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Introduction

- 1 Climate change is usually discussed in the future tense, and as a result our understanding of it is framed by the models we use to project climate futures. Models are not only used to study the physics of climate change, but also its relationship to the economy. Integrated Assessment Models (IAMs), which represent the interactions between environmental, technological and economic systems, have gained considerable influence in delimiting the possibility space (Beck & Mahony, 2018), largely due to their prominence in the most recent IPCC reports (Cointe, Cassen & Nadai, 2019; van Beek *et al.*, 2020). They have framed policy discussions, showing ambitious objectives to be still within reach (IPCC, 2018; Lövbrand, 2011), and establishing specific solutions, such as biomass energy with carbon capture and storage (BECCS), as all but unavoidable (Beck and Mahony, 2018; Carton *et al.*, 2020). In fact, there is an explicit ambition among modellers to chart out the future for decision-makers, or, to cite Edenhofer and Minx (2014), to act as “mapmakers” who help policymakers navigate the future.
- 2 Recent studies in the social sciences have thus pointed out how IAMs shape imaginaries, discourses and capacities for actions on climate change (Beck & Mahony, 2018; Beck & Oomen, 2021; Carton, 2020). From a similar perspective, we consider scenario building to be a kind of anticipatory knowledge. Anticipatory knowledge is

related to the organising activities in the present that produce the future. A project, to construct infrastructure, for example, involves anticipatory knowledge as project leaders try to envisage the future that they strive to make happen through their project (Graber, 2017). Scenario building involves a different form of anticipatory knowledge and a different relationship to the future, as it does not envisage one future, but explores several. It delimits a space of possible futures, or a “corridor” (Beck & Oomen, 2021) that will in turn shape the future, because it informs plans, decisions and actions.

- 3 IAM scenarios represent and anticipate the joint evolution of the climate and the economy. We start from the hypothesis that this is one means of (re-)inventing the way that economies relate to nature. It is thus crucial to question the economic assumptions underlying IAMs in order to understand how they may limit political and economic transformations. One of these assumptions in particular is as striking as it is apparently taken for granted: sustained economic growth throughout the twenty-first century. Virtually all the socio-economic scenarios tabled by IAMs envision a future with substantial economic growth, in spite of “a broad agreement that economic growth has in the past contributed to climate change” (Jakob *et al.*, 2020, p. 1). The scenarios that mitigate climate change thus fall in with the “green growth” narrative. While the development of no-growth or degrowth scenarios is beginning to emerge as a possibility (O’Neill *et al.*, 2020; 2021; Jakob *et al.*, 2020; Keyßer & Lenzen, 2021), overall, economic growth seems to remain unquestionable. Why is that? Is this limitation an inherent feature of IAMs, and if so, where is it rooted?
- 4 This paper aims to answer these questions, given that “no in-depth study examining the reasons for the omission of degrowth scenarios in mainstream IAM modelling exists” (Keyßer & Lenzen, 2021, p. 11). This requires several steps and a combination of methods in order to take into account both the socio-institutional organisation of scenarios research and the conceptual architectures of models. First, we provide some background on IAMs and on the organisation of the research community that produces them. This part draws on ethnographic research on the IAM community, combining interviews with modellers and IPCC authors, observation in conferences (especially meetings of the IAMC), and analysis of the relevant academic and grey literature (see Cointe, Cassen & Nadaï, 2019 for details). We then assess the absence of degrowth/no growth scenarios in the current literature, whether referenced in the IPCC Fifth Assessment Report (AR5) or not.¹ This involves reviewing the contents of the AR5 Scenarios Database.² Next, we look at two specific models (GCAM and WITCH), to understand what role the economic growth variable plays in these two models, how it is computed there, and on which data it is calibrated. This last part of our analysis draws on detailed consultation of the models’ documentation as well as informal conversations with modellers to check our understanding. Our main claim is that there are no degrowth/no growth scenarios because, in IAM research, economic growth is largely conceived of and computed as a “natural” driver, and not as an intervention point for policy.

1. The IAM community

- 5 The majority of long-term emission pathways are produced by Integrated Assessment Models. The IPCC AR5 lists 31 such models (some with variants), most of which have

been developed in Europe and the US, and which have produced scenarios included in the AR5 (Clarke *et al.*, 2014; Krey *et al.*, 2014, p. 1308-1311). The models on this list, and only these, will be considered to be IAMs. Since the IPCC assesses the peer-reviewed literature, the IPCC list can be considered as representative of what is currently considered as an IAM in the relevant research communities.³ The AR5 scenarios database was the result of an open call. Its developers defined four criteria that had to be met for submitted scenarios to be included in the database: scenarios had to be peer-reviewed, contain a minimum set of variables, represent a complete energy system, and provide data until at least 2030 (Krey *et al.*, 2014, p. 1311)

