Introduction to the *Handbook on the Economics of Climate Change*

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This *Handbook* comes to light at a time when economic sciences start to recognize the inevitable emergence of climate change as the defining topic of our time. Economic thinking is evolving in front of our eyes, calling for reflection and reconsideration. The chapters contain ideas and policies to support and accelerate the change. We now know that climate change embodies and forecasts the future of human civilization and therefore its economic organization. It is the purpose of the *Handbook* to contribute to the transformation of economics in the midst of this momentous evolution.

The importance of climate change in economics should be no surprise. It is natural and to be expected because, as the traditional definition goes, economics is about the production, use, and distribution of resources, a definition that was famously proposed by T. Koopmans in the middle of the 20th century. Resources are at the core of economics, this much is clear. What is perhaps less clear is the transformation that has occurred in our perception of resources. Now, for the first time, we have 7.3 billion humans who have come to dominate the planet creating a new geological period that has replaced the Holocene and which geologists now call the Anthropocene. Only now that we dominate the geology of the planet have we come to recognize that the most important resources for human societies are the atmosphere of the planet, its bodies of waters and its biodiversity, namely the global environment. The definition of economics proposed by T. Koopmans has not changed: it is our understanding of resources that has fundamentally changed. To achieve its goal the book is divided into three sections that cover critical new areas and ideas about economics and climate change: The political economy of climate change and climate policy, integrated assessment modelling, and climate change and sustainability. For the convenience of the reader and using abstracts provided by the authors, the content is summarized in the following.

Part I examines issues of "The Political Economy of Climate Change and Climate Policy" and expands the conventional economic answer to climate change: "Make polluters pay." The externality associated with emitting harmful greenhouse gases needs to be internalized so that those reaping the benefits of emitting also bear its costs. This answer rests on the assumption that any distributional issue can be overcome by appropriate compensation of losers by winners of climate policy. That climate policy in fact poses net benefits and represents a "so-called" Pareto Improvement are deep insights from welfare economics. Decades of frail climate policy, however, reveal that there are powerful impediments in correcting price signals and unleashing market forces in a transition to carbon-free technologies. Increasingly, researchers and politicians realize that problems of political economy and distribution, of both carbon underground and in the atmosphere, are at the heart of the impediments to climate policy and their solutions are tantamount to successful climate policy. They are explored in the first section of this book.

In Chapter 1, entitled "Distributional issues in climate policy: air quality co-benefits and carbon rent", James K. Boyce tackles the implementation of a carbon tax that brings benefit to the current population through better air quality and the recycled tax revenue. He points out that the case for, and against, climate policy is typically made on grounds of inter-generational equity, assuming a tradeoff between future environmental well-being and present economic well-being. Boyce points out however that this framing of the problem is somewhat limited as it ignores the potential to design policies that mitigate climate change while yielding net benefits for most people who are alive today. This chapter considers two ways that climate policy can bring substantial benefits to the present generation: (i) air quality improvements from reduced burning of fossil fuels; and (ii) recycling of the rent created by carbon pricing. Both these considerations entail important issues of intra-generational equity that the chapter develops, which change our evaluation of climate policy.

In Chapter 2, entitled "Evaluating policies to implement the Paris Agreement: a toolkit with application to China", Ian Parry, Baoping Shang, Nate Vernon, Philippe Wingender, and Tarun Narasimhan discuss the recent policy developments and future policy options in China who, with its 1.3 billion human population, has become the world's largest annual emitter of carbon dioxide (CO_2). They propose a spreadsheet model for evaluating alternative fiscal and regulatory instruments that policy makers may consider for implementing the UN 2015 Paris Agreement's mitigation pledges, or national implementation targets. Various policies are evaluated against alternative metrics, including impacts on (CO_2) emissions, revenue, deaths from local air pollution, economic welfare, and economic incidence across households and industries. The model is applied to China but could be transferred to most other countries. For China, in the central case, they consider a carbon tax or coal tax that progressively rises to \$35 per ton of CO_2, cuts CO_2 emissions by about 20 per cent and raises well over 1 per cent of GDP in revenue by 2030 while, cumulated over the period 2017–30, saves approaching 2 million lives and generates discounted welfare gains equivalent to over 30 per cent of 2015 GDP. They show that an equivalently scaled emissions trading system applied to large emissions sources has roughly half the environmental and fiscal effectiveness, while other policies (e.g., incentives for energy efficiency and renewable sources of energy, and taxes on electricity and road fuels) are substantially less effective. The authors show that using around 5 per cent of the revenue from carbon/coal taxes can compensate low-income groups for increased energy prices, while 10 per cent of the revenues could compensate energy-intensive and trade-exposed firms.

