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Climate change and agricultural productivity in Myanmar

Application of a new computable general equilibrium (CGE) model

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Abstract: Myanmar is facing climate change (CC) induced changes to the productivity of their critically important rice sector over the coming century. Moreover, the recent five-year Myanmarese Agriculture Development Strategy (ADS) sets out a vision of achieving an '…inclusive, competitive, food and nutrition secure, climate change resilient, and sustainable agricultural system…' by 2030. In this paper, we investigate the productivity pillar of the ADS strategy. Specifically, we employ a newly developed dynamically recursive 2021–40 computable general equilibrium model for Myanmar to analyse seven current and future CC scenarios for state- and region-specific paddy yield changes during the 2020s, 2050s, and 2080s, derived from IIASA and FAO's Global Agro-Ecological Zones GAEZ V.3 model scenarios, allowing us to analyse the relative importance of both rainfed and irrigation farming practices and of high input-use and low input-use technologies, and how these important agricultural technology farming decisions interact with CC-induced paddy yield changes. Our results suggest that, while Myanmarese smallholders, using low input-use farming technologies, may face small or even negative economic impacts from CC-induced rice paddy yield changes, high input-use farmers, across all states and regions, will benefit from CC-induced paddy yield changes towards the end of the century, highlighting the importance of expanding access to high input-use technologies, e.g. via expanded use of extension services and by providing better access to credit for smallholder farmers. We also find, counterintuitively, that farming households using irrigation farming practices will benefit less from CC-induced paddy yield changes compared to households using rainfed farming practices. Finally, our results point to strong differences in CC impacts between states and regions, indicating that mitigating action should be focussed on exposed regions such as the critically important Ayeyarwady region.

Key words: Myanmar, agricultural technology, climate change, rice productivity, computable general equilibrium model

JEL classification: C68, Q1, Q51, Q54

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1 Introduction

A top goal of the Myanmar Sustainable Development Plan 2018–30 (MPF 2018) is to ensure that expansion of the private sector leads to environmentally conscious and socially responsible economic growth (goal 3). In addition, the recent 2018/19–2022/23 Agriculture Development Strategy (ADS) sets out a vision of achieving an '…inclusive, competitive, food and nutrition secure, climate change resilient, and sustainable agricultural system…' by 2030 (MOALI 2018). In this paper, we investigate the productivity pillar of the ADS strategy. We focus on analysing: 1) how climate change (CC) may impact on agricultural productivity in Myanmar, including ongoing and future CC impacts on productivity, yields, and comparative advantage in the critical paddy rice sector; and 2) how this affects the scope for agricultural development, and how it may impact the future macroeconomic growth path of Myanmar and income distribution across Myanmar households.

Specifically, we analyse the macroeconomic repercussions of the paddy total factor productivity impacts of seven CC scenarios, defined by the GAEZ-FAO project. We use detailed paddy yield data, modelled using the Global Agro-Ecological Zones GAEZ V.3 model, and accessed via scraping of the World Bank's Climate Change Knowledge Portal (CCKP) homepage (World Bank 2021a). Based on the extracted data, we derive and analyse state- and region-specific yield impacts as well as Myanmar-wide yield impacts for each of the seven scenarios. The scenarios also span variations in rainfed and irrigation farming practices and in low input-use (LIU) and high input-use (HIU) farming technologies, allowing us to shed light on potential interactions between these central farm management choices and CC-induced paddy yield impacts.

To analyse the macroeconomic and distributional implications of our seven CC scenarios, we rely on a dynamically recursive computable general equilibrium (CGE) model to analyse crop-specific total factor productivity changes for paddy rice induced by CC, covering the current and two future decades: the 2020s, 2050s, and 2080s. The focus of the analysis is on assessing how CC-related changes in paddy yields, the most important agricultural crop in Myanmar, might affect the future economic growth path of Myanmar and the income levels of vulnerable households. The CGE model is calibrated to a new 2017 Myanmar Social Accounting Matrix (SAM) (van Seventer et al. 2020). To our knowledge, this is the first time that a CGE model has been calibrated to this new macroeconomic 2017 Myanmar SAM database, which allows for analysing income impacts among 20 different rural/urban farm/non-farm income quintile households

While the seven CC scenarios provide paddy yield impacts for the current and two future decades, i.e. the 2020s, 2050s, and 2080s (World Bank 2021a), we model these scenarios over the 2021–40 time period for which our model is specified. The idea is that we apply our 2021–40 dynamically recursive macroeconomic model framework as a laboratory in order to compare the relative impacts of current paddy yield changes with paddy yield changes as they apply to future decades beyond 2050, but without actually needing to create economic growth paths reaching that far into the future. For the same reason, we maintain a focus on relative growth impacts and specifically include caveats in the discussion of absolute value impacts throughout the paper.

The rest of the paper is organized as follows: the next section provides a background discussion of agricultural development policy and CC impacts in Myanmar with a particular focus on paddy rice; this is followed by a methods section which presents our simulation model framework and discusses the structure of the Myanmar economy; subsequently, we provide a results section where we present our analyses of the macroeconomic and distributional implications of our seven CC scenarios; and, finally, we present a conclusion and discussion section containing concluding remarks and discussion of our findings.

2 Background

The country of Myanmar, comprising seven states, seven regions, and the Nay Pyi Taw capital zone, consists of Coastal Mountainous Areas, the Ayeyarwady Deltaic Area, a central dry zone, the Shan Highlands, and the Northern Highland Area. It has varying climatic characteristics, including marked variations in annual rainfall and temperature patterns. The country is subject to meteorological, hydrological, and seismic hazards which, in recent years, have included cyclones (in 1968, 1975, 1982, 1994, 2006, 2008, and 2015), floods (e.g., in 2004, 2010, and 2015), and severe droughts (in 2010 and 2016) (Reuters 2016). The seasons in Myanmar consist of a hot summer season, a rainy/southwest monsoon season, and a cool relatively dry/northeast monsoon season (Aung et al. 2017). Hein et al. (2019) explain that, according to the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4), historical 1951–2000 climate trends and extreme events in South-East Asia include 0.1–0.3℃ temperature increases per decade and decreasing trends of precipitation and rainy days (1961–98). In addition, droughts normally associated with El Niño Southern Oscillation (ENSO) years have started occurring in Myanmar and other South-East Asian countries (Hein et al. 2019).

The Ayeyarwady delta basin is the largest river basin in Myanmar and is considered to be the rice bowl of the region (Oo et al. 2018). However, its deltaic nature and its very low-lying nature means that it, together with other low-lying coastal plains, is exposed to adverse CC effects, including higher temperatures, changing rainfall patterns and flow regimes, and rising sea levels (MOAI 2015). Furthermore, while before 2000, extreme events in the form of cyclones made landfall in coastal regions once every three years, they now seem to occur virtually every year. Indeed, in May 2008, cyclone Nargis, the worst cyclone to ever hit Myanmar, made landfall and wreaked havoc in the Ayeyarwady region and the eastern part of Yangon. Altogether, the cyclone killed >138,000 people; damaged mangroves, agricultural land, and buildings; caused saltwater intrusion into agricultural lands and freshwater sources; and caused loss of homes and livelihoods. In the aftermath, intensive rains caused excessive sedimentation of paddy fields (MOAI 2015.) Overall, Nargis destroyed 38,000 ha of natural and replanted mangroves, submerged over 63 per cent of paddy fields, and damaged 43 per cent of freshwater ponds (UNEP 2009). It also caused additional damage to 15,000 ha of summer rice areas (MOAI 2015). While the economic destruction and human cost of Nargis is beyond compare, it is interesting to note that cyclone Giri, a smaller but still powerful cyclone which made landfall in late October 2010 about 50 km northwest of Kyaukpyu in Rakhine state, 'only' resulted in 45 deaths and 70,000 people losing their homes, but the damage to monsoon paddy fields was >38,000 ha (MOAI 2015).

The central dry zone of Myanmar is a region which 'only' receives around 600 mm of rainfall per year compared to 5,000 mm per year in coastal and delta regions (MOAI 2015). Moreover, it is a zone which is prone to droughts and, while droughts have been observed with irregular intervals in the past, in some areas such as Magway region they now seem to occur more regularly, with a frequency of around once every three years (Hein 2012). The central dry zone is located in the central part of Myanmar, and its boundary covers the Lower Sagaing, Mandalay, and Magway regions. As Magway region borders Rakhine State, the region is exposed to extreme weather from cyclones making landfall in Rakhine State and causing heavy rainfall and flooding in the hinterland. At the same time, it is exposed to drought, e.g. related to the ENSO oscillation due to its overlap with the dry zone. In contrast, Shan state, which is located to the east of the dry central zone in the Shan Highlands, is better protected from extreme weather events.

Based on six decades of observed weather data, the Department of Meteorology and Hydrology (DMH) of Myanmar has analysed variations in normal weather patterns and concluded that climate variations in Myanmar include: 1) a mean temperature rise of 0.08℃ per decade; 2) increasing precipitation in most parts of Myanmar, but less precipitation in some parts; 3) later onset and earlier termination of the southwest monsoon; 4) more extreme weather events; and 5) rising sea levels (Nyo 2020). A smaller and more short-term WWF study of 19 DMH weather stations, covering three decades (1981–2010), found somewhat stronger increasing trends in temperature, amounting to 0.14℃ and 0.35℃ per decade for coastal and inland regions, while precipitation trends were found to be '…more ambiguous…' (Horton et al. 2017). Furthermore, Hein et al. (2019) quoted an unpublished study by Policarpio (2015) as saying that extrapolations for 2021–50 by the Regional Integrated Multi-Hazard Early Warning System (RIME), and the DMH predict warming of 1.2–1.8℃ over the period from June to November across the whole country, with a few minor exceptions. They also predict that the same level of rising temperature is likely to be seen during other months in lower Myanmar, the deltaic region, and the southern part of the country, and that December–May temperature increases of 2.5–3.0℃ are likely to affect other parts of the country (Hein et al. 2019).

Turning to agricultural production, Myanmar has traditionally been a country which has identified itself as the rice bowl of the region because of the fertile Ayeyarwady delta basin. While national production has been following a U-shaped growth path over recent years, Ayeyarwady's share of total paddy production has continued to increase from 2013/14 (27.2 per cent) to 2017/18 (30.5 per cent) (CSO 2019; Oo et al. 2018). At the same time, the agricultural sector's contribution to gross domestic product (GDP) declined from 46.7 per cent in 2005/06 and 29.5 per cent in 2013/14 to 23.3 per cent in 2017/18 (CSO 2019), reflecting that economic growth in non-agricultural sectors has been much stronger than in the agricultural sector. Despite the smallholder success story of scaling up smallholder production of beans and pulses to a level, and of sufficient quality, to sustain very large Myanmar export flows, agricultural productivity is often reported to be low in Myanmar, implying that producers and traders are at a comparative disadvantage when trying to penetrate export markets. That said, there has been discussion about Myanmar paddy productivity levels, but the gist of the discussion seems to be that official Myanmar productivity numbers appear to be inflated compared to United States Department of Agriculture (USDA) numbers and World Bank survey data (World Bank 2016). Hence, while official paddy yield data (3.8 tons/ha) would place Myanmar around the middle of Asian country rankings, much lower USDA yield data (2.7 tons/ha) would place Myanmar second from the bottom (just above Cambodia). Furthermore, World Bank survey data indicate that paddy yields may be even lower during the monsoon season (2.56 tons/ha) but higher during the off-season (3.41 tons/ha) (World Bank 2016). The discussion may partly reflect that official Myanmar data are for wet-paddy yields, but weighted wet-paddy yields derived from the World Bank survey data (3.35 tons/ha) still suggest that Myanmar data are biased upwards (World Bank 2016). Regardless, the USDA and World Bank data suggest that Myanmar paddy yields continue to lie around the bottom of Asian rankings, implying that there is likely to be considerable scope for future yield and production expansion.