- 6 For the purpose of our investigation, we thus define IAMs more restrictively than researchers who consider any model coupling the economy and environmental impacts to be an IAM. As a result, the models in macro-ecological modelling (e.g. D’Alessandro *et al.*, 2020; Nieto *et al.*, 2020) are not on the list of the AR5, and are thus not considered here to be IAMs. They do not seem to have produced scenarios for the AR6 database either (Riahi *et al.*, 2022; Krey *et al.*, 2022) A key component that is missing from these models is the detailed representation of the energy system sector.
- 7 Recent sociological analyses of the history and organisation of the IAM community have shown that the definition of IAMs as a distinct category of models is relatively recent and related to the IPCC process (Cointe *et al.*, 2019; van Beek *et al.*, 2020; Cointe, 2022). IAMs are models that are used to produce long-term socio-economic and emission scenarios. To do so, they combine elements from environmental sciences, economics and engineering. They also share an ambition to be policy-relevant: the scenarios they produce are meant to help decision-making. Integrated assessment modellers have established links with different climate research communities (such as climatology, impact studies, sustainable transitions) and organised their own conferences, databases and research infrastructure (Cointe *et al.*, 2019; van Beek *et al.*, 2020). Thus, they do not share a common theoretical basis, and the models in this category combine environmental, economic and technological modules in various ways (Cointe *et al.*, 2019; Crassous, 2008; Lefevre, 2016). In particular, they do not all represent the economy in the same way (see Section 4 below). This heterogeneous set of models has recently formed the basis of a very active field of research. Our focus on this set of models is explained by their influence on climate expertise, which largely stems from their central position within the IPCC process. As a —perhaps anecdotal— sign of this influence, two leading figures in the IAM community (Keywan Riahi and Detlef van Vuuren) made it onto the “top-5” of Reuters’ 2021 “Hot List” of the world’s most influential scientists.⁴ At any rate, the prominent position of IAM researchers within Working Group III of the IPCC has been documented (Corbera *et al.*, 2015; Hughes & Paterson, 2017; van Beek *et al.*, 2020), and so has their ability to secure European research funding (Lövbrand, 2011). In AR5, the IAM-based chapter on “Assessing Transformation Pathways” accounted for 8% of the total report but 30% of the Summary for Policy Makers (IPCC, 2017, p. 31).
- 8 The influence of IAMs and IAM researchers largely stems from the centrality of the scenarios they produce. Since the SA90 scenarios in the 1990s, the IPCC has used sets of reference baseline emission scenarios, which were all developed using IAMs (van Beek *et al.*, 2020). These reference scenarios are, by design, widely used, as input data for physical climate models projecting the potential evolution of the climate system, but also for the study of impacts, or as baselines for evaluating policy options. Whereas in

the 1990s there was only a handful of reference scenarios produced by a few models (Tirpak & Vellinga, 1990; Leggett *et al.*, 1992, Nakićenović *et al.*, 2000, Cointe, 2022), over the last fifteen years the scenario infrastructure has grown very sophisticated with the development of the so-called “RCP-SSP” matrix.

- 9 In 2005, the IPCC launched a reflection on the next generation of reference scenarios, to be used for its Fifth Assessment Report (IPCC, 2005), which was published in 2014. This led to the parallel development of two sets of reference scenarios: on the one hand, “Representative Concentration Pathways” (RCP) corresponding to specific levels of radiative forcing, but not associated with particular socio-economic assumptions; and on the other hand, “Shared Socio-Economic Pathways” (SSP) describing plausible evolutions of social and economic drivers (including demographics and GDP) (Moss *et al.*, 2010). SSPs are a framework to harmonise socioeconomic assumptions across models rather than a set of comprehensive scenarios. The SSP framework combines five contrasted storylines and quantified projections for key variables, such as economic growth, income, fossil fuel availability or population (O’Neill *et al.*, 2014; Riahi *et al.*, 2017). IAM modelers can then use these assumptions to project the evolution of greenhouse gas emissions according to various visions of how the world might develop. While the previous generations of reference scenarios had been directly coordinated by the IPCC, the development of this new scenario architecture was delegated to “the research community” (IPCC, 2007, p. i). This spurred the organisation not only of a dedicated research community, but also, maybe more importantly, of a research infrastructure around scenarios: scenario databases, large projects with standardised protocols, and conferences with working groups dedicated to data management, for instance. IAMs, and the community that works with them, have become the keystone of this climate scenario architecture.
- 10 The Integrated Assessment Modelling Consortium (IAMC) was established in 2007 to structure the IAM community and coordinate the development of new scenarios. This organisation brings together scientific organisations active in this community and has since become its main institutional embodiment. It meets annually, and has played a major role in organising and representing IAM research, as well as in developing its connections to other climate research communities. It has also driven a degree of standardisation in IAM research practices, notably through the organisation of knowledge-sharing about model characteristics and through the discussion of model validation. In addition to the IAMC, which was initially focused on the RCP, an International Committee on New Integrated Climate change assessment Scenarios (ICONICS) was established to coordinate work on the SSPs. IAM research mostly takes place in large collective projects (mainly EU funded projects and Energy Modelling Forum sessions), and these have contributed to the exchange of knowledge among modelling teams and to the establishment of shared research infrastructures. Scenarios are now collected and made available in databases hosted and managed by IIASA, a majority of which are available to the public. The IAMC data template, which enables standardised reporting of modelling output and thus facilitates comparison across models, served as the basis for the AR5, SR1.5 and AR6 scenario databases.
- 11 While these developments have to an extent improved the transparency of IAMs and encouraged the use of their results by non-modellers, they have also led to a form of convergence in models and modelling assumptions, in that modelling groups increasingly work with shared protocols and data templates (see Cointe *et al.*, 2019).

Indeed, work in large model intercomparison projects directs the research agenda of different research groups towards the same research questions, which tend to be influenced not only by the IPCC schedule and agenda, but also by global climate negotiations and target-setting in a process of “policy calibration” (van Beek *et al.*, 2022). IAM teams, especially in Europe, tend to rely heavily on European project money and have succeeded in establishing themselves as providers of “useful research” that are able to assess European climate policy objectives (Lövbrand, 2011). Work within intercomparison projects has implied the development of common protocols and the use of shared baseline scenarios across models as part of common research protocols (see Cointe, 2019). The database infrastructure also involves the complex work of harmonising the types of output variables, the regional and sectoral details, and so on, so that modellers have a sufficiently large set of variables to report in the database (which concretely means filling in a spreadsheet). This was necessary because different IAMs have different variable structures, units, or region names, hence the necessity of harmonising output to ensure scenarios are comparable. The lists of variables, for example, have been developed iteratively over the course of several research projects, and in relation to each project’s objectives and research focus, though specific variables were added for IPCC-related databases.

