Research Note

On Growth Projections in the Shared Socioeconomic Pathways

*Halvard Buhaug and Jonas Vestby**

Abstract

The recently developed Shared Socioeconomic Pathways (SSPs) have enabled researchers to explore coupled human–nature dynamics in new and more complex ways. Despite their wide applicability and unquestionable advantage over earlier scenarios, the utility of the SSPs for conducting societal impact assessments is impaired by shortcomings in the underlying economic growth projections. In particular, the assumed economic convergence and absence of major growth disruptions break with historical growth trajectories in the developing world. The consequence is that the SSP portfolio becomes too narrow, with an overly optimistic lower band of growth projections. This is not a trivial concern, since resulting impact assessments are likely to underestimate the full human and material costs of climate change, especially for the poorest and most vulnerable societies. In response, we propose that future quantifications of the SSPs should incorporate the likelihood of growth disruptions, informed by scenarios of the relevant political contexts that historically have been important in curbing growth.

How will climate change shape societies in coming decades, and what steps could be taken to avoid the gravest consequences? The recently developed Shared Socioeconomic Pathways (SSP) framework, which plays an integral role in the ongoing Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment cycle, constitutes the most comprehensive attempt to date to model societal development consistent with different climate change scenarios (O'Neill et al. 2014; Riahi et al. 2017). The SSPs span a range of alternative futures, determined by assumptions about challenges to climate change mitigation and adaptation. Four pathways (SSP1, SSP3–SSP5) capture the four possible combinations of low versus high barriers to adaptation and mitigation, whereas the fifth (SSP2) represents a middle-of-the-road pathway. Central drivers of these

* We thank Elisabeth Gilmore, Håvard Hegre, Nina von Uexkull, and colleagues at PRIO for comments on earlier drafts. This research has received financial support from the European Research Council through grant 648291 and from the Research Council of Norway through grant 268135/E10.

Global Environmental Politics 19:4, November 2019, https://doi.org/10.1162/glep_a_00525

challenges include changes in demographic, economic, technological, social, political, and environmental factors.

The SSPs serve two key functions: to provide "a basis for integrated scenarios of emissions and land use" and to facilitate "climate impact, adaptation and vulnerability analyses" (O'Neill et al. 2017, 169). There is some tension between these functions, since the former is determined mostly by the development trajectories of large economies and major greenhouse gas (GHG) emitters, whereas the latter is much more sensitive to future development in low-income countries and the world's poor. In other words, there is little overlap between the countries that contribute the most to anthropogenic climate change and those that are the most vulnerable to its impacts (Althor et al. 2016). Presently, the SSP framework appears better suited to fulfilling the first task than the second.

In this research note, we show that existing quantifications of the SSPs, despite their wide applicability and unquestionable advantage over earlier scenario exercises, have clear limitations for researchers seeking to conduct societal adaptation and impact assessments because of shortcomings in the economic growth models underlying the SSPs. In particular, the assumption of growth convergence, whereby poorer countries gradually catch up with wealthy economies as long as educational attainment improves, and the related assumption of a future without major growth disruptions break with historical development trajectories. The result is an overly narrow and optimistic range of projected development outcomes. In response, we encourage revising or expanding the SSPs to incorporate growth projections that are sensitive to the underlying political and security contexts. Assumptions about such conditions are already embedded in the narratives that accompany the quantified SSPs (O'Neill et al. 2014, 2017), but presently, they exist in isolation from the growth projections. By bringing the political context explicitly into the quantitative scenarios, the SSP modeling community would help the IPCC get one step closer to achieving its objective: "to provide governments at all levels with scientific information that they can use to develop climate policies."

Socioeconomic Development in the SSPs

The IPCC *Fifth Assessment Report* defines a scenario as a "plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces … and relationships" (Field et al. 2014, 1772). Scenarios can be an invaluable tool for evaluating complex problems where uncertainty is high (Pulver and VanDeveer 2009; Schoemaker 1991). Around a decade ago, a group of modelers and researchers started developing a new set of scenarios of future GHG concentrations, the so-called Representative Concentration Pathways (RCPs) (Moss et al. 2010). To complement these scenarios and facilitate mitigation and impact assessments consistent with the RCPs, a second group of scholars developed five stylized Shared Socioeconomic Pathways of future development (SSP1–SSP5), distinguished by different assumptions about challenges to climate change adaptation and mitigation (O'Neill et al. 2014; Riahi et al. 2017).