Since Myanmar became independent in 1948, crop production has been the major agricultural activity and continues to be mostly dependent on monsoon rains to this day (Nyo 2020). Early institutions included a State Agricultural Marketing Board established in 1946, which mostly focussed on marketing rice exports, and the Agricultural Development Bank established in 1953 to provide agricultural credit. The latter had little success, however, as illustrated by the fact that in 1961 traditional production methods continued to dominate, while the share of irrigated agricultural production was unchanged from before the Second World War (Nyo 2020) This was followed by the socialist period of authoritarian rule (1962–88) when the focus was on agricultural exploitation and the government had complete control over trading and procurement systems. Although restrictions on the procurement and domestic trade of rice and other crops were gradually removed in 1987, and price controls were gradually removed during 1988 as part of a move towards a market economy, government interventions in agricultural cropping decisions were only gradually relaxed, and in an ad hoc way, by the government with an eye to their agricultural objectives. These included: 1) generating a rice surplus; 2) becoming self-sufficient in edible oil production; and 3) increasing the production and exports of pulses and industrial raw material crops (Nyo 2020)

During the following years, existing dams and reservoirs were renovated and new infrastructure was constructed to provide adequate water supplies for agricultural production. In 1992, double cropping, involving summer paddy production on irrigated paddy land, was introduced, and summer paddy production subsequently expanded significantly (Nyo 2020). During this period, the Ministry of Agriculture, Livestock and Irrigation (MOALI) also implemented CC-related changes to cropping systems, including the introduction of stress-resistant plant varieties and adjustments to farming practices involving maximizing water use and efficiency. Since that time, crop diversification and the use of stress-resistant varieties has been common. The arguably most important adaptation strategy from this period was the introduction of hybrid rice production methods involving modified systems of rice intensification and alternate wetting and drying irrigation techniques. Other adaptations involved the introduction of drought-resistant varieties in the dry zone and organic vegetable farming and orchards (Nyo 2020)

Following the 2011 elections, wide-ranging economic reforms, with the aim of '(B)uilding the modern industrialized nation through the agricultural development, and all-round development of other sectors of the economy', meant that policy makers switched policy objectives and started focussing more on poverty reduction and rural development. Policies were focussed particularly on introducing high-yielding seeds and improving production quality, as well as on transforming the traditional systems of rainfed farming practices into an irrigated farming system and mechanizing conventional small-scale farms (Nyo 2020). Subsequent policy reform initiatives were focussed on measures to remove market distortions, reduce transaction costs, support value chains, and improve product quality, as well as on producing and providing high-quality high-yielding seeds to farmers and employing extensionists to educate and train farmers in good agricultural practices.

Additional overarching policy aims were also identified. These included the National Comprehensive Development Plan, which comprised a series of five-year plans for the period from 2011 to 2031 and aimed to maximize domestic and international export market shares, improve food security, and achieve green growth harmonizing with the natural environment (Nyo 2020). They also included the Myanmar National Adaptation Plan of Action, which was developed to prioritize adaptation measures within eight thematic areas. The plan prioritized agriculture, early warning systems, and forests (first-priority level sectors) over public health and water resources (second-priority level sectors), coastal zone (third-priority level sector), and energy, industry, and biodiversity (fourth-priority level sectors) (MECF 2012). More recently, and as mentioned in the introduction, the Myanmar Sustainable Development Plan was launched in 2018, with three pillars, five goals, 28 strategies, and 251 action plans. This plan included a key policy intention to pursue '(E)stablishing an economic model that balances agriculture and industry and supports the holistic development of the agriculture, livestock and industrial sectors, so as to enable rounded development, food security and increased exports' (MPF 2018).

To sum up, the multitude of government policy aims, which were partly initiated under earlier governments and further refined and vastly extended under the democratic governments since 2011, are summarized in the following 11 agriculture policies (FAO 2021), which aim:

- to emphasize production and utilization of high-yielding and good quality seeds;
- to conduct training and education for farmers and extension staff in advanced agricultural techniques;
- to implement research and development activities for sustainable agricultural development;
- to protect farmers rights and benefits;
- to assist farmers to get a fair price for their produce;
- to assist in lowering production costs, increasing high-quality crop production, and developing and strengthening markets;
- to encourage the transformation from conventional to mechanized agriculture, the production of climate-appropriate crops, and the extension of irrigated areas;
- to undertake renovation and maintenance works on old irrigation, pumping, and underground water systems;
- to support rural development and poverty reduction activities through development of the agriculture sector;
- to encourage local and international investment in the agriculture sector for the development of advanced agricultural technology and commercial agricultural production; and
- to justify and amend existing agricultural laws and regulations in line with current economic situation.

Turning to the design of the current agricultural development strategies, it is worth noting the findings of a consultancy report prepared for the International Finance Corporation which focussed on outlining possibilities for the Global Agriculture and Food Security Program—Private Sector Window (GAFSP—PrSW) to provide long- and short-term loans, credit guarantees, equity and advisory services to support private sector activities for improving agricultural development and food security in Myanmar. The report surveyed and ranked the ten largest agricultural sectors and singled out rice (as being critical for food security in Myanmar, but also detrimentally impacted by past policy uncertainty), and beans and pulses (as being the largest combined export sector with estimated annual sales of >$1bn). However, despite both sectors being economically important and having development potential in terms of their large numbers of smallholder producers, they were both deselected as current agricultural developments due to the lack of 'investment-ready opportunities' (CEPA 2016). Instead, the report highlighted investment cases in: 1) poultry and dairy (due to projected near-term increases in domestic demand); 2) agribusiness input sectors including mechanization (to support the increasing competitiveness of Myanmar's agricultural sector); and 3) investment in logistics in agribusiness (including investment in storage, e.g. in the form of cold-chain facilities, and transportation, which remains a key constraint on the agribusiness sector) (CEPA 2016).

In addition to its weak 'investment-ready opportunities' among major crops, the World Bank indicates that Myanmar's agricultural system is particularly vulnerable to CC as higher temperatures may reduce yields of important crops, including rice and other staple crops such as wheat and maize. Furthermore, the World Bank argues that changes in precipitation patterns may increase the risk of 'short-term crop failures' and 'long-term production declines'. With reference to the IPCC Fourth Assessment Report's predictions for Southeast Asia, the World Bank (World Bank 2021a) adds that:

- Irrigation systems will be affected by changes in rainfall and runoff, and subsequently, water quality and supply;
- Temperature increases of ~2–4°C will threaten agricultural productivity, stressing crops and reducing yields;
- Changes in temperature, moisture, and carbon dioxide concentrations will negatively affect major cereal (e.g., rice, wheat, maize, and millet) and tree crops; and
- Increases in rice and wheat production associated with CO_2 fertilization will be offset by reductions in yields resulting from temperature and/or moisture changes.

The World Bank also suggests that increased occurrence of droughts is likely to lead to crop failure in rainfed agricultural areas and to increased demand for irrigation. It also argues that a rise in temperature of 1–2°C combined with lower solar radiation could risk causing rice spikelet sterility (infertile rice seeds), and that higher temperatures may increase the appearance of crop diseases, insect pests, and rodents (World Bank 2016). Regardless, as noted in the final bullet point above, there are likely to be both benefits and costs in terms of climate impacts on paddy (and other crop) yields. In addition, impacts may vary across ecological settings, implying that taking a 'Southeast Asian' view may be a bit crude when discussing Myanmar paddy yield impacts at the state and region levels. That said, the World Bank is right to warn that '(T)he extensive, low-lying Ayeyarwady/Yangon Deltaic regions are particularly vulnerable to sea level rise', and that future global sea level rises of >0.2–0.6 m could mean that the Ayeyarwady delta shoreline could advance by 10 km by 2100, which would seriously affect local communities and agricultural production (World Bank 2021a).

The 2017 Myanmar SAM has not previously been used to construct a Myanmar CGE model. However, it has been used to construct a Myanmar multiplier model and to produce a set of multiplier analyses to analyse the early macroeconomic impacts of the Covid-19 epidemic in Myanmar (Diao et al. 2020).

3 Methods

We utilize a twin set of demographic and macroeconomic models to analyse implementation of our seven CC-related paddy yield impact scenarios. We do so to analyse the economic growth and distributional consequences as they pertain to economic impacts on different states and regions, and distributional income impacts across a range of household groups. Specifically, we simulate: 1) a single counterfactual 2021–40 growth path; and 2) seven CC-related paddy yield impact scenarios based on prior CC modelling of paddy yields for three decades covering the 2020s, 2050s, and 2080s (World Bank 2021a) but modelled over the 2021–40 time period. The idea is that we apply our 2021–40 dynamically recursive macroeconomic model framework as a laboratory in order to compare the relative impacts of paddy yield changes as they apply to future decades beyond 2050, but without actually needing to create economic growth paths reaching that far into the future. For the same reason, we maintain a focus on relative growth impacts and specifically include caveats in the discussion of absolute value impacts.

Our dynamically recursive macroeconomic model for Myanmar is specified around a core static macroeconomic CGE model framework (Löfgren et al. 2002). This so-called multi-sector model framework enables a range of production activities and retail commodities to be captured (see Table 1). It is a standard neo-classical framework where producers maximize the profits of their production decisions, consumers maximize the utility of their demand decisions, the government collects taxes to fund its spending, savings are collected and channelled into productive investment projects, and domestic retailers engage with foreign traders to trade in import and export goods. This model framework is ideal for our current purposes as it enables automatic modelling of both backward and forward feedback effects of changes to paddy productivity. Specifically, our multi-sector framework, with its detailed account of production sectors (including the paddy production sector), detailed account of production specifications (including a paddy production yield parameter), and detailed accounts of intermediate demand and income-driven household demand and savings-investment behaviour, implies that we are able to simulate the detailed consequences of our seven CC-related paddy yield impact scenarios with a focus on GDP and household income distribution impacts.

We calibrated our static CGE model based on the recently established 2017 Myanmar SAM (van Seventer et al. 2020). To our knowledge, this is the first time that this SAM dataset has been used to calibrate a Myanmar CGE model. The calibration allowed us to specify our CGE model with: 43 activities and 43 commodities; nine production factors including land, natural resource livestock, natural resource fish stock, and agricultural and non-agricultural physical capital stocks; four uneducated/primary/secondary/tertiary educated labour factor types;[1] and 20 rural/urban farm/non-farm income quintile household types (van Seventer et al. 2020) Furthermore, to properly capture the distributional implications of our CC-related paddy yield impact analyses, we disaggregated our demographic model to encompass projections for each of the 20 abovementioned household types and used these household-specific projections to produce a full set of household-specific labour factor ownership projections for each of our four labour categories, including uneducated labour and primary/secondary/tertiary educated labour.

Specifically, we calibrated our four labour factor updating equations on the basis of a set of household-specific demographic projections derived from a standard demographic model specification (Jensen et al. 2019). The 20 household-specific demographic models were calibrated to a set of MOLIP-UNFPA 2014–50 rural–urban population projections for Myanmar (MOLIP 2017) and based on Myanmar-specific demographic parametric assumptions derived from the United Nation's World Population Prospects 2019 database (UN 2020). Sets of base year activity-specific labour demand and household-specific labour factor ownership matrices were derived from labour force data accompanying the underlying 2017 SAM dataset (van Seventer et al. 2020) and from the 2015 LFS (MOLES 2016). Subsequent calibration and counterfactual simulation of our labour factor updating equations, covering the 2021–40 period, and complementary projections of labour factor ownership growth paths were based on the aforementioned household-specific demographic projections over the same period. These were corrected for age-specific labour force participation rates as published by the Central Statistical Organization (CSO 2018) and complemented with an assumption that the relative shares of the different educational attainment-focussed labour factor categories remain fixed.