- 12 This harmonisation and coordination limit the range and the forms of the economic futures considered, in the sense that scenarios that are developed using alternative methodologies, or within other research communities, are less likely to be included in the databases that serve as the basis for IPCC assessment, and so are less visible (Riahi *et al.*, 2021, p. 3-15; Saheb *et al.*, 2022). This is due to the entry cost of familiarisation with the data format, but also to the fact that the variable template is tailored to what IAMs can report as output data and to the variables considered in IAM research projects. The organisation of IAM research and its evolution towards a more integrated community are thus crucial to understanding the range of futures considered. Recent literature has warned again the risk of narrowing the future as a result of over-reliance on IAMs based on a relatively limited set of assumptions (Beck & Oomen, 2021; Braunreiter *et al.*, 2021).

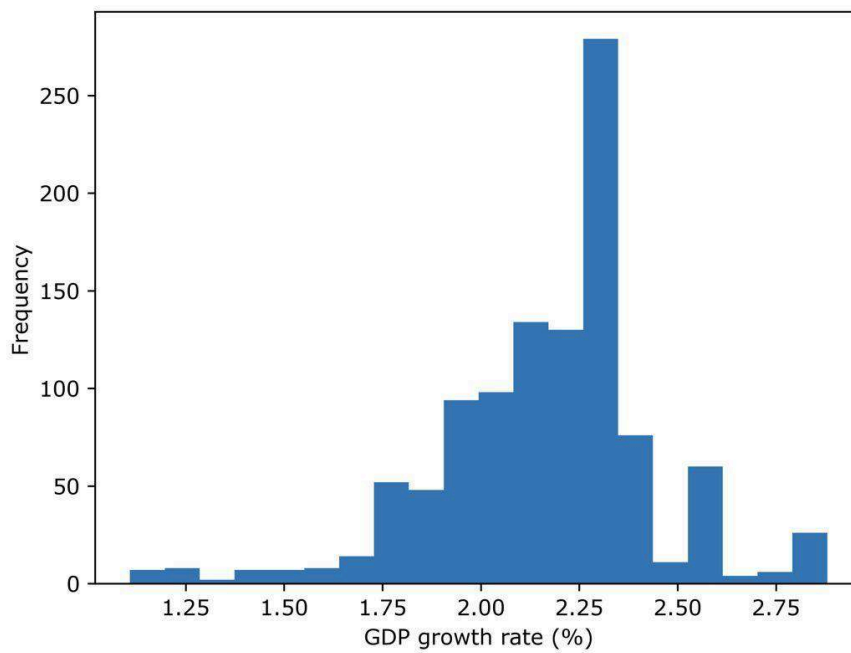
2. The absence of degrowth or no growth scenarios in Integrated Assessment Modelling

- 13 In this section, we make the case that the work done by the IAM community ignores degrowth. To back our claim, we reviewed the scenarios in the AR5 database, which covers all the IAM-produced scenarios used for the IPCC Fifth Assessment Report (all model runs assessed in IPCC reports have been made publicly available since 2014).⁵ We looked at the growth rates in these scenarios to see what image of future economic growth IAMs produced.
- 14 Just what degrowth is remains the object of serious academic disputes that are often laden with normative assumptions. For example, degrowth is defined by Jason Hickel (2020, p. 1106) as “a planned reduction of energy and resource throughput designed to bring the economy back into balance with the living world in a way that reduces inequality and improves human well-being”. According to this definition, analysing the presence of degrowth in IAMs would therefore imply considering the relationships between series of interrelated variables: throughput (flow of resources and energy),

- working hours, R&D investments, inequalities, output production and distribution, a wide array of factors impacting human well-being and so on. We rarely, if ever, have access to this level of details. Nor is it our purpose to take a stance on what degrowth is.
- 15 To find a criterion to investigate the presence or absence of degrowth in scenarios, we start from two premises that seem to be largely shared among degrowth scholars (see Kallis *et al.*, 2018): first, that a degrowth policy aims at reducing material throughput; second that absolute decoupling between GDP and throughput is impossible. Combining the two, we find that reducing GDP is a necessary consequence of a degrowth scenario. It could be objected that absolute decoupling could in fact be possible, so that a degrowth scenario would be possible with GDP growth. We take no stance on the possibility or not of absolute decoupling. We simply point out that such a possibility would undermine pleas for degrowth policies and would make degrowth scenarios barely distinguishable from so-called green growth ones. We therefore only claim that degrowth policies, with the world functioning as degrowth scholars envision it would do, should translate into GDP reductions, hence making a negative growth rate a good proxy for detecting whether assumptions of degrowth research are considered in IAMs.
 - 16 We therefore use GDP growth rate to determine whether the IAM community considers degrowth at all, much as Keyßer & Lenzen (2021) do. To eliminate the confounding possibility of a declining population, we look more precisely at the GDP per capita growth rate. Now a necessary condition is not a sufficient condition, and a decline in GDP should not be equated with a degrowth scenario. If we were to find a scenario with a negative growth rate, we should not rush into claiming we had found a degrowth scenario. However, the absence of reductions in GDP does signal the absence of degrowth scenarios. If we accept the premise that degrowth and green growth are incompatible, when growth is observed, it can only be green growth.
 - 17 Let us start globally. Out of the 1,184 scenarios available in the AR5 database, 1,071 scenarios (produced by 31 models) allow the computation of annual growth rates of average world GDP per capita over the period 2010–2050. The distribution of these growth rates is displayed in Fig. 1.⁶ They are all positive, ranging from 1.11% to 2.88% (the mean is 2.17% with a standard deviation of 0.28). It is clear that none of these scenarios envisions a world without economic growth, let alone a world with degrowth of the economy.
 - 18 It is also clear that the scenarios from the AR5 database picture a future of green growth, that is, a situation where growth and reduced emissions are compatible. In Fig. 2 we plot the annualized growth rate of GHG emissions against the annualized growth rate of GDP over the period 2010–2050. We see that scenarios that successfully mitigate GHG emissions are not associated with lower GDP growth.
 - 19 We can refine our understanding by looking at regional data. For the AR5, the world is partitioned into five economic regions: Asia, Africa and the Middle East, Latin America, OECD countries in 1990, and the Reforming Economies of Eastern Europe and the Former Soviet Union.⁷ Out of the 1,184 scenarios, 805 give sufficient information to compute the annual growth rate of GDP per capita for each region, which makes 4,025 regional growth rates in total. Again, almost all are positive, with a mean value of 3% (with a standard deviation 1.08, reflecting regional heterogeneity). Among the 4,025 values, the only four negative rates are from a single model in Africa and the Middle East, where GDP growth is being outpaced by an increase in population, thus pushing GDP per capita growth into negative territory. Excluding these four unusual

