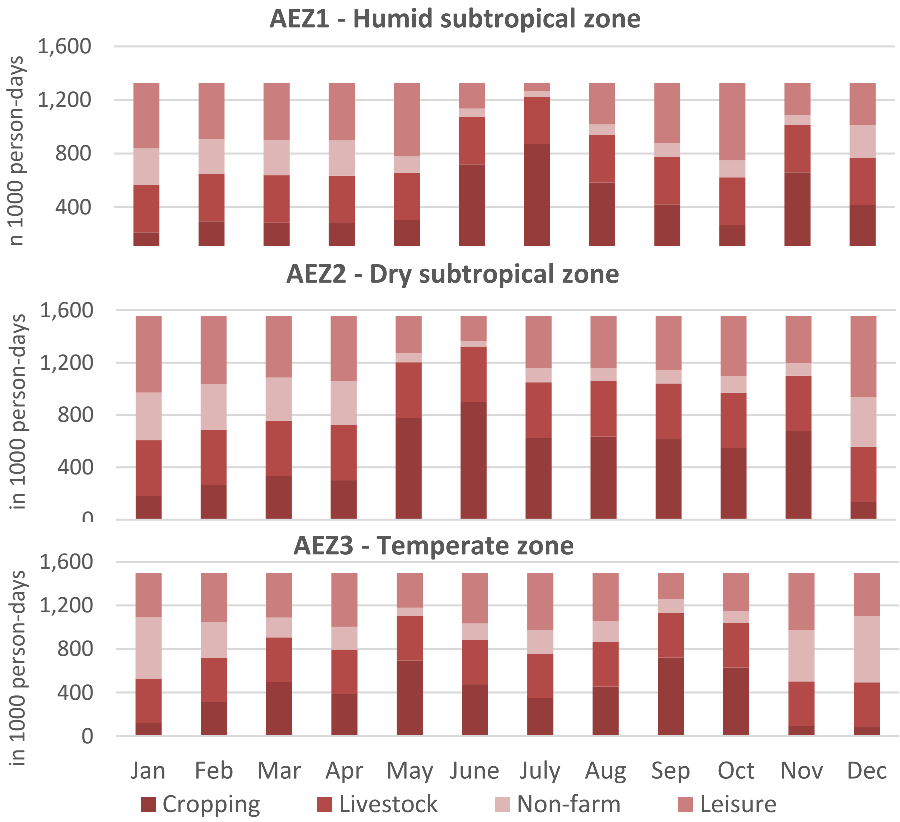

Figure A5 - Seasonal labour demand by AEZ (in 1000 person-days per month)

Source: Feuerbacher et al., 2020

Appendix A6– Details on Seasonal Activities in the Model Database

Crops are cultivated in different seasons or with different cropping patterns, e.g., double or single cropping of maize; these activities were disaggregated accordingly. Cropping activities account for 52% of the output of seasonal activities, by value, and 43% of total person-days. Rice production is labour intensive - 250 person-days per hectare – and accounts for ~38% of cropping labour. Table A5.1 reports the shares in total output and required person-days for seasonal activities (those that use seasonal labour). Livestock activities, comprising more than a third of total seasonal labour, and leisure have slightly flexible labour demand. Nonfarm activities have highly flexible labour demand and follow a counter-cyclical pattern, i.e., their labour demand is lowest during peak periods and highest during lean seasons, such as during the winter months in AEZ3.

Table A6.1 - Seasonal activities: 2012 Social Accounting Matrix for Bhutan

Activity	%-Share in total seasonal output value	Person-days (in thousand)	Share in total person-days employed in production	Seasonal labour substitution elasticity σ
Milled, rice	12.7	6,065	16.0	
Double cropping of maize	1.8	1,102	2.9	
Single cropping of maize	5.2	2,971	7.8	
Other cereals and oilseeds	2.5	1,100	2.9	
Vegetables - first season	4.5	786	2.1	0
Vegetables - second season	4.5	1,107	2.9	
Potato - first season	5.9	1,411	3.7	
Potato - second season	0.2	96	0.3	
Spices	4.3	453	1.2	
Fruits	10.1	1,032	2.7	
Total cropping activities	51.6	16,123	42.5	
Cattle husbandry	9.6	8,249	21.8	0.1
Other animals	5.3	2,049	5.4	0.1
Dairy production	12.5	3,914	10.3	0.2
Total livestock activities	27.4	14,212	37.5	
Other cereal milling	1.0	146	0.4	1.5
Cereal processing	2.6	345	0.9	1.5
Ara[a] production	4.0	786	2.1	1.5
Total food proc. activities	7.6	1,277	3.4	
Community forestry	8.6	4,164	11.0	1.5
Textile weaving	4.8	2,123	5.6	1.5
Total non-farm activities	13.4	6,287	16.6	
Total seasonal activities	100.0	37,899	100.0	
Total seasonal leisure		14,655		0.2

Note: Each seasonal activity is further disaggregated by agroecological zones (AEZ).
[a] Ara is a traditional home-brewed alcoholic beverage made from cereals
Sources: Feuerbacher et al., 2017