We also extracted time series of capital stock growth rates and capital depreciation rates for Myanmar from the Penn World Tables database, version 10.0, to calibrate our capital updating equation. Specifically, we initialized our 2017 capital stock from the most recent Penn World Tables 2019 data (PWT 2021) by applying the 2017 depreciation rate (7.3 per cent) and 2017–18 capital stock growth rate (10.1 per cent) to scale 2017 investment (MKK29.6 trillion) from the

[1] The original dataset only included eight production factors, including one physical capital factor, but we split the aggregate capital factor account into two separate agricultural and non-agricultural capital factor accounts to ensure that agricultural factor income, including paddy value-added generation, accrues solely to our farm households who are the sole recipients of factor income from agricultural capital.

SAM (van Seventer 2020), whereby we arrived at the 2017 capital stock estimate of MKK172.5 trillion.

Finally, we used historical Myanmar GDP growth rates from the World Bank's World Development Indicators database (World Bank 2021c) to run our model forward from 2017 to the base year for our policy simulations—2021. Specifically, we varied the total factor productivity of our production activities to target the real GDP growth path between 2017 and 2021, and thereby to establish 2021 as the base year for our future policy simulations. We subsequently used the same approach to calibrate our counterfactual 2021–40 growth path to historical 2011–19 real (6.6 per cent p.a.) and nominal (12.2 per cent p.a.) GDP growth rates (World Bank 2021c) against which our CC-related paddy yield scenarios are assessed.

The structure of our macroeconomic CGE model is illustrated in Table 1, where all the data are derived from the underlying 2017 SAM dataset (van Seventer et al. 2020). The economic structure of Myanmar is presented in Table 3. This includes sector-specific effective sales tax rates (effective aggregate commercial tax and special goods tax rates) and effective import tariff rates (effective customs duty rates); domestic production and goods supply shares; and sector-specific export and import shares (of sector-specific domestic production and commodities supplies). The effective sales tax rates indicate that there is little indirect taxation of primary agricultural goods, while higher effective rates of commercial and special goods tax rates apply to secondary commodities (including minerals, processed food and beverages, refined petroleum products, etc.) and select services (including electricity and water utilities, construction, land transport, hotels, etc.) Effective import duties are virtually non-existent for the agricultural and service sectors. Effective duty rates are >1 per cent for most extraction and manufacturing goods sectors (including other mining, food and beverages, textiles, print media, refined petroleum products, mineral products, and other manufacturing products).

The structure of the economy, as illustrated by the domestic production and goods supply shares in Table 1, clearly demonstrates that Myanmar continues to be a lower-middle-income country with a moderately important primary production sector (11.4 per cent), a sizeable manufacturing production sector (41.4 per cent), and a small services production sector (47.2 per cent) when compared to more developed service-oriented economies. The lack of a developed service-focussed economy is even more pronounced when comparing value shares of primary agriculture, forestry, and fishing (12.5 per cent), secondary manufacturing (48.5 per cent), and tertiary services (39.0 per cent) commodity supplies. Looking more narrowly at the primary production sector, the paddy rice production sector accounts for an impressive 2.2 per cent of the total production value of the Myanmarese economy, or 20 per cent of the total primary sector production value. Despite paddy rice production having been neglected for decades, these numbers illustrate the important role it continues to play in today's Myanmar economy.

Looking at the import and export shares in Table 1, they are either very high or very low. The table shows relatively high export shares for paddy, vegetables and other crops, fuel minerals and other mining products, textiles, telecommunications, hotels and restaurants, and information services. It also shows relatively high import shares for textiles, refined petroleum products, other manufacturing products, postal and courier services, and telecommunications. On average, export shares for the primary agricultural and secondary manufacturing sectors (14–15 per cent) are higher than for services (5 per cent), while the average import share for manufacturing (19 per cent) is much higher than for agriculture (<1 per cent) and services (4 per cent). The small import shares of primary agricultural commodities suggest that the domestic agricultural production sector is less exposed to competition from imports. However, relatively high agricultural export shares for paddy, vegetables, and other crops indicate that these sectors are exposed to international standards and terms of trade, and that there may be potential for these sectors, including paddy rice, to further expand their export market penetration if reliable domestic production and commodity supplies can be ensured.

To identify the main income sources of our 20 household types, in Table 2, we present an aggregated version of the household income sources matrix of the 2017 SAM (low education labour includes workers with maximum primary education attainment, while high education labour includes workers with minimum secondary education). The table indicates that, while rural households receive a third of their income from each of the low education labour (32–36 per cent) and high education labour (32–36 per cent) categories, urban households receive much lower shares of their income from low education labour (5–17 per cent) and higher shares from high education labour (40–41 per cent). Another striking difference is that, while farm households receive 24–31 per cent of their income from natural resources and 5–7 per cent of their income from agricultural capital returns (non-farm households receive income from neither natural resources nor agricultural capital), non-farm households receive similar shares of their income from enterprise distributed profits stemming from non-agricultural returns (25 –53 per cent).

To understand the share of factor income across institutions, in Table 3, we present an aggregated version of the factor income distribution matrix from the 2017 SAM. As above, the data indicate that returns to low education are mainly shared among rural households (90 per cent), while returns to high education labour are mainly shared between rural households (57 per cent) and non-farm urban households (40 per cent). These numbers also highlight that urban farm households is a relatively small household category compared to the other three main household categories. Returns to agricultural capital accrue to rural farm households (4 per cent) while returns from non-agricultural capital, as indicated above, are retained by non-farm enterprises. The latter enterprise earnings are subsequently distributed to rural non-farm households (14 per cent), urban non-farm households (40 per cent), and the government via distributed state-owned enterprise earnings (27 per cent). Enterprise taxes (4 per cent) and enterprise savings (14 per cent) account for the remaining parts of enterprise sharing of non-agricultural factor income. Returns to natural resources overwhelmingly accrue to rural farm households (91 per cent), while a minor share accrues to urban farm households (9 per cent).

To show the relative labour productivity levels of different labour types across different sectors, we provide average labour wages in Table 4. These are derived from the 2017 SAM sector-level factor income flows and accompanying sector-level labour employment matrices (van Seventer et al. 2020). Perhaps surprisingly, non-educated workers have higher average wages than primary education workers in investment goods, particularly in public administration (but note that the latter average wage is derived from a small number of non-educated public administration employees). Apart from the two aforementioned anomalies, average wages increase monotonically with education levels, reflecting increasing returns to education and skills acquisition in Myanmar.

In this paper, we apply the macroeconomic modelling framework outlined above to analyse seven CC-related scenarios of paddy yield impacts for Myanmar (Table 5). The seven CC scenarios were derived from a large body of work focussing on modelling the agricultural yield impacts of various climate scenarios using the Global Agro-Ecological Zones GAEZ V.3 model (Fischer et al. 2012) and used by the World Bank to underpin its CCKP homepage, from which the data used for this paper were scraped (World Bank 2021a). Full documentation of the CCKP data resource is available on the World Bank homepage (World Bank 2021b). The Appendix to this paper provides a complete list of the Myanmar state- and region-specific geographical locations which were used for scraping of the GAEZ V.3 CC-related Myanmar paddy yield change scenarios and for calculation of state- and region-specific average future paddy yield changes for the 2020s, 2050s, and 2080s decades.[2] While the scraped data from the CCKP homepage contained CC-related yield changes for multiple agricultural crops, and while our model framework covers the entire range of primary agricultural activities, we focus, in this paper, on the CC impact on paddy yields. This is a pertinent issue given that paddy rice, as noted above, accounts for 20 per cent of the total primary production value in Myanmar, is essential for supporting the livelihoods of many poor rural households, and is seen as a crop with potential for development and scope for generating increased export earnings.

The seven scenarios of future CC-related paddy yield changes analysed in this paper (Table 5), include: 1) a comparison of scenarios 1–3 of paddy yield changes for the 2020s, 2050s, and 2080s (assuming all farmers employ rainfed farming practices); 2) a comparison of scenarios 4–6 of paddy yield changes for the 2020s, 2050s, and 2080s (assuming farmers use a mix of rainfed and irrigation farming practices); and 3) a comparison of scenarios 6–7 of paddy yield changes for paddy farmers using, respectively, HIU and LIU technologies and with yield changes derived for the 2080s (and assuming farmers use a mix of rainfed and irrigation farming practices). While scenarios 1–6 assume farmers use HIU technologies, scenarios 1–3 can be viewed as representing a baseline exploring CC-related impacts if only basic (rainfed) farming practices are employed. Scenarios 4–6 can be viewed as representing a more realistic set of CC-related paddy yield change scenarios derived from weighted averages of rainfed and irrigated farming practice paddy yield data. Finally, the comparison of scenarios 6–7 can be viewed as a sensitivity analysis of the importance of the maintained assumption in scenarios 1–6 of farmers using HIU farming technologies.

In order to provide detailed and representative scenario input data, we decided to extract GAEZ V.3 yield data for a range of representative Myanmar geographical locations spanning the country's 15 states and regions (see Table A1 in the Appendix for details of the specific locations used for data extraction). Based on this dataset, we constructed a set of average state and regional paddy yield impacts for each of our seven CC scenarios and, using state- and region-specific 2017–18 paddy farm area data, we produced aggregate weighted Myanmar-wide paddy yield impacts for each of our scenarios. Our approach to modelling Myanmar-wide CC impacts on paddy yields has the twin benefit of providing appropriate aggregate Myanmar-wide simulations and allowing for decompositions of macroeconomic impacts across Myanmar states and regions.

Table 6 presents the set of derived average state- and region-specific paddy yield changes and production-weighted Myanmar-wide paddy yield changes for each of our seven CC scenarios. As the table verifies, while there is some interesting variation in some of the individual growth paths of state- and region-level paddy yield impacts, most seem to experience a maximum yield impact in the 2050s and either stabilize or fall back to a smaller, but still positive, yield impact in the 2080s. One of the important exceptions to note is that the Ayeyarwady region paddy yield impacts decline in the 2080s scenarios 6–7 with mixed farming practice, and this means that the Myanmar-wide yield impact becomes negative in scenario 7.

[2] The data scraped from the CCKP portal and used to design the seven scenarios analysed in this paper are available from the authors upon request.