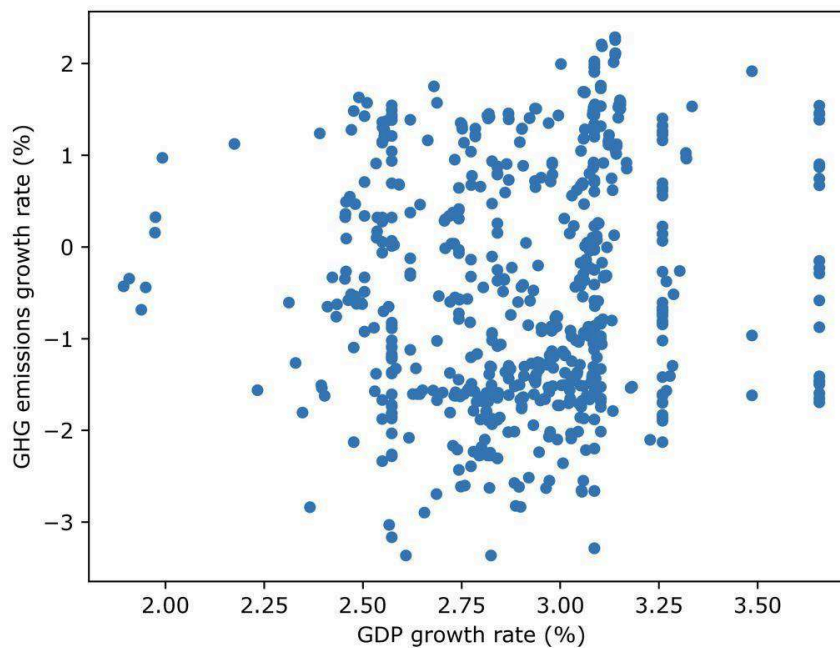
scenarios, the growth rates range from 0.74% to 5.67%. Specifically, growth rates for developed countries, or the “North” (OECD countries in 1990), range from 0.74% to 2.17%, with a mean of 1.51%. The AR5 scenarios do not exhibit the rebalancing of income that is advocated within the degrowth literature, with negative growth rates in more affluent countries to make ecological room for positive economic growth in the global “South”.

Figure 1. Distribution in the AR5 database of annualized growth rates of global GDP per capita, over the period 2010–2050.



Credits: figure and calculation by the authors.

Figure 2. Annualized growth rates of GHG emissions vs. annualized growth rates of GDP, in the AR5 database (global scale, over the period 2010-2050)



Credits: Figure and calculation by the authors.

- 20 The picture is clear: economic growth, at both a global and a regional level, plays a major role in the future depicted in the scenarios from IAMs. These scenarios do not challenge the presence of economic growth in the coming decades, and degrowth is not actually part of the possible futures as described by the AR5 database. On the contrary, scenarios with strong mitigation picture a green growth future. These scenarios are not predictions, but explorations of the future; that no degrowth futures are explored thus suggests a commitment to economic growth. This has fuelled discourses suggesting that economic growth is a blind spot of mitigation scenarios (Kuhnhenh, 2018).
- 21 We have considered other sources of evidence regarding the omission of degrowth or no-growth scenarios. As we have seen, the formatting and standardising work that modellers have to do to meet the IPCC criteria and include their model outputs in the AR5 database is relatively demanding. This induces a standardisation of the outputs and scenarios that are included in the database, which can inadvertently exclude less established work exploring new scenarios or methods.
- 22 To look for exploratory works in the IAM community that may include no growth or degrowth scenarios, we first scanned the website of the IAM-C.⁸ It collates various sorts of contributions, descriptions of models and scenarios, scientific papers and programmes of the annual meetings. Research with keywords such as “degrowth”, “de-growth”, “zero growth” and “negative growth” yielded no results, whereas “growth” appeared many times (we found combinations such as “zero emissions” or “negative emissions”, but nothing that applied to economic growth).⁹ It seems that degrowth is not a topic currently investigated by the IAM community.

- 23 In order to strengthen this result, we checked the literature using Scopus and Web of Science. We investigated articles with keywords (e.g. title, abstract and author keywords) such as “negative”/“zero” combined with “economic”/“GDP growth” to find modelling exercises using IAMs. We did not find any article using an IAM (i.e. a model that is present in the AR5 database) and exploring a zero-growth/degrowth future.
- 24 These searches only give access to work that has reached the communication or publication stage. They do not imply that no work is currently being developed in these directions. To get a sense of the current state of affairs in IAM research, we asked several colleagues who are themselves modellers and involved in the IAM community if they were aware of any work (articles or grey literature) related to the topic of degrowth within the IAM community. They confirmed that scenarios with zero- or negative growth are currently not investigated in the community. This does not mean that the subject of degrowth is ignored by members of the IAM community, as some have expressed their views on it (e.g. Jakob & Edenhofer, 2014; Jakob *et al.*, 2020). It simply suggests that IAMs are not currently used as a working tool to investigate degrowth options. In the next section, we will try to explain why.