The quantification of the SSPs consists of end-of-century population and urbanization projections, including changes in fertility and education (Jiang and O'Neill 2017; KC and Lutz 2017), as well as three alternative projections of growth in gross domestic product (GDP), developed by modeling teams at the Organisation for Economic Co-operation and Development (OECD) (Dellink et al. 2017), the International Institute for Applied Systems Analysis (IIASA) (Cuaresma 2017), and the Potsdam Institute for Climate Impact Research (PIK) (Leimbach et al. 2017), respectively. Governance and security developments are not part of the quantitative scenarios. Instead, aggregate descriptions of the regional and global political contexts are embedded in the qualitative storylines that accompany the SSPs (O'Neill et al. 2017).

All three SSP teams modeling future economic growth adopted the augmented Solow growth model, which is widely used for estimating economic development due to its simplicity, connection with microeconomic theory, and good empirical fit to a large share of the global economy (Mankiw et al. 1992).[1] A central feature of the Solow model is the convergence mechanism: that development is associated with diminishing marginal returns on investments, such that it is cheaper and more viable for less advanced societies to absorb inventions from the technology frontier than for advanced societies to develop new technology. The augmented model assumes that the rate of convergence is conditional on human capital. If the convergence mechanism is a major driving factor of growth, we should observe a steady narrowing of the income gap between developed and developing countries as time progresses, assuming that the populations in developing countries become increasingly educated.

In the real world, economic convergence has been much less pronounced, despite significant educational improvements in poor countries (Acemoglu 2009; Rodrik 2014). This is visualized in Figure 1A, which shows average economic growth since 1970 as a function of GDP per capita in 1970. The figure provides little indication of convergence in the contemporary era; poor countries have been growing as fast as—but not much faster than—rich countries on average (the solid line is nearly horizontal), but there is much greater variation in growth rates among lower-income countries. Figure 1B compares historical development with projected future growth, derived from the SSP3

1. The PIK model deviates from the other two in that it provides projections for thirty-two regions rather than for individual countries (Leimbach et al. 2017). The OECD Env-Growth model includes an additive element that models natural resource extraction (Dellink et al. 2017). The IIASA model goes one step further in modeling conditional convergence, allowing an interaction between (initial) income per capita and education levels in society (Cuaresma 2017). This modeling choice reflects the idea that convergence is more contingent on having societies that have the ability to create and adopt new technologies than what is assumed in the augmented Solow model.

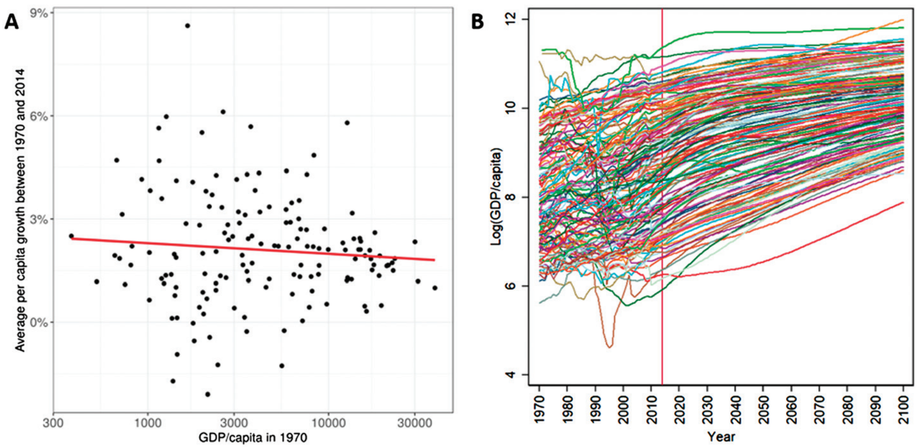

Figure 1
Historical and Projected Future Levels of Economic Development. (A) Average economic growth, 1970–2014, as a function of initial level of development in 1970. Each plot represents an independent country; the solid line represents global linear trend. (B) Historical and projected future levels of GDP per capita. Each line represents an independent country. The historical GDP estimates are derived from Penn World Table v.9.0 (Feenstra et al. 2015), whereas projections are derived from the OECD model for SSP3 (Dellink et al. 2017). The vertical line at year 2014 denotes the transition from empirical data to projected estimates. To aid visualization, a limited number of extreme outliers (petro-states in the Persian Gulf region) are excluded.