Table 1: 2017 Macroeconomic structure of Myanmar (per cent)

Production activity/ Retail commodity sectors	Sales tax rates (TQ)	Import tariff rates (TM)	Production value shares (Xshr)	Supply value shares (Qshr)	Export value shares (E/X)	Import value rates (M/Q)
Paddy	0.0%	0.0%	2.2%	2.9%	28.5%	0.1%
Vegetables	0.0%	0.0%	0.3%	0.4%	23.7%	0.5%
Fruits	0.0%	0.0%	0.4%	0.5%	3.9%	5.2%
Beans	0.0%	0.0%	0.8%	1.0%	0.0%	0.0%
Other crops	0.0%	0.0%	2.2%	3.0%	38.1%	1.7%
Livestock	0.0%	0.0%	2.9%	2.3%	0.7%	1.0%
Forestry and logging	0.0%	0.0%	0.1%	0.1%	4.9%	0.1%
Fisheries	0.0%	0.0%	2.5%	2.3%	2.4%	0.0%
Fuel minerals	4.6%	0.0%	2.1%	2.1%	98.3%	1.6%
Other mining including support services	0.9%	4.0%	0.9%	0.9%	52.1%	2.7%
Food, beverage and tobacco products	2.9%	4.0%	16.3%	16.4%	3.3%	6.8%
Wearing apparel and textiles	0.9%	1.2%	3.4%	3.8%	43.2%	20.9%
Printing and reproduction of recorded media	3.3%	4.0%	2.1%	2.0%	0.0%	0.3%
Coke and refined petroleum products	0.4%	1.2%	2.1%	3.6%	6.9%	35.9%
Non-metallic mineral products	1.1%	4.0%	1.7%	1.7%	0.1%	11.0%
Other manufacturing products	0.1%	2.6%	12.8%	17.9%	11.9%	31.1%
Electricity, gas and steam	3.9%	0.0%	1.8%	1.8%	1.0%	1.2%
Water supply, sewerage	3.8%	0.0%	0.1%	0.1%	0.0%	0.1%
Construction	3.9%	0.0%	6.9%	5.5%	0.0%	0.0%
Sale of motor vehicles	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Maintenance and repair of motor vehicles	0.0%	0.0%	0.8%	0.6%	0.0%	0.0%
Wholesale and retail trade	0.6%	0.0%	13.7%	10.5%	0.0%	0.0%
Land transport	7.7%	0.0%	2.6%	3.2%	3.8%	29.1%
Water transport	0.0%	0.0%	1.0%	0.8%	2.4%	0.0%
Air transport	0.0%	0.0%	0.1%	0.1%	2.4%	0.0%
Warehousing and transportation support activities	9.6%	0.0%	0.3%	0.3%	0.4%	1.0%
Postal and courier	0.0%	0.0%	0.0%	0.0%	0.0%	26.5%
Telecommunication	1.9%	0.0%	1.1%	1.5%	82.1%	42.6%
Hotels	46.6%	0.0%	0.1%	0.2%	73.1%	0.0%
Restaurants	0.0%	0.0%	2.7%	2.0%	24.6%	0.0%
Publishing, motion pictures, video, TV and radio	0.0%	0.0%	0.0%	0.0%	0.1%	6.5%
Computer programming, consultancy and information service activities	0.0%	0.0%	0.2%	0.1%	59.3%	0.0%
Banking	0.0%	0.0%	0.6%	0.5%	1.2%	6.8%
Insurance and other financial auxiliary services	0.0%	0.0%	0.0%	0.0%	1.0%	0.0%
Real estate	0.0%	0.0%	0.3%	0.2%	0.0%	0.0%
Owner occupied dwellings	0.0%	0.0%	1.1%	0.9%	0.0%	0.0%
Professional, scientific and technical activities	3.5%	0.0%	2.0%	1.6%	0.0%	0.0%
Other administrative and support services	1.5%	0.0%	0.2%	0.2%	0.0%	0.0%
Travel agencies	0.6%	0.0%	0.6%	0.5%	68.2%	12.1%
Public administration and defence	0.0%	0.0%	6.7%	5.1%	0.0%	0.0%
Education	0.0%	0.0%	2.1%	1.6%	0.0%	0.0%

Health	0.0%	0.0%	0.7%	0.6%	0.0%	0.0%
Domestic and other services	5.1%	0.0%	1.3%	1.1%	0.9%	4.4%
Primary sectors	0.0%	0.0%	11.4%	12.5%	14.3%	0.8%
Manufacturing sectors	1.5%	2.5%	41.4%	48.5%	15.0%	18.6%
Service sectors	2.1%	0.0%	47.2%	39.0%	4.9%	4.4%
All sectors	1.6%	2.1%	100.0%	100.0%	10.1%	10.9%

Note: TQ – Sales tax rates, TM – Import tariff rates, E – Exports, M – Imports, X– Domestic production, Q – Domestic supply, Xshr – Domestic production value share, Qshr – Domestic supply value share.

Source: authors' calculations based on 2017 Social Accounting Matrix for Myanmar (van Seventer et al. 2020).

Table 2: Household income sources (per cent)

Income types		Household types			
		Rural farm	Rural non-farm	Urban farm	Urban non-farm
Factor income	Labour – low education	32%	36%	17%	5%
	Labour – high education	32%	36%	41%	40%
	Agricultural capital	5%	0%	7%	0%
	Non-agricultural capital	0%	0%	0%	0%
	Natural resources	24%	0%	31%	0%
Enterprise profits		0%	25%	0%	53%
Government transfers		2%	1%	1%	0%
Foreign remittances		5%	3%	4%	1%
TOTAL		100%	100%	100%	100%

Note: low education labour factor income (income from 'no education' and 'primary education' labour); high education labour factor income (income from 'secondary education' and 'tertiary education' labour); capital factor income (distributed income from 'capital' factor and distributed profits from 'enterprises'); natural resources income (income from 'land', 'livestock', and 'fish stocks'). The four household types are derived for our 20 households by aggregating over quintiles.

Source: authors' calculations based on 2017 Social Accounting Matrix for Myanmar (van Seventer et al. 2020).

Table 3: Factor income distribution (per cent)

	Low education labour	High education labour	Agricultural capital	Non-agricultural capital	Natural resources	Enterprises
Enterprises	0%	0%	0%	100%	0%	0%
Rural farm	47%	30%	91%	0%	91%	0%
Rural non-farm	43%	27%	0%	0%	0%	21%
Urban farm	2%	3%	9%	0%	9%	0%
Urban non-farm	8%	40%	0%	0%	0%	59%
SoE transfers to government	0%	0%	0%	0%	0%	0%
Enterprise tax	0%	0%	0%	0%	0%	0%
Enterprise savings	0%	0%	0%	0%	0%	20%
TOTAL	100%	100%	100%	100%	100%	100%

Note: low education labour factor income (includes income from 'no education' and 'primary education' labour); high education labour factor income (includes income from 'secondary education' and 'tertiary education' labour); natural resources income (includes income from 'land', 'livestock', and 'fish stocks'). The four household types are derived for our 20 households by aggregating over quintiles.

Source: authors' calculations based on 2017 Social Accounting Matrix for Myanmar (van Seventer et al. 2020).

Table 4: Average labour wages by production sector and labour type (1000s MKK p.a.)

Production sector	Labour type			
	No education labour	Primary education labour	Secondary education labour	Tertiary education labour
Primary sector	702	546	463	680
Secondary sector	2,232	2,381	2,747	5,449
- investment goods	3,397	3,190	3,757	6,013
- other manufacturing goods	1,774	2,079	2,323	5,044
Tertiary sector	2,170	2,310	2,917	6,080
- construction	2,537	2,829	3,072	7,811
- public administration	55,715	31,173	34,000	41,671
- other services	1,903	2,027	2,395	3,857
Average wages	1,323	1,297	1,791	5,573

Source: authors' calculations based on 2017 Social Accounting Matrix for Myanmar (van Seventer et al. 2020).

Table 5: Future climate change scenarios of paddy yield impacts for Myanmar (implemented for 2021–40)

Scenario 1	Climate change impact on paddy yields during 2020s - rainfed farming practice - high input-use technology
Scenario 2	Climate change impact on paddy yields during 2050s - rainfed farming practice - high input-use technology
Scenario 3	Climate change impact on paddy yields during 2080s - rainfed farming practice - high input-use technology
Scenario 4	Climate change impact on paddy yields during 2020s - mixed rainfed and irrigated farming practice - high input-use technology
Scenario 5	Climate change impact on paddy yields during 2050s - mixed rainfed and irrigated farming practice - high input-use technology
Scenario 6	Climate change impact on paddy yields during 2080s - mixed rainfed and irrigated farming practice - high input-use technology
Scenario 7	Climate change impact on paddy yields during 2080s - mixed rainfed and irrigated farming practice - low input-use technology

Source: authors' own specifications.

In the next section, we analyse the seven CC scenarios. While the CC scenarios are simulated for three different future decades spanning the coming 70 years, we analyse and compare the future climate scenario impacts by assuming that they occur immediately, in 2021, and are sustained throughout our time horizon 2021–40. Our focus is on how projected CCs, via the critically important paddy rice sector, may affect the ongoing Myanmarese economic development process. Through our multi-household model, we also focus on potential distributional implications, including potential spillovers from rural farming households to the remaining part of the economy. Although our model does not formally span the 70 years of the underlying CC scenarios, we believe our simulations will enable an appropriate macroeconomic comparison of future projected CC impacts on paddy yields, including Myanmar-wide macroeconomic impacts and distributional impacts across individual states and regions and among our 20 household types. For the same reason, and as mentioned earlier, we maintain a focus on relative growth impacts and specifically include caveats in the discussion of absolute value impacts.

Specifically, we present our simulation results below with a focus on (1) macroeconomic GDP impacts, including impacts on GDP components, and (2) distributional household impacts on labour factor ownership and household welfare, including household income and consumption impacts. We present cumulative net present value (NPV) economic impacts over 2021–40 (at 2017 prices), based on a 10 per cent depreciation rate equivalent to the average 10 per cent real interest rate which has characterized Myanmar for most of the last decade, during 2011–19 (World Bank 2021c). We also present annual dynamic real GDP time series impacts. The time series results are presented in real value terms (2017 prices), but without discounting, i.e. without taking the time value of money into account.

Table 6: Future climate change scenarios of paddy yields from rainfed and mixed rainfed and irrigation farming practices across Myanmar states and regions (% change)

	2020s		2050s		2080s		
	Scenario 1: Rainfed High input use	Scenario 4: Mixed practice High input use	Scenario 2: Rainfed High input use	Scenario 5: Mixed practice High input use	Scenario 3: Rainfed High input use	Scenario 6: Mixed practice High input use	Scenario 7: Mixed practice Low input use
- Kachin State	2.3%	1.9%	3.5%	3.2%	4.0%	3.8%	4.8%
- Kayah State	2.2%	2.0%	-2.3%	-0.6%	-0.9%	0.6%	2.0%
- Kayin State	1.9%	1.7%	4.0%	3.3%	4.2%	2.0%	3.4%
- Chin State	1.8%	1.2%	5.3%	3.5%	8.8%	5.9%	13.5%
- Sagaing Region	1.0%	1.1%	3.5%	3.1%	2.7%	2.6%	6.2%
- Taninthayi Region	1.9%	1.6%	4.4%	3.3%	5.5%	2.3%	3.6%
- Bago Region	1.3%	1.0%	5.8%	3.9%	-0.1%	-1.6%	-6.0%
- Magway Region	0.2%	0.5%	2.6%	2.2%	-1.2%	-0.8%	-4.5%
- Mandalay Region	0.7%	1.0%	5.1%	4.0%	3.0%	2.1%	2.4%
- Mon State	2.1%	1.9%	4.5%	3.8%	6.1%	3.8%	2.9%
- Rakhine State	1.1%	1.4%	3.3%	3.2%	2.3%	2.7%	5.5%
- Yangon Region	2.6%	1.8%	5.4%	3.7%	0.9%	-1.2%	-4.6%
- Shan State	4.0%	3.3%	7.2%	6.1%	9.0%	7.7%	0.5%
- Ayeyarwady Region	1.6%	1.3%	3.3%	2.5%	1.3%	-0.7%	-4.8%
- Nay Pyi Taw	-1.0%	-0.4%	2.5%	1.9%	-4.3%	-3.5%	-1.2%
Myanmar (weighted average)	1.8%	1.6%	3.9%	3.2%	2.9%	1.5%	-0.6%

Note: mixed farming practice yield changes were derived by weighting underlying climate change yield predictions for ‘rainfed’ and ‘irrigated’ farming practice by the 2017/18 share of irrigated paddy production (32.7%) (CSO 2018).

Source: World Bank (World Bank 2021a) and authors’ own calculations.