3. Economic growth in Integrated Assessment Models

- 25 To understand these results, we need to delve into the practical work around these models: how modellers build their scenarios, and how they calibrate their models. We also need to understand the mechanics of these models: their input and their output, and which modelling choices, such as behavioural assumptions or functional relationships, impinge on the transformation of input to output. This will help us to trace the centrality of economic growth in this community.
- 26 It is useful to recall what economic growth is. It is derived from gross domestic product, a conventional measure of economic output. Measured at current prices, economic output is nominal GDP. Real GDP is a measure of the volume of economic output, that is the GDP at constant prices, which corrects for prices changes from year to year (due to inflation or quality changes), generally using a price index to deflate nominal GDP. From a statistical point of view, nominal GDP is first computed, and then deflated to obtain real GDP. Both of these operations are done by national accountants and involve some intricacies. Moreover, there is, of course, considerable debates on what GDP actually measures and whether other measures should be used to better capture aspects of economic activities. Economic growth is the variation of real GDP from one year to the next. It is a measurement of the expansion of GDP, and conventionally represents the variation in economic output. Sometimes economic growth is corrected for population changes, and is thus understood as the growth of (real) GDP per capita.
- 27 In economic modelling, and especially in IAMs, GDP is not computed from statistical sources. It is the name of a variable that quantifies the economic output within the model, a model that drastically simplifies real economic relations to a set of inter-related variables, that can then be computed and projected. Economic growth is thus the rate of change of the GDP variable, a variable that is the counterpart within the model of actual GDP (often in real terms). The GDP variable does not play the same role in all integrated assessment models. Although they can have common features, all models are different. For our purpose, we have chosen to distinguish between them depending on whether GDP growth is an *input* of the model (exogeneous growth), or

whether it is an *output* (endogenous growth). We have looked more thoroughly into two models of each type. We do not claim the two models are representative, but that they exhibit typical features that help to explain the role played by economic growth as a variable or a parameter in IAMs.

3.1. Global Change Assessment Model (GCAM)

- 28 Let us consider the Global Change Assessment model (GCAM) developed by the Joint Global Change Research Institute (JGCRI) in the United States. Now in Version 5.3, it has been developed since the 1980s from the pioneering work of Edmonds and Reilly (1983). It has been included in IPCC reports since the Second Assessment Report (1995). This model has a very rich description of energy systems, with a detailed representation of energy production and demand, and of agriculture and land systems.¹⁰ These systems compute, for example, how energy can be supplied to satisfy final demand and the corresponding environmental impacts. The final energy demand is scaled according to the GDP variable, and so GDP paths are an important determinant of the results. However, GDP growth is simply assumed here, as the macro-economic system is reduced to one equation: GDP is simply the product of total population and labour productivity, which are two inputs to the model. Given a population path, GDP is thus entirely determined by the assumption of labour productivity.¹¹ In GCAM, GDP is a driver of the demand for energy and agricultural produce, something that is assumed and cannot be acted upon.
- 29 Future GDP paths are *exogenous* in this type of model. They are external assumptions that can be changed according to whatever the modeller wants to investigate. Here nothing precludes there being declining GDP paths and testing the consequences of this assumption for energy, agriculture and land systems, and their environmental impacts.
- 30 Explaining why negative rates of GDP growth are not present in scenarios produced by this type of model has nothing to do with the built-in features of the model, because GDP growth is a parameter that can be changed at will. The answer has to be found in the way modellers choose their assumptions and coordinate them with those of other teams.

3.2. World Induced Technical Change Hybrid (WITCH)

- 31 The WITCH model is built on different principles. WITCH was developed in the mid-2000s by a modelling team led by Valentina Bosetti, Carlo Carraro and Massimo Tavoni (Bosetti *et al.*, 2006) at Fondazione Eni Enrico Mattei (FEEM) in Italy. It is now housed in the European Institute on Economics and the Environment. It appeared for the first time in an IPCC assessment report with the AR5. Its name emphasises the endogenous character of technical change. In WITCH, GDP is a constant-elasticity-substitution (CES) combination of a composite final good and energy services (Emmerling *et al.*, 2016). Both have to grow for GDP to grow. The composite good is a Cobb-Douglas combination of capital and labour. As is the case in growth models of this kind, long-term growth is driven by the growth of total factor productivity (TFP), while capital and population growth also contribute to macroeconomic growth. Conversely, the total productivity of energy services also raises the production potential of energy itself. Energy is described as the combination of several energy vectors. Endogenous

technical change is concentrated on the technical progress of energy production and services. Investing in the production capacity of a certain type of energy (e.g. wind farms) reduces the cost of this energy, and R&D investments into energy efficiency can reduce energy requirements overall. Following recent developments, WITCH can now also be run with an endogenous labour-leisure decision in which labour is determined on the basis of a multi-variate utility function, typically resulting in shorter working hours as capital and productivity increase.

- 32 Growth is largely enabled here by TFP growth and energy productivity growth. It is key to understanding where growth comes from. TFP is simply calibrated to reproduce a given baseline, which is a given (GDP) growth path from which any climate change mitigation or damage is absent. To put it simply, TFP is set in the calibration process, so that the growth path computed by the model in its baseline scenarios accurately tracks the chosen growth path (Emmerling *et al.*, 2016, p.12-13). The chosen growth path is a growing path: nowadays the usual choice is one with moderate economic growth (namely the SSP2, see below), (Dellink *et al.*, 2017). This calibration procedure gives TFP growth that makes GDP growth possible in mitigation scenarios. Indeed, when policies are introduced to meet mitigation targets, TFP is kept at its baseline value, calibrated as explained.
- 33 This simple description of an IAM with an endogenous GDP path raises two sets of questions. The first pertains, as with models with exogenous GDP paths, to the coordination of modelling teams around paths of growing GDP. The second is related to the mechanics of the model, and specifically to why increasing TFP translates into increasing economic output and not decreasing labour and capital input. The next section will deal with these two questions.