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"regional rivalry" scenario, in which the future is characterized by (inter alia) sustained high population growth, slow technological development, little improvement in education attainment, and slow transition into renewable energy consumption, jointly implying high challenges to climate change adaptation and mitigation. Although SSP3 (along with SSP4) represents the most pessimistic scenario in the SSP framework, Figure 1B reveals that projected future growth rates for the least developed countries vastly exceed observed growth in the recent past. For countries with GDP per capita below US$ 1,000 in 2013,[2] projected average economic growth until year 2100 is 3.2 percent per year. By comparison, the average yearly growth rate between 1970 and 2013 for these twelve countries was 0.1 percent.

Despite weak indication of convergence in the past, all but one of the fifteen growth projections in the SSP framework feature strong convergence between the poorest and richest economies. This is visualized in Figure 2, which

2. These are Burundi, Central African Republic, the Democratic Republic of the Congo, Eritrea, Liberia, Madagascar, Malawi, Mali, Mozambique, Niger, Togo, and Zimbabwe.

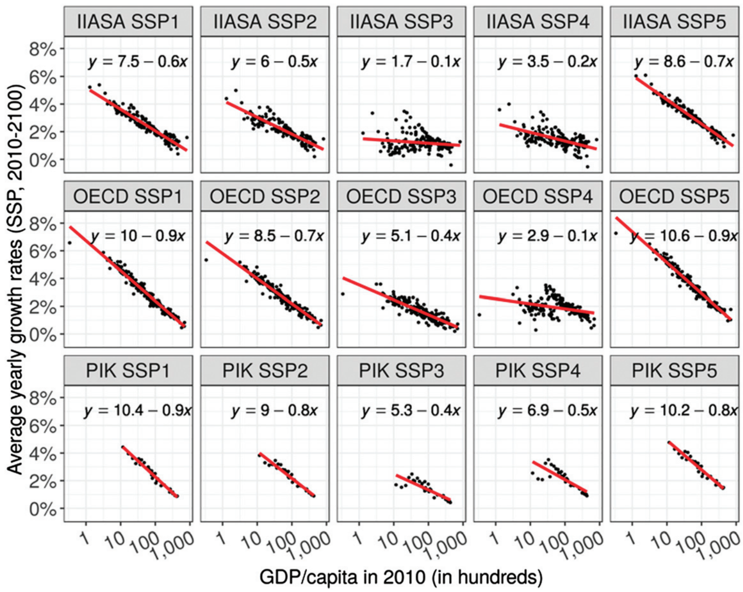

Figure 2
Economic Convergence Rate by Model and Growth Scenario in the SSP Framework. The plots show projected economic growth by country (IIASA, OECD models) and region (PIK model), 2010–2100, as a function of GDP per capita in 2010. Rows represent alternative growth models; columns represent alternative SSPs. Solid lines denote the global linear relationship between current level of development and future growth rate.

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plots projected average growth until the end of the century as a function of contemporary level of development. Compared to the historical baseline, these models produce very optimistic futures. For example, the OECD model's quantification of SSP3 (as shown in Figure 1) suggests that nearly all developing countries will follow growth pathways akin to or better than Sweden's past development, with the Democratic Republic of the Congo, Zimbabwe, and Guinea obtaining the highest growth rates of all countries in the twenty-first century.

The only GDP growth projection in the SSP framework that departs from global economic convergence is the IIASA model's quantification of SSP3 (Cuaresma 2017). This is the pathway that comes closest to historical trends and could as such better be considered "business as usual" than the most pessimistic scenario. The nonconvergence between poor and rich countries in this model is obtained by imposing a freeze in educational enrollment rates (a predictor of GDP growth) at 2010 levels. For all other models, we observe a powerful negative correlation between present development and future growth across all socioeconomic scenarios.