4 Results

In this section, we analyse the macroeconomic impacts of the seven CC scenarios of paddy yield impacts as they are predicted to affect the regions and states of Myanmar over the coming 70 years. We present our CC scenario results in three sub-sections covering: 1) paddy yield impacts for the 2020s, 2050s, 2080s using 'rainfed farming technologies' (sub-section 4.1; scenarios 1-3); 2) paddy yield impacts for the 2020s, 2050s, 2080s using 'mixed rainfed and irrigation farming technologies' (sub-section 4.2; scenarios 4-6); and 3) comparison of high and low input-use technology paddy yield impacts for the 2080s using 'mixed rainfed and irrigation farming technologies' (sub-section 4.3; scenario 7).

4.1 Paddy yield impacts for the 2020s, 2050s, 2080s (rainfed farming technologies)

The macroeconomic and distributional impacts of our three rainfed farming practice scenarios 1–3 are presented in Tables 7–9 and Figure 1. The 2021–40 NPV GDP impacts and a breakdown across GDP demand components are presented in Table 7, while a decomposition of state- and province-level NPV GDP impacts is presented in Table 8, and an overview of NPV household income distributional impacts is presented in Table 9. Dynamic real GDP impacts are presented in both Table 7 and Figure 1, while the Myanmar-wide paddy yield impacts are presented in Table 7. The paddy yield impacts analysed in this section are derived from HIU technology scenario data (World Bank 2021a).

Overall, the underlying CC scenario data suggest that average Myanmar-wide paddy yield impacts will increase by around 1.8 per cent above the baseline during the 2020s, by around 3.9 per cent above baseline during the 2050s, and by around 2.9 per cent above baseline during the 2080s (Table 7). Looking across the three scenarios, the NPV GDP impacts are almost proportional to the underlying yield changes: 1) the '2020s' paddy yield expansion (1.8 per cent) will lead to a 0.25 per cent NPV GDP expansion over a 20-year period like ours (scenario 1); 2) the '2050s' paddy yield expansion (3.9 per cent) will lead to a 0.54 per cent NPV GDP expansion over a 20-year period; and 3) the '2080s' paddy yield expansion (2.9 per cent) will lead to a 0.40 per cent NPV GDP expansion over a 20-year period. If the yield impacts were to materialize immediately, the absolute impacts would be, respectively, US$3.1 billion, US$6.7 billion, and US$5 billion NPV GDP expansions. Hence, based on these predictions, CC is likely to be beneficial to Myanmarese paddy cropping over the coming 70-year period. It should be kept in mind, however, that these analyses assume rainfed paddy farming practices and HIU technologies. This does not, however, invalidate the current analyses. Remembering the relatively low share of irrigated production (around one-third) and the fact that farmers may switch to HIU technologies over time, it may be that these scenarios may turn out to be correct (e.g. via policy interventions). With that in mind, note that future food security and export development strategies focussed on returning Myanmar to its former role as the rice bowl of the region may have promise.

The proportional increases in NPV GDP impacts also extend to the dynamic real GDP impacts presented in Table 7 and Figure 1. Looking at scenario 1, a '2020s' yield expansion will increase NPV GDP by 0.25 per cent over a 20-year period (Table 7), but Figure 1 demonstrates that the NPV GDP expansion covers slightly varying growth trends of the real GDP demand components. Whereas real private consumption growth is flatter, the real investment growth path is slightly steeper, indicating that investment and snowballing capital accumulation are driving the rapid growth expansion. Hence, our results suggest that CC-induced paddy yield growth could well help to expand income and savings generation in Myanmar, and thereby help to fund critical investment and capital accumulation for the ongoing economic development process over the coming decades. Furthermore, this mechanism is particularly pronounced for the '2050s' paddy yield expansion (3.9 per cent), which leads to a 0.54 per cent NPV GDP expansion covering a 0.60 per cent NPV private consumption expansion and a 0.63 per cent NPV investment expansion. However, short-term real private consumption and investment impacts of 0.37 per cent and 0.26 per cent are replaced by 0.82 per cent and 1 per cent impacts in the long term. This would indicate that CC may by itself (possibly with the assistance of policy interventions to convince farmers to adopt new HIU technologies) set in motion an income and savings generation process as well as snowballing investment and capital accumulation, which may help Myanmar's development process over the very long term.

Looking at the breakdown of NPV GDP impacts across states and provinces in Table 8, the projected long-term CC benefits of increased paddy yields (2080s rainfed CC scenario 3) will mostly benefit the states and provinces with the largest potential for paddy farming. These include Shan state, which accounts for 41 per cent of the nation-wide NPV GDP benefits, the fertile Ayeyarwady delta (23 per cent), and the western Sagaing region (19 per cent). Other provinces, which will benefit to lesser extents include the northern Kachin state (6 per cent), the southern Kayin state (8 per cent), and the southern Taninthayi region (5 per cent), while Nay Pyi Taw capital zone (-3 per cent) and Kayah state (-0.2 per cent) will face adverse impacts.

Interestingly, while CC scenarios 1–2 for the 2020s and 2050s suggest that the fertile Ayeyarwady delta region will be the main beneficiary of CC-related yield improvements (44–45 per cent of total NPV GDP gains) compared to Shan state (24–29 per cent), the relative benefits are reversed in CC scenario 3 for the 2080s (Shan state: 41 per cent; Ayeyarwady: 23 per cent). Hence, while Shan state is predicted to experience continuing expansion of rainfed paddy yields throughout the 2080s, Ayeyarwady paddy yields and NPV GDP gains are predicted to decline strongly after the 2050s. This may reflect predictions of CC leading to increased salinity, coastal erosion, and inundation for the Ayeyarwady delta region (Nyo 2020). Interestingly, removing the key Ayeyarwady region from the analysis means that there is an increase in NPV GDP impacts from the CC-related paddy yield changes from the 2020s to 2050s. However, these remain fairly constant between the 2050s and 2080s (Table 8), implying that the predicted declines in paddy yields and NPV GDP gains, following the 2050s peak, stem entirely from climate-induced yield reductions in the key Ayeyarwady delta region. Nevertheless, while paddy yields may drop in Ayeyarwady and the comparative advantage of paddy production in Shan state may improve after the 2050s, the potential for future expansion (and CC mitigation) continues to be greatest in the Ayeyarwady region, which still accounts for the largest share of paddy production in Myanmar.

The distributional NPV household income impacts are presented in Table 9. Perhaps surprisingly, the greatest income benefits of rainfed CC paddy yield expansion across the three 2020s, 2050s, and 2080s CC scenarios 1–3 accrue to urban households. Hence, urban household incomes increase by, respectively, 0.33 per cent, 0.71 per cent, and 0.53 per cent compared to rural income expansions of 0.26 per cent, 0.55 per cent, and 0.41 per cent, respectively. The main reason for this surprising result is, as mentioned earlier, that the increase in rural farmer income helps to increase savings generation in Myanmar and thereby helps to fund critical investment and capital accumulation, which, however, mostly benefit urban household capital owners. Nonetheless, it can also be noted that the bottom income quintile 1q household types all benefit relatively more than other household types, implying that CC-related paddy yield changes may help to improve income distribution and living conditions among the poorest population groups.

4.2 Paddy yield impacts for the 2020s, 2050s, 2080s (mixed rainfed and irrigation farming technologies)

In this section, we acknowledge that around one-third of Myanmar's paddy production is produced using irrigation farming practices, and, accordingly, our analyses in this section are focussed on CC scenarios 4–6, where we investigate a set of mixed rainfed and irrigation farming practice-weighted state- and region-level paddy yield impacts for the 2020s, 2050s, and 2080s.

The macroeconomic and distributional impacts of our three mixed rainfed and irrigation farming scenarios 4–6 are presented in Tables 10–12 and Figure 1 (second column). Table 10 presents the 2021–40 NPV GDP impacts, including breakdowns across GDP demand components, and average Myanmar-wide mixed rainfed and irrigation farming paddy yield shocks. Table 11 presents state- and region-level breakdowns of NPV GDP impacts, and Table 12 presents an overview of distributional impacts across household types. The analyses in this section are similar to those in the previous section, based on HIU scenario data (World Bank 2021a).

Compared to the pure rainfed farming practice (RFP) in scenarios 1–3, the mixed farming practice (MFP) in scenarios 4–6 predicts continuing positive but uniformly smaller paddy yield impacts for the 2020s (RFP: 1.8 per cent; MFP: 1.6 per cent), 2050s (RFP: 3.9 per cent; MFP: 3.2 per cent), and 2080s (RFP: 2.9 per cent; MFP: 1.5 per cent). This reflects that, as mentioned in the background section, CC impacts will benefit rainfed farming practices more than irrigated farming practices. The widening impacts also indicate that the disparity between rainfed and irrigated farming practices will grow over time, suggesting that the relative advantage of irrigation farming practices may decline in the future. This does not mean that irrigation practices will become superfluous; on the contrary, irrigation practices are still likely to represent a comparative advantage in many parts of Myanmar, but the comparative advantage may not be as big as previously.

In terms of macroeconomic impacts, the lower paddy yield impacts are reflected almost linearly in NPV GDP impacts across the three scenarios, including the 2020s (RFP: 0.25 per cent; MFP: 0.22 per cent), 2050s (RFP: 0.54 per cent; MFP: 0.44 per cent), and 2080s (RFP: 0.40 per cent; MFP: 0.21 per cent) (Table 10). The MFP scenarios 4–6 clearly demonstrate that a large part of the macroeconomic gains are only likely to be temporary and that, as paddy yields are affected negatively by CC over the very long term, between the 2050s and 2080s, macroeconomic benefits are likely to fall back to 2020s levels by the 2080s after a temporary increase during the 2050s. If the yield impacts were to materialize immediately, the absolute NPV GDP impacts would be, respectively, US$2.8 billion, US$5.5 billion, and US$2.6 billion, implying that the expected macroeconomic gains from CC-induced paddy yield changes will still be considerable. Again, it should be kept in mind that the current CC predictions assume HIU technologies but, as smallholders may switch to HIU farming technologies over time, the analyses do suggest that future food security and export development strategies focussed on paddy rice production expansion may be worth pursuing.

Relative to the rainfed farming practice scenarios 1–3, the dynamic macroeconomic impacts of the mixed farming practice scenarios 4–6 are reduced virtually proportionally to the reductions in CC paddy yield changes (Figure 1, column 2). In particular, it can be verified that the growth paths for real GDP and the key real private consumption and real investment demand components for each of the 2020s, 2050s, and 2080s in scenarios 4–6 are visibly lower compared to their sister 2020s, 2050s, 2080s scenarios 1–3. It is clear that the patterns identified in the previous analyses of rainfed farming practice of real investment having a smaller initial impact but, subsequently, a much steeper growth path than real private consumption, characterizes all of the mixed farming scenarios 4–6 as well. Hence, while real private consumption (RCP) growth paths are flatter, real investment

(RINV) growth paths are again somewhat steeper, indicating that it is investment demand and the resulting capital accumulation that are driving the growth impacts (beyond the growth impacts of the factor productivity expansions themselves). Specifically, while the NPV impacts are similar for the three scenarios, including the 2020s (RCP: 0.25 per cent; RINV: 0.26 per cent), 2050s (RCP: 0.49 per cent; RINV: 0.52 per cent), and 2080s (RCP: 0.23 per cent; RINV: 0.24 per cent), and the short-term real investment impacts are consistently lower including for the 2020s (RCP: 0.15 per cent; RINV: 0.11 per cent), 2050s (RCP: 0.30 per cent; RINV: 0.22 per cent), and 2080s (RCP: 0.14 per cent; RINV: 0.10 per cent), the long-term real investment impacts are consistently higher, including for the 2020s (RCP: 0.33 per cent; RINV: 0.41 per cent), 2050s (RCP: 0.67 per cent; RINV: 0.82 per cent), and 2080s (RCP: 0.32 per cent; RINV: 0.38 per cent) (Table 10). This confirms that CC-induced paddy yield growth, even when accounting for the use of mixed farming practices, may help to expand income and savings generation in Myanmar. Similar to the rainfed farming practice simulations, our mixed farming practice simulations suggest that CC-induced growth impacts will be strongest during the 2050s, indicating that CC-induced paddy yield increases may stimulate income and savings over the coming several decades and thereby help to fund critical investment and capital accumulation for the ongoing economic development process.