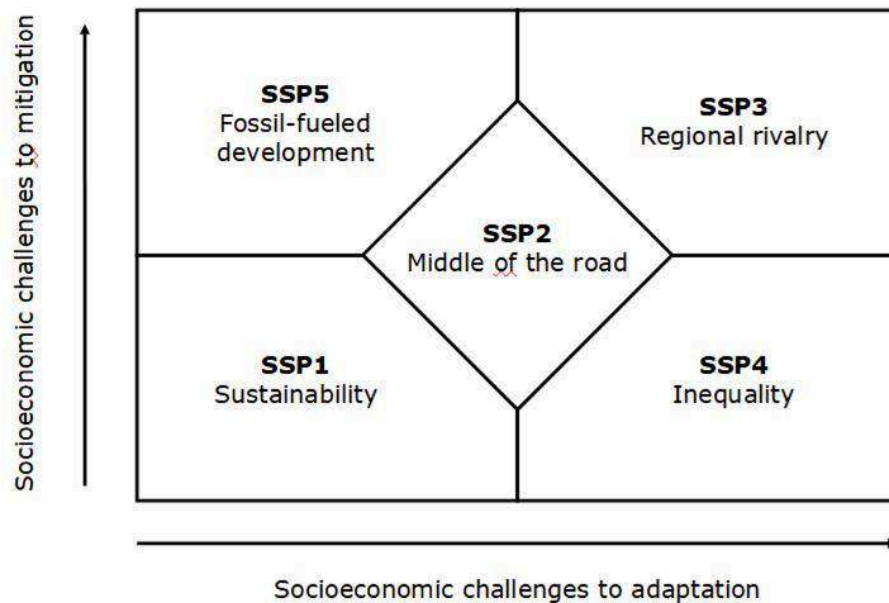
4. Explanation of the absence of no growth/degrowth scenarios

4.1. Research coordinated around scenarios that are deemed plausible

- 34 As exemplified by GCAM and WITCH, IAMs rely on exogenous data to calibrate the evolution of GDP or TFP, regardless of whether they have exogenous or endogenous growth paths. IAM research is now increasingly coordinated around common baselines that provide —among other things— calibration for GDP data.
- 35 As mentioned above (Section 2), the IAM community has become better organised since the early 2000s, leading to greater harmonisation across groups. The common framework of the socio-economic evolution is defined by the Shared Socioeconomic Pathways (SSP) (O'Neill *et al.*, 2017). The SSPs were developed as part of the new scenario framework initiated in 2005 (IPCC, 2007; Moss *et al.*, 2010) to map out the space of plausible evolutions for society.¹² They were “designed to span a relevant range of uncertainty in social futures” (O'Neill *et al.*, 2017, p. 170). The SSPs were first defined as storylines set along two dimensions: high or low socioeconomic challenges to mitigation and high or low socioeconomic challenges to adaptation. Five SSPs were developed to fill the four quadrants of the matrix and its centre (Fig. 3; O'Neill *et al.*, 2014). These SSPs are defined by narratives and by qualitative descriptions of plausible

global trends that are consistent with the selected outcomes in terms of challenges to mitigation and to adaptation. The narratives, as O'Neill *et al.* (2017, p. 171) explain, “aim to convey a basic ‘storyline’ that can guide the specification of further elements of the scenarios, including quantitative elements”. They thus inform the quantification of relevant variables that is necessary for them to be used as input in models. The elements considered include demographics, human development, economy and lifestyle, and institutional trends. The evolution of GDP is thus defined as part of the SSPs.

Figure 3: The SSP matrix



Source: O'Neill *et al.*, 2014.

- 36 All five SSPs project positive GDP, although not to the same degree. The lowest growth pathway is SSP3, which corresponds to “high challenges for mitigation, high challenges to adaptation”; high growth in the SSPs is associated with technological innovation which lowers challenges for mitigation and/or for adaptation, depending on the pathway. Three quantifications of long-term growth in the SSPs were published in the Special Issue presenting the SSPs (Dellink *et al.*, 2017; Leimbach *et al.*, 2017; Crespo Cuaresma, 2017), one of which was developed at the OECD using the ENV-Growth model (Dellink *et al.*, 2017). A scan of the documentation available from the IAM-C “common Integrated Assessment Models documentation” wiki suggests that, when not using the SSP quantifications, IAMs mostly rely on OECD data for GDP projections.¹³
- 37 IAM work thus appears to be coordinated around a relatively small set of GDP projections, all of which are in line with the “growth paradigm” (Schmelzer, 2016). The current structure of the IAM community around model intercomparison projects – which require a certain degree of harmonisation of assumptions and baselines– and scenario databases –which determine the output variables that are collected– probably reinforces convergence among the scenarios considered (Cointe *et al.*, 2019). The vast majority of scenarios in the AR5 database were produced in model intercomparison projects, and scenarios from outside the IAM community were less represented in the

database. The situation is similar in the AR6, where it is noted that “scenarios from different communities, in the emerging literature, or not structurally consistent with the literature may be overlooked” because they were less likely to access the database (Riahi *et al.*, 2021, p. 3-15).

- 38 As mentioned above, despite the relatively broad range of futures that the SSP-RCP framework make available, the “middle of the road” scenario (SSP2) is the usual choice for calibrating growth in WITCH, as well as in other IAMs. This scenario aligns with the OECD long-term economic growth projection at the global level, which is, according to the IPCC AR6, “reasonably consistent with SSP2” (Riahi *et al.*, 2021, p. 3-24).
- 39 The collective infrastructure of IAM research thus seems to favour coordinated work around scenarios that do not question economic growth. However, this does not in itself preclude consideration of lower growth, no-growth or degrowth scenarios. In their presentation of the SSP narratives, O’Neill *et al.* (2017) note that a lower growth variant of SSP1 (the “green road” low challenges SSP, which is a high growth scenario) could be envisioned, although it would require dramatic shifts in lifestyles.¹⁴ More recently, O’Neill *et al.* (2020, p. 1080) list “futures with no or limited growth in high-income countries” as relevant alternative scenarios to explore beyond existing scenarios. As the survey we presented in Section 3 suggests, this has scarcely been discussed to date in IAM-relevant arenas, and the extent to which such scenarios would be taken up or deemed useful for the purpose of IAM research remains to be explored.¹⁵