Barriers to Sustained Economic Growth

It is clear that the current quantifications of the SSPs fail to account for important barriers to sustained economic growth that historically have been influential in preventing convergence (Acemoglu 2009). In Figure 3, we plot projected future growth against the share of years with negative growth since 1970. With the same exception for IIASA SSP3, we find that countries that have experienced frequent growth disruptions in the recent past are expected to enjoy especially high rates of growth over the next eighty-five years. This is not an entirely inconceivable prospect. After all, continued investments in human capital—the key driver of economic convergence in the SSPs—may be an important element in reducing adverse volatility (Koren and Tenreyro 2007; Lucas 1988) and help the least developed countries succeed in escaping the poverty trap. But is a rapid and lasting global decline in economic growth disruptions sufficiently likely that it warrants coverage by fourteen of the fifteen quantified growth pathways?

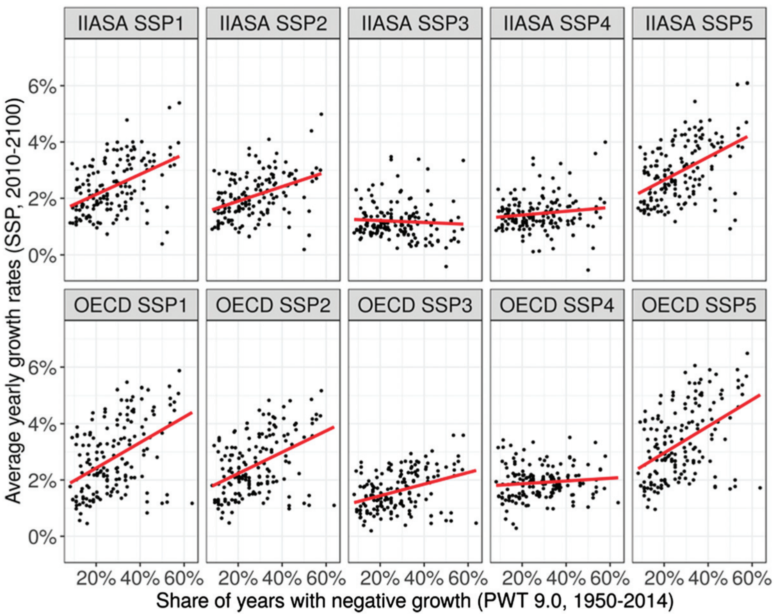

Figure 3
Projected Economic Growth by Rate of Historical Growth Disruptions. The plots show projected economic growth by country, 2010–2100, as a function of share of years with negative growth, 1950–2014. Rows represent alternative growth models; columns represent alternative SSPs. Solid lines denote the global linear relationship between past growth disruptions and future growth rate.

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We think not. For one thing, low school enrollment rates and poor quality of education, even if remedied in accordance with the targets of the Sustainable Development Goals (United Nations 2018), will certainly not be the only driver of economic instability in poor countries (e.g., Collier 2007). Besides, human capital is unlikely to prosper in the absence of improvements in other societal structures that also directly affect economic performance. The absence of SSP projections consistent with persistent growth disruptions and an increasing income gap between high- and low-income countries limits the scientific merit—and political relevance—of loss and damage assessments that aspire to cover the full range of plausible climate change and socioeconomic development futures.

Most barriers to economic growth take the form of intermittent growth disruptions in individual countries rather than endemic and exogenously given factors that limit overall development potential (though see Lucas 1990). Common causes of growth disruptions include commodity price shocks (Deaton 1999), distortionary fiscal policies (Easterly 1993), political instability (Alesina et al. 1996), and armed conflict (Gates et al. 2012). Such events are much more prevalent in poor countries (Blattman and Miguel 2010) and represent a central explanation for why developing countries experience years with negative growth at significantly higher rates than do developed countries (North et al. 2009).

Some of these disruptions are difficult to forecast and are as such impossible to account for in the SSPs. However, it is possible to identify country-specific structural conditions that historically correlate with growth and that may be possible to model into the future in a scenario framework. In Figure 4, we illustrate three structural features and their link to economic performance. Consistent with recent research (e.g., Deaton 1999; Ross 2015), Figure 4A reveals a strong positive association between natural resource dependence and economic instability, where major exporters of raw commodities, notably petroleum, have much higher average rates of negative growth. Heavy reliance on extractive industries and primary commodity exports are associated with a number of perverse socioeconomic effects, including limited economic diversification that leaves the economy vulnerable to trade fluctuations and commodity price shocks (Koren and Tenreyro 2007); weak state capacity due to underdeveloped tax institutions (Fearon 2005); and high risk of corruption, extortion, coups, and insurgencies due to highly valuable, immobile assets that can be captured and controlled through the threat or use of armed force (Acemoglu and Robinson 2001; Boix 2008; Hirschman 1978).