While aggregate Myanmar-wide NPV GDP impacts are generally smaller for the mixed farming practice scenarios 4–6 relative to the rainfed farming scenarios 1–3, the breakdown of the impacts of the NPV GDP across states and provinces in Table 11 indicates that relative province-level shares of benefits and losses are similar for the 2020s and 2050s scenarios 1–2 (Table 8) and scenarios 4–5 (Table 11). For example, the NPV GDP impact shares for Ayeyarwady under rainfed farming practices (2020s: 45 per cent; 2050s: 44 per cent) (Table 8) are relatively similar to the impact shares under the mixed farming practices scenarios (2020s: 43 per cent; 2050s: 41 per cent) (Table 11). The same is the case for other major producing provinces including Shan state and Sagaing region. However, province-level NPV GDP impact shares change strongly between the 2050s and the 2080s, and shares differ markedly between the two 2080s scenarios 3 and 6, exemplified by the three main producing regions including the Ayeyarwady region (RFP: 41 per cent; MFP: -23.7 per cent), the Shan state (RFP: 23 per cent; MFP: 69 per cent), and Sagaing region (RFP: 19 per cent; MFP: 35 per cent) (Tables 8 and 11).

The sharp changes in the distribution of gains and losses from CC-related paddy yield impacts between the 2050s and 2080s can be explained almost entirely by sharp changes in predicted yields for the key Ayeyarwady delta region. Hence, the province-level results in Tables 8 and 11 clearly show that the potential paddy yield benefits for the Ayeyarwady region are reduced between the 2050s and 2080s due to climatic variations and negative interaction effects between irrigation farming practices and climatic variations over time. More generally, the underlying CC predictions of Ayeyarwady paddy yields (Table 2) seem to indicate that the increased occurrence of extreme weather events, such as droughts and, in particular, saline floodings of the fertile Ayeyarwady delta, may gain more prominence and importance beyond the 2050s, including disproportionately reducing yields from irrigated paddy farming practices in the Ayeyarwady delta.

It is interesting to note that removing the key Ayeyarwady delta region from the analysis means that the NPV GDP impacts from CC-related paddy yield changes again increase from the 2020s to the 2050s but remain fairly constant between the 2050s and the 2080s (Table 11). This is similar to our findings from the rainfed scenario analyses above, and it underlines that, while paddy yields may not be declining for several decades (according to the underlying CC-related yield predictions), there is likely to be a need for initiatives to mitigate against yield reductions, especially in the Ayeyarwady delta region, beyond the 2050s. Such mitigation efforts may need to take place (or at least be started) years or possibly decades before the actual yield reductions start to occur. For example, mitigating against future coastal erosion is a momentous task, and identification, cultivation, and adoption of salt-alkali tolerant rice varieties, suitable to varying Myanmararese conditions, may take decades, not least because a standardized system to evaluate rice salt tolerance remains elusive and because the mechanism of salt tolerance in rice is still not well understood (Qin et al. 2020).

The distributional NPV household income impacts of the mixed farming practice scenarios 4–6 are presented in Table 12. Again, it is evident that the largest share of NPV GDP impacts, across the three 2020s, 2050s, and 2080s scenarios, accrue to urban households. Hence, urban household incomes expand by, respectively, 0.29 per cent, 0.58 per cent, and 0.28 per cent compared to rural income expansions of 0.23 per cent, 0.45 per cent, and 0.21 per cent, respectively. The main reason for this result is, again, that the increase in rural farmer income helps to increase savings generation in Myanmar and thereby helps to fund critical investment and capital accumulation, which, however, mostly benefit urban household capital owners. Nonetheless, as before, it should be noted that the bottom income quintile 1q household types all benefit most in relative terms, and that the CC-related paddy yield changes may therefore help to improve income distribution and living conditions among the poorest population groups over the coming decades, but with reduced impact after the 2050s.

4.3 Comparison of high and low input-use technology paddy yield impacts for the 2080s (mixed rainfed and irrigation farming technologies)

Finally, we analyse the importance of the use of high and low input technologies, and how these interact with climate-related changes in paddy yields. We limit this final analysis to presenting macroeconomic impacts in Table 13. Furthermore, while we already analysed scenario 6 in the previous section, we restate the macroeconomic impacts of this scenario in Table 13 for completeness.

The macroeconomic impacts of LIU technology scenario 7, presented in Table 13, demonstrate that input use technology has potentially important and province-specific interaction effects with CC-related yield variations. Hence, as noted in the methods section, LIU technology scenario 7 shows considerable variation in yield impacts across Myanmar states and regions and relative to HIU technology scenario 6. While the main producing provinces, including the Ayeyarwady delta region and Shan state, are predicted to experience either significant yield declines for LIU technology farming (e.g. Ayeyarwady: -4.8 per cent) or stagnant yield increases (e.g. Shan state: 0.5 per cent, which does not compare well with the 7.7 per cent yield gains for HIU technology farming (Table 2)), there are other states and regions where CC-related yield impacts are more favourable for LIU vs. HIU technology farming (e.g. the important Sagaing region—HIU: 2.6 per cent yield increase; LIU: 6.2 per cent yield increase). These results can be helpful, for example, in directing attention to extension services and other supporting services in order to target the areas where increased adoption of HIU technologies are best rolled out to leverage future CC-related paddy yield changes.

While the extent to which Myanmar paddy farmers apply LIU or HIU technologies is unclear, our simulations suggest that this is sufficiently important to be a deciding factor in whether future CC-related yield changes, and related macroeconomic impacts, will be positive or negative. Hence, our simulations 6 and 7 show that, assuming all Myanmar paddy farmers use either HIU or LIU technologies, the Myanmar-wide CC-related yield impacts will be either 1.5 per cent or -0.6 per cent, and the NPV GDP growth impacts will be either 0.21 per cent or -0.09 per cent in the 2080s (Table 13). This analysis suggests that the average 2080s paddy yield impact will be somewhere in the range between -0.6 per cent and 1.5 per cent and that the NPV GDP growth impact will be somewhere in the range between -0.09 per cent and 0.21 per cent. Given that zero is part of both ranges and that the ranges are not wide, this analysis suggests that the very long-term 2080s aggregate Myanmar-wide CC-related impact on paddy yields will be small and will have a relatively small NPV GDP growth impact over the very long term. This is not to say that CC cannot have economic consequences over the coming decades and that it will not have distributional consequences, but the very long-term aggregate economy-wide impact, when we get to the 2080s, is likely to be relatively limited even if a large part of paddy production has switched to using HIU technology at that point.

Finally, the final demand component NPV impacts and dynamic growth paths follow the same patterns observed for scenarios 1–6 above, implying that NPV private consumption (HIU: 0.23 per cent; LIU: -0.10 per cent) and NPV investment (HIU: 0.24 per cent; LIU: -0.14 per cent) growth rates are similar, while the dynamic growth impacts differences are more pronounced: (1) RCP growth (HIU: 0.15 per cent; LIU: -0.06 per cent) is larger (in absolute terms) than short-term RINV growth (HIU: 0.11 per cent; LIU: -0.05 per cent), while (2) long-term RINV growth (HIU: 0.15 per cent; LIU: -0.06 per cent) is larger (in absolute terms) than long-term RCP growth (HIU: 0.11 per cent; LIU: -0.05 per cent). In sum, this implies that the income-savings mechanism will have snowballing impacts on investment demand and capital accumulation regardless of whether it is a positive yield impact starting a positive capital accumulation process or a negative yield impact starting a negative capital decumulation process.

Table 7: 2021–40 macroeconomic impacts of future climate change scenarios of yields from rainfed farming practice in Myanmar (billion USD in 2017 prices)

		2020s rainfed farming practice CC scenario 1		2050s rainfed farming practice CC scenario 2		2080s rainfed farming practice CC scenario 3	
NPV GDP impacts[1]	Base	∆value	% change	∆value	% change	∆value	% change
NPV GDP	1,254	3.1	0.25%	6.7	0.54%	5.0	0.40%
- Priv. consumption	721	2.0	0.28%	4.3	0.60%	3.2	0.44%
- Govt. consumption	203	0.0	0.00%	0.0	0.00%	0.0	0.00%
- Investment	380	1.1	0.29%	2.4	0.63%	1.8	0.47%
- Exports	366	0.9	0.24%	1.8	0.50%	1.4	0.37%
- Imports	416	0.9	0.21%	1.8	0.44%	1.4	0.33%
Dynamic impacts - no discounting	Base	short term (2021) (%)	long term (2040) (%)	short term (2022) (%)	long term (2040) (%)	short term (2022) (%)	long term (2040) (%)
Real GDP (cum.)[1]	1,254	0.14%	0.35%	0.29%	0.76%	0.22%	0.56%
- Priv. consumption	721	0.17%	0.38%	0.37%	0.82%	0.28%	0.60%
- Govt. consumption	203	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
- Investment	380	0.12%	0.46%	0.26%	1.00%	0.20%	0.74%
- Exports	366	0.10%	0.36%	0.20%	0.78%	0.15%	0.57%
- Imports	416	0.07%	0.34%	0.16%	0.74%	0.12%	0.55%
CC yield change	Base	∆value	% change	∆value	% change	∆value	% change
Paddy	-	1.78%	1.78%	3.88%	3.88%	2.85%	2.85%

Note: [1] 10% discount rate applied to derive cumulative 2021–40 NPV real GDP components.

Source: authors' own calculations.

Table 8: 2021–40 NPV GDP impacts of future climate change scenarios of yields from rainfed paddy farming practice across Myanmar states and regions (billion USD in 2017 prices)

		2020s rainfed farming practice CC scenario 1		2050s rainfed farming practice CC scenario 2		2080s rainfed farming practice CC scenario 3	
NPV GDP impacts[1]	Base	∆value	% of GDP	∆value	% change	∆value	% change
Myanmar (cum.)[2]	1,254	3.17	100.0%	6.88	100.0%	5.07	100.0%
Myanmar excl. Ayeyarwady (cum.)[2]		1.74	54.7%	3.83	55.6%	3.88	76.6%
- Kachin State		0.17	5.2%	0.26	3.7%	0.29	5.8%
- Kayah State		0.03	1.0%	-0.03	-0.5%	-0.01	-0.2%
- Kayin State		0.18	5.6%	0.37	5.4%	0.40	7.9%
- Chin State		0.02	0.5%	0.05	0.7%	0.08	1.5%
- Sagaing Region		0.37	11.6%	1.23	17.9%	0.96	19.0%
- Taninthayi Region		0.08	2.5%	0.18	2.7%	0.23	4.5%
- Bago Region		0.00	0.0%	0.00	0.0%	0.00	0.0%
- Magway Region		0.00	0.0%	0.00	0.0%	0.00	0.0%
- Mandalay Region		0.00	0.0%	0.00	0.0%	0.00	0.0%
- Mon State		0.00	0.0%	0.00	0.0%	0.00	0.0%
- Rakhine State		0.00	0.0%	0.00	0.0%	0.00	0.0%
- Yangon Region		0.00	0.0%	0.00	0.0%	0.00	0.0%
- Shan State		0.93	29.4%	1.67	24.3%	2.08	41.1%
- Ayeyarwady Region		1.44	45.3%	3.06	44.4%	1.19	23.4%
- Nay Pyi Taw		-0.03	-1.1%	0.09	1.3%	-0.15	-3.0%

Note: [1] 10% discount rate applied to derive cumulative 2021–40 real GDP impacts for provinces and states. [2] Note that sum of state and province impacts differ from total Myanmar impact in Table 7 due to non-linearities.