4.2. Growth is deemed a natural fact and not an intervention point.

- 40 Models with exogenous GDP like GCAM show that scenarios with a growing GDP variable are not a consequence of the structure of the model, but an assumption imposed by modellers. The conclusion is similar for models with endogenous GDP, like WITCH. In such a model, the TFP is calibrated so that the model reproduces a growing reference baseline from an external source (like the OECD).¹⁶ In policy scenarios, the same TFP path is then used, and gives birth to a growing economy. In both cases, there is a growing time-series (whether GDP or TFP) that is kept fixed across scenarios and thus appears natural, although it is the consequence of the social work of coordinating around a representation of a future.

We have just discussed how modellers coordinate their work around growing baselines. We now turn to our second point: explaining why models still project economic growth in policy scenarios. Several reasons can be put forward.

- 41 First, the TFP does not vary when policy measures are introduced. Although the TFP path is produced by modelling choices, as it is precisely calibrated to reproduce a given baseline path of GDP, TFP is then taken as a given, as a fact of nature so to speak (as shown above, the scenarios from WITCH use the TFP calibrated from the SSP2 scenarios). It is important to remember that TFP is not a natural concept, a measure of underlying technological forces: it is an artefact of the way growth is modelled, a residual. As Abramovitz (1956, p. 11) put it, TFP is “some sort of measure of our ignorance about the causes of economic growth”, or to be more specific, the measure of our ignorance when GDP is modelled through a Cobb-Douglas function. That such an elusive quantity is taken as a given seems unjustified, but it is a common practice.
- 42 Secondly, the way models are constructed makes it difficult to modify TFP. Despite the advent of theoretical models of endogenous (TFP) growth *à la* Aghion-Howitt-Romer

more than thirty years ago, endogenising TFP is not standard practice in modelling exercises of economic growth in general, or in IAMs in particular. The consequence of this is that TFP growth is not an intervention point: no decision by modelled agents can affect it. TFP is fixed and cannot be acted upon, whereas degrowth proponents may call straightforwardly for a productivity slowdown (Jackson & Victor, 2011), or for policies that would lead to a productivity slowdown (Kallis *et al.*, 2018). By construction, these policies cannot find their place in models where TFP is exogenously calibrated to correspond to a growing baseline.

- 43 Thirdly, once there is TFP growth, the model uses this TFP growth to produce more economic output. TFP growth really is a “manna from heaven”, a mysterious thing thanks to which the same input yields more output. It is thus a great facilitator that alleviates production constraints. The GDP growth thus produced can be used for more investment. Climate mitigation scenarios require high levels of investment, as mitigation implies a massive evolution of capital stocks. GDP growth is therefore generally seen as facilitating substantial emission reductions, as opposed to being a central prerequisite for the degrowth position.
- 44 Making room for new investments is one of the reasons TFP growth is used for output growth. The other reason is that output growth allows more consumption to be served. In economics, consumption is often seen as a desirable good, which is positively related to welfare. In IAMs with endogenous (GDP) paths, this is usually embedded in a utility function that increases with consumption. For example, in WITCH, economic decisions are made so that, provided policy measures ensure mitigation targets are met, intertemporal utility is maximised. The shape of the utility function, which depends exclusively on consumption (C), means that the objective has a strong pro-consumption bias. As per design, it would be foolish to forgo GDP growth as it allows more consumption for a given investment. It is thus no surprise that increasing TFP leads to increased output.
- 45 Conversely, reducing input (such as hours-worked) is of no social value, and is not even a possibility in most models. Although there are well known technical difficulties in calibrating them, one could at least use utility functions that involve a consumption-leisure trade-off. The fact that this is not currently done reflects the way that consumption remains the central value in IAMs.

Conclusions

- 46 We have documented the observation that degrowth is not part of the future depicted by IAMs (Keyßer & Lenzen, 2021; Kuhnenn 2018; Hickel *et al.*, 2021). We have also investigated the reasons behind this absence: they are various in nature, but all contribute to the prominence of economic growth in the imagined future world economy. Pro-growth biases are ingrained both in modelling tools, such as the choice of utility functions, depending only on consumption alone, and in modelling practices, such as the coordination around growing baselines. We have insisted on this latter aspect as it appears to us to be the more important factor. From a modelling perspective, it is also the easier to change: any modelling team with some spare time can run scenarios with a stagnant TFP or GDP, even if this is outside the intercomparison exercises. Since writing the first version of this manuscript, discussions about post-growth scenarios have emerged within the IAM and scenarios

community, and there are currently attempts to question pro-growth biases, for instance by focusing on energy demand or on well-being, though these do not necessarily involve modelling decreases in GDP. The most prominent examples are the so-called low-energy demand scenario (Grübler *et al.*, 2018) or the sustainable development pathways (Soergel *et al.*, 2021). We therefore hope that there will soon be more modelling exercises that will consider degrowth scenarios and will analyse the consequences of these alternative GDP paths.