Figure 4B presents violin plots of the distribution of economic growth for four types of political systems. Three patterns are immediately noticeable. First, average annual growth is higher in more democratic countries, although the difference between regime types is modest. Second, the share of country-year observations that experience negative growth is inversely related to level of democracy, and this pattern is especially apparent for large negative growth values. However, closed autocracies also experience very high positive growth more

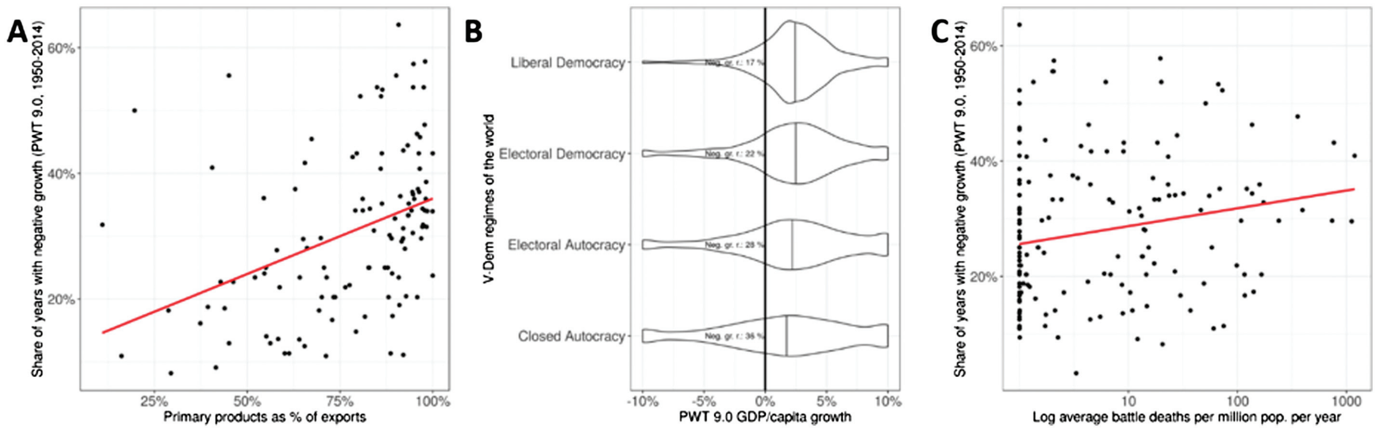

Figure 4

Economic Performance and Societal Contexts Since 1950. (A) Share of years with negative growth as a function of natural resource dependence. (B) Distribution of observations across rates of annual growth in GDP per capita for liberal democracies, electoral democracies, electoral autocracies, and closed autocracies. The vertical line in each density plot represents the average yearly growth rate for the given regime type. Extreme outliers are removed to aid visual interpretation. (C) Share of years with negative growth as a function of population-weighted conflict severity in the period. Data on primary commodity exports are taken from Bazzi and Blattman (2014); conflict severity statistics are based on the UCDP Battle-Related Deaths Dataset v.5.0 (Allansson et al. 2017) and the PRIO Battle Deaths Dataset v.3.1 (Lacina and Gleditsch 2005); per capita economic growth is calculated from Penn World Table 9.0 using real GDP from national-accounts data (Feenstra et al. 2015).

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often than other regimes, implying a larger spread (and ditto uncertainty) in overall growth rates. Liberal democracies, in contrast, are quite predictable; the large mass of observations falls in the range between 0 percent and 8 percent yearly growth. These insights are well known: democracies enact economic reforms conducive to growth; invest more in public goods, such as health and schooling; and reduce the incentives and viability of disruptive behavior, such as coup, conflict, and corruption (Acemoglu et al. 2019; Knutsen 2013; Rafaty 2018).

Figure 4C plots share of years with negative growth against countries' severity of armed conflict. Unsurprisingly, the data reveal a powerful positive relationship. War causes human and material losses; triggers population displacement and capital flight; deters long-term investment; and erodes the social fabric necessary for trade, state building, and inclusive human development. Poor economic performance, in turn, is among the strongest predictors of civil war (Hegre and Sambanis 2006), materialized through a multitude of causal channels (cf. Cederman et al. 2011; Collier and Hoeffler 2004; Fearon and Laitin 2003; Gartzke 2007). The result may be a *conflict trap*: a vicious cycle of poverty and conflict (Collier et al. 2003; Hegre et al. 2017) that cripples affected communities' ability to cope with, and adapt to, threats imposed by climate change. Put simply, armed conflict is development in reverse (Costalli et al. 2017; Gates et al. 2012).