Source: authors' own calculations.

Table 9: 2021–40 distributional impacts of future climate change scenarios of yields from rainfed paddy fields across Myanmar household types (billion USD in 2017 prices)

		2020s rainfed farming practice CC scenario 1		2050s rainfed farming practice CC scenario 2		2080s rainfed farming practice CC scenario 3	
NPV household income[1]	Base	∆Income	% change	∆Income	% change	∆Income	% change
All households	1,128.0	3.23	0.29%	6.92	0.61%	5.12	0.45%
Rural households	695.9	1.79	0.26%	3.84	0.55%	2.84	0.41%
Rural farm households	406.3	0.94	0.23%	2.02	0.50%	1.49	0.37%
- Rural farm 1q	27.7	0.07	0.26%	0.15	0.56%	0.11	0.41%
- Rural farm 2q	56.6	0.14	0.25%	0.31	0.54%	0.23	0.40%
- Rural farm 3q	78.7	0.19	0.24%	0.40	0.51%	0.30	0.38%
- RuralfFarm 4q	107.4	0.26	0.24%	0.56	0.52%	0.41	0.38%
- Rural farm 5q	136.0	0.28	0.21%	0.60	0.44%	0.44	0.33%
Rural non-farm households	289.6	0.85	0.29%	1.82	0.63%	1.35	0.47%
- Rural non-farm 1q	41.5	0.14	0.33%	0.29	0.70%	0.22	0.52%
- Rural non-farm 2q	54.1	0.16	0.29%	0.34	0.63%	0.25	0.46%
- Rural non-farm 3q	54.9	0.16	0.30%	0.35	0.64%	0.26	0.47%
- Rural non-farm 4q	63.4	0.18	0.28%	0.38	0.60%	0.28	0.45%
- Rural non-farm 5q	75.6	0.21	0.28%	0.45	0.60%	0.34	0.45%
Urban households	432.1	1.44	0.33%	3.08	0.71%	2.28	0.53%
Urban farm households	36.1	0.08	0.22%	0.17	0.48%	0.13	0.36%
- Urban farm 1q	1.4	0.00	0.24%	0.01	0.52%	0.01	0.39%
- Urban farm 2q	2.2	0.01	0.25%	0.01	0.53%	0.01	0.39%
- Urban farm 3q	3.8	0.01	0.24%	0.02	0.52%	0.01	0.39%
- Urban farm 4q	7.4	0.02	0.23%	0.04	0.50%	0.03	0.37%
- Urban farm 5q	21.3	0.05	0.21%	0.10	0.46%	0.07	0.34%
Urban non-farm households	396.0	1.36	0.34%	2.91	0.73%	2.16	0.54%
- Urban non-farm 1q	12.6	0.05	0.38%	0.10	0.81%	0.08	0.60%
- Urban non-farm 2q	26.8	0.09	0.33%	0.19	0.71%	0.14	0.53%
- Urban non-farm 3q	44.8	0.15	0.34%	0.33	0.73%	0.24	0.54%
- Urban non-farm 4q	67.8	0.24	0.35%	0.50	0.74%	0.37	0.55%
- Urban non-farm 5q	244.0	0.84	0.34%	1.79	0.73%	1.32	0.54%

Note: [1] 10% discount rate applied to derive cumulative 2021–40 real household impacts.

Source: authors' own calculations.

Table 10: 2021–40 macroeconomic impacts of future climate change scenarios of yields from mixed rainfed and irrigated farming practice in Myanmar (billion USD in 2017 prices)

		2020s mixed farming practice CC scenario 4		2050s mixed farming practice CC scenario 5		2080s mixed farming practice CC scenario 6	
NPV impacts[1]	Base	∆value	% change	∆value	% change	∆value	% change
Real GDP (cum.)	1,254	2.8	0.22%	5.5	0.44%	2.6	0.21%
- Priv. consumption	721	1.8	0.25%	3.5	0.49%	1.7	0.23%
- Govt. consumption	203	0.0	0.00%	0.0	0.00%	0.0	0.00%
- Investment	380	1.0	0.26%	2.0	0.52%	0.9	0.24%
- Exports	366	0.8	0.21%	1.5	0.41%	0.7	0.19%
- Imports	416	0.8	0.18%	1.5	0.36%	0.7	0.17%
Dynamic impacts – no discounting	Base	short term (2021) (%)	long term (2040) (%)	short term (2022) (%)	long term (2040) (%)	short term (2022) (%)	long term (2040) (%)
Real GDP (cum.)[1]	1,254	0.12%	0.31%	0.24%	0.62%	0.11%	0.29%
- Priv. consumption	721	0.15%	0.33%	0.30%	0.67%	0.14%	0.32%
- Govt. consumption	203	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
- Investment	380	0.11%	0.41%	0.22%	0.82%	0.10%	0.38%
- Exports	366	0.08%	0.32%	0.17%	0.63%	0.08%	0.30%
- Imports	416	0.07%	0.30%	0.13%	0.60%	0.06%	0.28%
CC yield change	Base	∆value	%-change	∆value	%-change	∆value	%-change
Paddy	-	1.56%	1.56%	3.15%	3.15%	1.47%	1.47%

Note: [1] 10% discount rate applied to derive cumulative 2021–40 NPV real GDP components.

Source: authors’ own calculations.

Table 11: 2021–40 NPV GDP impacts of future climate change scenarios of yields from mixed rainfed and irrigated paddy farming practice across Myanmar states and regions (billion USD in 2017 prices)

		2020s mixed farming practice CC scenario 4		2050s mixed farming practice CC scenario 5		2080s mixed farming practice CC scenario 6	
NPV GDP impacts[1]	Base	∆value	% of GDP	∆value	% change	∆value	% change
Myanmar (cum.)[2]	1,254	2.79	100.0%	5.60	100.0%	2.61	100.0%
Myanmar excl. Ayeyarwady (cum.)[2]		1.58	56.7%	3.29	58.7%	3.23	123.7%
- Kachin State		0.14	5.1%	0.23	4.1%	0.28	10.6%
- Kayah State		0.03	1.0%	-0.01	-0.1%	0.01	0.3%
- Kayin State		0.16	5.8%	0.31	5.6%	0.19	7.4%
- Chin State		0.01	0.4%	0.03	0.6%	0.05	2.0%
- Sagaing Region		0.41	14.7%	1.09	19.5%	0.92	35.4%
- Taninthayi Region		0.07	2.4%	0.13	2.4%	0.09	3.6%
- Bago Region		0.00	0.0%	0.00	0.0%	0.00	0.0%
- Magway Region		0.00	0.0%	0.00	0.0%	0.00	0.0%
- Mandalay Region		0.00	0.0%	0.00	0.0%	0.00	0.0%
- Mon State		0.00	0.0%	0.00	0.0%	0.00	0.0%
- Rakhine State		0.00	0.0%	0.00	0.0%	0.00	0.0%
- Yangon Region		0.00	0.0%	0.00	0.0%	0.00	0.0%
- Shan State		0.77	27.8%	1.43	25.5%	1.80	69.2%
- Ayeyarwady Region		1.21	43.3%	2.32	41.3%	-0.62	-23.7%
- Nay Pyi Taw		-0.01	-0.5%	0.06	1.2%	-0.12	-4.7%

Note: [1] 10% discount rate applied to derive cumulative 2021–40 real GDP impacts for provinces and states; [2] note that sum of state and province impacts differ from total Myanmar impact in other tables due to non-linearities.

Source: authors' own calculations.

Table 12: 2021–40 distributional impacts of future climate change scenarios of yields from mixed rainfed and irrigated paddy farming practice across Myanmar household types (billion USD in 2017 prices)

		2020s mixed farming practice CC scenario 4		2050s mixed farming practice CC scenario 5		2080s mixed farming practice CC scenario 6	
NPV household income[1]	Base	∆Income	% change	∆Income	% change	∆Income	% change
All households	1,128.0	2.84	0.25%	5.65	0.50%	2.67	0.24%
Rural households	695.9	1.57	0.23%	3.13	0.45%	1.48	0.21%
Rural farm households	406.3	0.83	0.20%	1.65	0.41%	0.78	0.19%
- Rural farm 1q	27.7	0.06	0.23%	0.13	0.45%	0.06	0.21%
- Rural farm 2q	56.6	0.13	0.22%	0.25	0.44%	0.12	0.21%
- Rural farm 3q	78.7	0.16	0.21%	0.33	0.42%	0.15	0.20%
- Rural farm 4q	107.4	0.23	0.21%	0.45	0.42%	0.21	0.20%
- Rural farm 5q	136.0	0.25	0.18%	0.49	0.36%	0.23	0.17%
Rural non-farm households	289.6	0.75	0.26%	1.49	0.51%	0.70	0.24%
- Rural non-farm 1q	41.5	0.12	0.29%	0.24	0.57%	0.11	0.27%
- Rural non-farm 2q	54.1	0.14	0.26%	0.28	0.51%	0.13	0.24%
- Rural non-farm 3q	54.9	0.14	0.26%	0.29	0.52%	0.14	0.25%
- Rural non-farm 4q	63.4	0.16	0.25%	0.31	0.49%	0.15	0.23%
- Rural non-farm 5q	75.6	0.19	0.25%	0.37	0.49%	0.18	0.23%
Urban households	432.1	1.27	0.29%	2.52	0.58%	1.19	0.28%
Urban narm households	36.1	0.07	0.20%	0.14	0.39%	0.07	0.19%
- Urban narm 1q	1.4	0.00	0.21%	0.01	0.43%	0.00	0.20%
- Urban narm 2q	2.2	0.00	0.22%	0.01	0.44%	0.00	0.21%
- Urban narm 3q	3.8	0.01	0.21%	0.02	0.43%	0.01	0.20%
- Urban narm 4q	7.4	0.02	0.20%	0.03	0.41%	0.01	0.19%
- Urban narm 5q	21.3	0.04	0.19%	0.08	0.37%	0.04	0.18%
Urban non-farm households	396.0	1.20	0.30%	2.38	0.60%	1.13	0.28%
- Urban non-farm 1q	12.6	0.04	0.33%	0.08	0.66%	0.04	0.31%
- Urban non-farm 2q	26.8	0.08	0.29%	0.16	0.58%	0.07	0.28%
- Urban non-farm 3q	44.8	0.13	0.30%	0.27	0.59%	0.13	0.28%
- Urban non-farm 4q	67.8	0.21	0.31%	0.41	0.61%	0.19	0.29%
- Urban non-farm 5q	244.0	0.73	0.30%	1.46	0.60%	0.69	0.28%

Note: [1] 10% discount rate applied to derive cumulative 2021–40 real household impacts.

Source: authors' own calculations.