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NOTES

1. The research presented in the article was carried out before the release of the IPCC Sixth Assessment Report, which is why it considers AR5 only. The literature moves fast on this issue, as it does on most topics related to climate change and mitigation.
2. "AR5 scenario database. Introduction" IIASA's website. URL : <https://tntcat.iiasa.ac.at/AR5DB/> [consulted 12 May 2021]
3. Working Group III used a similar database for the Sixth Assessment Report of the IPCC, which includes 3131 scenarios produced using about 50 model families. The models that contributed most scenarios to the database were also among the main scenarios providers in the AR5 database (Riahi *et al.*, 2022; Guivarch *et al.*, 2022).
4. URL: <https://www.reuters.com/investigates/special-report/climate-change-scientists-list/> [consulted 12 May 2021]
5. At the time of writing, in May 2021, the contribution of Working Group III to the IPCC Sixth Assessment Report was not available.
6. Considering growth rate of GDP delivers a similar picture.
7. As demonstrated by their names, the definition of regions shows a strong path dependency. This gives an idea of the difficulty of changing the categories around which modellers coordinate their work.
8. URL : <https://www.iamconsortium.org/> [consulted 12 May 2021]
9. The query was made on the website on March 18, 2021, using the dedicated search engine. We also looked into programs of the annual meetings, when available. At date of revision (April 4, 2022), there was one positive match: a call for papers for a special issue of *Economic Systems Research*, the journal of the International Input-Output Association, which will be devoted to degrowth.
10. See the documentation of the model: <http://jgcri.github.io/gcam-doc/>.

11. There exists in GCAM a soft link between energy systems and macro-economic growth, in the form of an elasticity of GDP to energy price, but it is generally not used.
 12. The SSP narratives were elaborated during a workshop organised by the National Center for Atmospheric Research (NCAR) that took place in Boulder (USA) in November 2011 (O'Neill *et al.*, 2012).
 13. We have looked at the “Socioeconomic drivers” section on the pages of each models documented in the wiki, where information on the GDP projections used is usually provided: https://www.iamcdocumentation.eu/index.php/IAMC_wiki, consulted 12 May 2021.
 14. IAMs are currently better at representing technological change than they are at representing lifestyle or behavioural change.
 15. The AR6 makes a similar observation that scenarios with a “stabilisation (or even decline) of income levels in developed countries” are “not common among IAM outcomes, that are more commonly based on the idea that decarbonization can be combined with economic growth by a combination of technology, lifestyle and structural economic changes” (Riahi *et al.*, 2021, p. 313). Degrowth pathways are mentioned as worth exploring in AR6, especially Working Group 3 chapters 3 and 5, but few if any scenarios of that kind were submitted to the database (Riahi *et al.*, 2021, p. 383).
 16. Not all models with endogenous (GDP) growth like WITCH have an explicit TFP, but, to the best of our knowledge, they have functional equivalents in the form of efficiency parameters that are tuned so that the baseline matches exogenous specifications (typically from SSP or OECD scenarios).
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ABSTRACTS

The range of climate change mitigation scenarios in the IPCC reports frames the futures and policies that we deem possible. In the mitigation pathways produced by Integrated Assessment Models (IAM), economic growth is sustained throughout the century, as we show by surveying the GDP trajectories considered in the IPCC AR5 scenario database and in the more recent IAM literature. We unpack the reasons for IAM’s commitment to GDP growth, and seek to understand the quasi-absence of no-growth and degrowth scenarios. An overview of the current organisation of IAM research highlights the internal dynamics within the IAM community and the resulting coordination of choices. We then analyse the representation of economic growth in two IAMs, GCAM (exogenous growth) and WITCH (endogenous growth). From a technical point of view, degrowth scenarios could be considered, but the modelling teams have coordinated their work around growth scenarios. Ultimately, the absence of degrowth/no growth scenarios stems from the fact that, economic growth is largely conceived of and computed as a “natural” driver in IAM research, and not as an intervention point.

Les scénarios d’atténuation du changement climatiques recensés dans les rapports du GIEC contraignent l’éventail des futurs et des politiques envisagés. Les scénarios d’atténuation produits par les modèles d’évaluation intégrés (IAM) supposent un maintien de la croissance

économique tout au long du siècle, ce que nous montrons en passant en revue les trajectoires de PIB considérés dans la base de données du cinquième rapport du GIEC et dans la littérature récente émanant des IAM. Nous analysons les raisons pouvant expliquer la quasi-absence de scénario sans croissance ou décroissant dans cette littérature. A partir d'un panorama de l'organisation actuelle de la recherche autour des IAMs, nous soulignons le rôle des dynamiques internes au sein de la communauté des IAM et les choix de coordination qui en résultent. Nous analysons ensuite la représentation de la croissance dans deux modèles : GCAM (modèle à croissance exogène) et WITCH (modèle à croissance endogène). D'un point de vue technique, il serait possible de considérer des scénarios de décroissance, mais les équipes de modélisation ont jusqu'à présent coordonné leur travail autour de scénarios de croissance. L'absence de scénarios sans croissance ou de décroissance s'explique essentiellement par le fait que, dans la recherche autour des IAM, la croissance économique reste considérée et calculée comme un facteur « naturel » et non comme un point d'intervention.

Los escenarios de mitigación del cambio climático identificados en los informes del IPCC limitan la gama de futuros y políticas consideradas. Los escenarios de mitigación producidos por los Modelos de Evaluación Integrada (IAM) suponen un crecimiento económico continuo a lo largo del siglo, lo que demostramos al revisar las trayectorias del PIB consideradas en la base de datos del Quinto Informe del IPCC y en la literatura reciente de los IAM. Analizamos las razones que podrían explicar la virtual ausencia de escenarios de no crecimiento o decrecientes en esta literatura. Con base en una descripción general de la organización actual de la investigación en torno a los IAM, destacamos el papel de la dinámica interna dentro de la comunidad IAM y las opciones de coordinación resultantes. Luego analizamos la representación del crecimiento en dos modelos: GCAM (modelo de crecimiento exógeno) y WITCH (modelo de crecimiento endógeno). Desde un punto de vista técnico, sería posible considerar escenarios de declive, pero hasta ahora los equipos de modelización han coordinado su trabajo en torno a escenarios de crecimiento. La ausencia de escenarios sin crecimiento o declive se explica principalmente por el hecho de que, en las investigaciones sobre IAM, el crecimiento económico sigue siendo considerado y calculado como un factor “natural” y no como un punto de intervención.

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Mots-clés: décroissance, PIB, scénarios d'atténuation, modèles d'évaluation intégrés

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