Integrating the Political Context in the Quantified SSPs

Despite the historical prevalence of growth disruptions and a good scientific understanding of important structural drivers, the economic growth models in the SSP portfolio abstain from incorporating negative shocks. For most countries, most of the time, this is not a problem, and the augmented Solow model has been shown to perform well in predicting welfare growth for the countries that account for the vast majority of global GDP (Mankiw et al. 1992). For the same reason, the SSPs are well suited to evaluating implications of alternative societal development trajectories for global GHG emissions and climate change mitigation challenges. However, such models tend to return overly optimistic projections in the long term, especially for countries at greater risk of experiencing growth disruptions:

> Forecasts are rarely constructed as a weighted average of a scenario in which there is no civil war, and a scenario in which a civil war occurs; rather, they are usually made under the implicit assumption that there will be no overwhelmingly negative shock, even though such shocks have occurred in the past and could well occur again. (Ho and Mauro 2014, 24)

The modelers in the SSP community themselves point to this limitation, acknowledging that known barriers to growth, such as resource dependence, war, and lack of good governance structures—all of which are part of the SSP narratives (O'Neill et al. 2014, 2017)—are unaccounted for in the GDP projections (Dellink et al. 2017). The consequence is that the range of futures provided through the quantified SSP framework becomes too narrow (Christensen et al. 2018) and covers too small of an area of the conceivable probability space due to an overly optimistic lower band of growth projections. Of particular concern is the fact that the countries for which the GDP projections will fit the least well (i.e., developing countries with a history of recurring growth disruptions) are the very same countries where vulnerability to climate change is considered the highest and for whom sound adaptation and impact assessments may be most in demand (Barnett 2006; Busby et al. 2013).

Existing attempts to use the quantified SSP scenarios to develop projections for societal factors that historically are sensitive to economic growth, such as agriculture (Meijl et al. 2018), food security (Hasegawa et al. 2015), and armed conflict (Hegre et al. 2016), are thus at risk of overestimating future production and security improvements and underestimating the relative cost of choosing a development pathway akin to regional rivalry (SSP3) or inequality (SSP4) over sustainable development (SSP1). Although modelers need high-growth scenarios, and there are reasons to remain optimistic about long-term development in many of today's poor countries, sound and comprehensive impact assessments also require projections that are at least as pessimistic as the recent past.

Conclusions

Improving our ability to produce economic predictions that align well with observed data has merit in its own right, but it is particularly important if we seek to assess societal impacts of climate change, which depend critically on the estimated vulnerability of the affected social system. As we have documented in this research note, common economic growth projections—a core component of the SSP framework—produce overall too optimistic estimates of future development for the poorest and most vulnerable countries of the world, where even the worst-case scenario implies economic growth rates many times higher than experienced growth in recent decades. This concern may be of little significance to SSP-based GHG emissions and mitigation assessments (e.g., Rogelj et al. 2018), but inflated and uninterrupted growth projections for the least developed countries signal unrealistic reductions in vulnerability and may result in overly modest loss and damage estimates, thereby undermining material incentives for choosing a sustainable development pathway over less stringent emission policies.

Efforts are currently under way to assess the merit of modeling growth in the SSPs as an endogenous process between economic development and armed conflict (Gilmore et al. 2018). Elsewhere, users have combined the SSPs with stakeholder and expert assessments to provide context-specific, multiscale evaluation of climate impacts and policy options under climate change (Kebede et al. 2018; Palazzo et al. 2017). These efforts are undoubtedly useful and demonstrate significant flexibility in the scenario framework. However, to aid users unaware of the ahistorical growth projections and facilitate adaptation and impact assessments under less optimistic development futures, we encourage GDP modelers in the SSP community to incorporate assumptions about structural drivers of growth disruptions, such as trade and resource dependence, quality of governance, and social cohesion. By bringing the political context explicitly into the SSPs, the scientific community will be better positioned to provide decision makers with scientific information required to identify optimal climate policies.

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