Table 13: 2021–40 macroeconomic impacts of future climate change scenarios of yields from mixed rainfed and irrigated paddy farming practice in Myanmar—comparison of high and low yield input technology use (billion USD in 2017 prices)

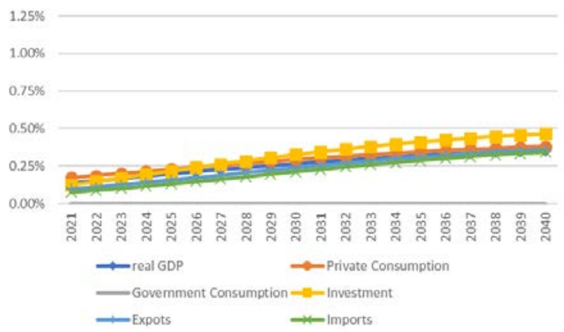
		2080s Mixed Rainfed and Irrigated Paddy cropping CC scenario 6 (high input technology)		2080s Mixed Rainfed and Irrigated Paddy cropping scenario 7 (low Input technology)	
NPV impacts[1]	Base	∆value	%-change	∆value	%-change
Real GDP (cum.)	1,254	2.6	0.21%	-1.2	-0.09%
- Priv. Consumption	721	1.7	0.23%	-0.7	-0.10%
- Govt. Consumption	203	0.0	0.00%	0.0	0.00%
- Investment	380	0.9	0.24%	-0.4	-0.11%
- Exports	366	0.7	0.19%	-0.3	-0.09%
- Imports	416	0.7	0.17%	-0.3	-0.08%
Dynamic impacts – no discounting	Base	short term (2022) (%)	long term (2040) (%)	short term (2022) (%)	long term (2040) (%)
Real GDP (cum.)[1]	1,254	0.12%	0.31%	-0.05%	-0.13%
- Priv Consumption	721	0.15%	0.33%	-0.06%	-0.14%
- Govt Consumption	203	0.00%	0.00%	0.00%	0.00%
- Investment	380	0.11%	0.41%	-0.05%	-0.17%
- Exports	366	0.08%	0.32%	-0.04%	-0.13%
- Imports	416	0.07%	0.30%	-0.03%	-0.13%
CC yield change	Base	∆value	%-change	∆value	%-change
Paddy	-	1.47%	1.47%	-0.64%	-0.64%

Note: [1] 10% discount rate applied to derive cumulative 2021–40 NPV real GDP components

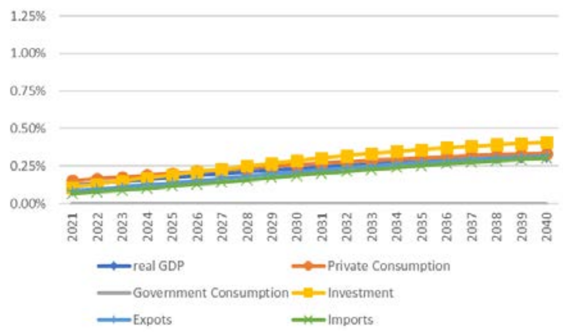
Source: authors' own calculations.

Figure 1: Dynamic real GDP impacts of future climate change scenarios of yields from rainfed as well as mixed rainfed and irrigated paddy fields in Myanmar (billion USD in 2017 prices)

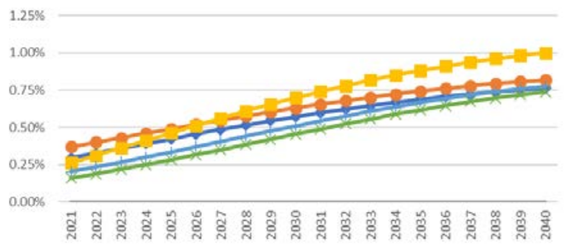
Scenario 1: 2020s climate change scenario of yields from rainfed paddy farming practice



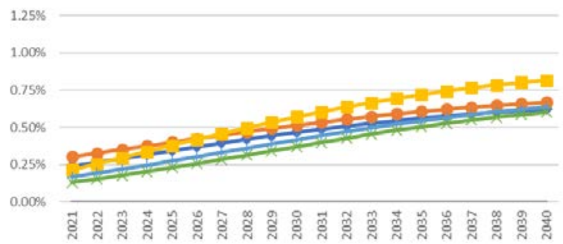
Scenario 4: 2020s climate change scenario of yields from mixed rainfed and irrigated paddy farming practice



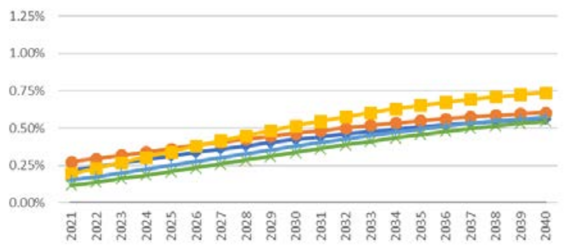
Scenario 2: 2050s climate change scenario of yields from rainfed paddy farming practice



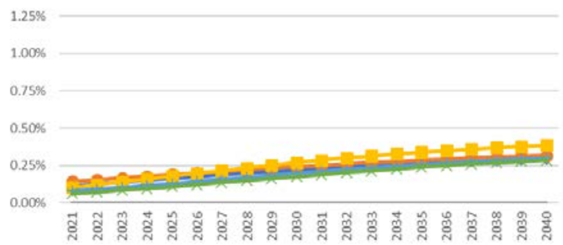
Scenario 5: 2050s climate change scenario of yields from mixed rainfed and irrigated paddy farming practice



Scenario 3: 2080s climate change scenario of yields from rainfed paddy farming practice



Scenario 6: 2080s climate change scenario of yields from mixed rainfed and irrigated paddy farming practice



Source:authors' own calculations.

5 Conclusions

In this paper, we employed a dynamically recursive macroeconomic model to analyse seven current and future CC scenarios for Myanmar state- and region-specific paddy yield changes during the 2020s, 2050s, and 2080s. The scenarios were derived from those produced using the IIASA and FAO's Global Agro-Ecological Zones GAEZ V.3 model and scraped from the World Bank's CCKP homepage. This allowed us to analyse the relative importance of both rainfed and irrigation farming practices and of high input-use and low input-use technologies, and how these important farming decisions interact with CC-induced paddy yield changes.

One key finding is that, if Myanmarese policy makers continue to limit access to irrigation farming practices at the same (low) level as is currently available to Myanmarese smallholder paddy farmers and if large numbers of Myanmarese smallholders continue to use LIU farming technologies, then our results suggest that the very long-term Myanmar-wide average paddy yield impacts will be small, and possibly negative. This would imply that NPV GDP and household income distributional impacts may also be adverse. On the other hand, if Myanmarese policy makers took a decision to actively promote and expand access to HIU farming technologies, e.g. via expanded use of extension services and by providing better access to credit for smallholder farmers, then virtually all smallholders from all states and regions would benefit from CC-induced paddy yield changes.

On the other hand, our results also suggest that increasing access to irrigation farming practices actually reduces the benefit gained from CC-induced paddy yield changes. This result is somewhat of a conundrum. While it is difficult to second-guess why these perverse interaction effects arise, one guess could be that the choice between rainfed and irrigation farming practices may not be a real choice in most situations. Most often, smallholders will live under ecological circumstances which clearly merit using either rainfed or irrigation farming practices, but without the other alternative being available or even being attractive (perhaps because of the cost of maintaining an irrigation system). Hence, there may not be a real choice for most smallholders, and this may also be reflected in the underlying GAEZ V.3 yield impacts where use of irrigation practices may simply be correlated with lower baseline paddy yields and thereby with a lower ability to adapt to the ongoing CCs.

Our results also clearly demonstrate how results differ between states and regions, sometimes very strongly so. One comparison can be made between the Ayeyarwady and Shan state impacts, where the very long-term 2080s NPV GDP gains for Ayeyarwady are much smaller, and sometimes even negative, whereas the NPV GDP gains for Shan state increase over time in virtually all situations (except for the LIU farming technology scenario). These nuanced results, combined with the perhaps surprising general result that most CC scenarios seems to bring net benefits rather than net costs, suggest that it could be wise for World Bank researchers to carefully consider the advice they give about local state- and region-specific impacts in a given Southeast Asian country, based solely on aggregate Southeast Asian evidence.

A number of caveats are also in order. First, we apply a dynamically recursive model with a limited 20-year time horizon to analyse CC scenarios with timespans of up to 70 years. Although it would have been ideal to have a model with a time horizon of 70 years, we still believe that our approach is sound. First of all, we essentially use our dynamic model as a static model framework—we simulate for a fixed time period, regardless of the time horizon of the underlying CC scenario shocks, and we focus on relative impacts. Furthermore, our 'dynamic model' framework gives us the benefit of being able to trace dynamic impacts over a fixed period beyond one year, implying that we are able to study growth impacts within our 'static model'-style approach.

Another important caveat is that we had to interpolate between underlying rainfed and irrigated farming practice scenario outcomes in order to derive our mixed farming practice scenario shocks. There is obviously nothing to suggest that there could not be non-linearities involved in a larger part of the population switching to use HIU technologies while the rest continue to use LIU technologies. On the other hand, we also have difficulty finding reasons why non-linearities would be very large. With that in mind, we still believe that our analyses are defensible.

A final caveat relates to our use of scraped GAEZ V.3 data from the World Bank CCKP homepage. While the breakdown of the FAO homepage, which used to house the interface to access the larger GAEZ V.3 database, did set us back somewhat, we believe that the current scenarios have afforded us a great opportunity to focus on the single most important crop in Myanmar, and we believe that the scenarios we were able to scrape did, in the end, give us an opportunity to tell a coherent story about how CC may affect paddy farmers and the broader Myanmar economy over the coming decades.

In conclusion, our results clearly demonstrate that CC will result in adverse outcomes for many, but it may also provide opportunities for other (smallholders) to reap benefits in terms of increased paddy farming yields. Nonetheless, our results also demonstrate that future mitigation efforts should focus on the critically important Ayeyarwady delta region, with a particular focus on mitigating negative interaction effects between irrigation paddy farming practices, on the one hand, and climatic changes and increased occurrences of extreme weather events, including saline floodings of the fertile delta, coastal erosion, and inundation, etc., on the other.

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Appendix: State- and region-specific locations used to derive GAEZ V.3 climate change-related paddy yield changes for Myanmar 2020s, 2050s, and 2080s

This appendix presents the list of state- and region-specific geographical locations in Myanmar, which was used as the basis for scraping of GAEZ V.3 climate change-related Myanmar paddy yield change scenarios for 2020s, 2050s, and 2080s, on the World Bank's online Climate Change Knowledge Portal (World Bank 2021a). This list of locations is presented in Table A1 below. The scraped data are available from the authors upon request.

Table A1: State- and region-specific locations used to derive average future climate change-related paddy yield changes

State/Region									
Kachin	Hopin Kachin	Hpakant	Hsawlaw	Kawnglanghpu	Lung Sha Yang	Myitkyina	Shwegu	Sumprabum	Tanai
Kayah	Loikaw								
Kayin	Hpa-An	Payathonzu							
Chin	Hakha	Matupi							
Sagaing	Hkamti	Homalin	Kalewa	Kani	Katha	Kyunhla	Lahe	Mawlaik	Monywa
	Nanyun	Paungbyin	Pinlebu	Wuntho	Ye-U				
Tanintharyi	Bokpyin	Dawei	Myeik	Palauk	Palaw				
Bago	Bago	Gyobingauk	Hswar	Pyay	Pyu	Taungoo			
Magway	Gangaw	Kyaw	Taungdwingyi	Thayet	Kyaukhtu	Saw			
Mandalay	Kyaukpadaung	Mandalay	Mogok	Myingyan	Nyaung-U	Yamethin			
Mon	Kyaikkhami	Mawlamyine	Ye						
Rakhine	Gwa	Kyaukpyu	Kyauktaw	Kyeintali	Maungdaw	Rathedaung	Sittwe	Taungup	
Yangon	Yangon								
Shan	Ho-mong	Hsihseng	Intaw	Kengtung	Kunhing	Kutkai	Lashio	Mabein	Manton
	Matman	Mong Kung	Mong Pan	Monghpyak	Nansang	Nyaung Shwe	Tangyan		
Ayeyarwady	Hinthada	Kyonpyaw	Labutta	Pyapon	Wakema				
Naypyidaw	NayPyidaw								

Source: World Bank's Climate Change Knowledge Portal. Country Myanmar (Burma) (World Bank 2021a).