Chapter 3, entitled "Bargaining to lose: a permeability approach to post-transition resource extraction", is authored by Natasha Chichilnisky-Heal who turns to the source of emissions, discussing resource extraction in resource-based developing economies and the rich political economy that comes with the multi-national extraction industry. The chapter is based on previous work entitled "Bargaining to lose: the permeability approach to post-transition resource extraction" where Natasha Chichilnisky-Heal introduced an original and fertile explanation for the resource curse. Her "permeability" approach questions the traditional treatment of the state as a decision maker having the public good as an objective, replacing it by the result of a bargaining game between the state and international organizations. Her new theory is illustrated with unique hands-on experience in the case of copper and gold mines in post-communist Mongolia and in post-socialist

Zambia, the largest in the world, and focuses on a bargaining game between the state and key financial organizations: the Bretton Woods Institutions (IMF, World Bank) and multinational corporations (MNCs) such as the resources conglomerate Rio Tinto. Permeability is the process by which external non-state actors such as the International Monetary Fund and Multinational corporations, by virtue of their relationships with cash strapped resource-rich governments, enter into crucial roles in the governance of these nations. This chapter goes beyond the traditional theory of the resource curse and proposes a relationship between permeability and a reduction in democratic accountability of these governments to their domestic constituencies, which Chichilnisky-Heal calls political underdevelopment. The argument runs as follows: external actors (multilateral and MNCs) bargain extensively with host governments over the regulation of extractive industries and offer development aid or loan packages over the regulation of extractive industries, and often tie development aid and loan packages to the satisfactory adjustment of regulations or conclusion of investment deals in the extractive sector. She argues, using data from the two cases mentioned, that this phenomenon skews the democratic process, providing the governments of these states with yet another constituency – the constituency of external actors. This perverts the democratic process not simply by making the government economically beholden to the external actors, as has been extensively argued, but by giving the external actors a permanent seat at the bargaining table of domestic politics. Permeability is not a binary process but rather an ordinal variable that measures the degree to which a democratic government and its processes have been "permeated" by actors other than its domestic constituent basis. The implications for the global environmental policies and the global environment itself are presented both theoretically and in practical terms, providing striking examples in the nations discussed.

Chapter 4, entitled "Host–MNC relations in resource-rich countries", Natasha Chichilnisky-Heal and Geoffrey M. Heal develop further the analysis of Chapter 3 within a theoretical context and from the perspective of the global commons and an individual firm's investment decision. The chapter discusses the relationship between a resource-rich developing country and a multinational corporation (MNC) that is developing the nations' resources for the international market. The authors model the connections between transparency, permeability (a term as well as a concept introduced by Natasha Chichilnisky-Heal and defined anew in this chapter as the amount of resource rent that leaves the country) and economic development, considering the polar cases of democracy and autocracy. It begins by considering the role of permeability in domestic politics, showing that a decrease in permeability will always benefit the incumbent, whether the country is a democracy or an autocracy. It then suggests that the relation between the host and the MNC has the features of a classical and quite intractable version of the hold-up problem, and that this may provide the MNC with incentives to influence political outcomes within the host country by whatever means are at its disposal. The hold-up problem can be overcome by the use of a Bilateral Investment Treaty that restricts the host country's ability to alter the terms of any agreement into which it has entered, and we investigate why a country might enter into a treaty that limits its freedom of action in this way. A possible answer is to be found in the capacity of a small number of poor countries to "tip" an equilibrium where none sign such treaties to one where all sign, in the process making all worse off. This chapter's analysis provides a micro foundation for the "obsolescing bargain model" of host–MNC relations.

In Chapter 5, entitled "Bargaining to lose the global commons", Natasha Chichilnisky-Heal and Graciela Chichilnisky apply the analysis of Chichilnisky-Heal in Chapter 3 to the global commons. Natasha Chichilnisky-Heal's "permeability" approach questions the treatment of the state as a decision maker having the public good as an objective and replaces it by the results of a bargaining game between the state and the International Organizations (IMF, World Bank). Her new theory is illustrated by her unique hands-on experience for the cases of copper and gold mines in Mongolia and in Zambia. Chapter 5 generalizes Chichilnisky-Heal's "bargaining to lose" approach to the resource curse providing economic models that validate the original conclusions and exploring its implications for the global commons: the atmosphere, the oceans and biodiversity. Chichilnisky-Heal "permeable state" is a transition to a new globalized society where the sovereign state – a relatively recent creation – is receding giving rise to a new set of global economic agents and institutions that better explain the dynamics of the destruction of the global commons in today's globalized world. We show that the permeable state theory is connected to explanations for the resource curse as a global market failure magnified by globalization and originating in the lack of property rights on natural resources during the pre-industrial period. We explore Chichilnisky-Heal's approach to the resource curse and its natural implications for the environmental crisis of the global commons. "Permeability" magnifies the losses from bargaining by the nation state. The results are ever-increasing overexploitation of resources and inefficient ever-increasing exports at increasingly lower prices. This complements the results arising from ill-defined property rights on resources in the private sector that drive Chichilnisky's (1994) explanation of the overexploitation of resources in developing nations. The latter are based on the inefficiency of market solutions that imply the (overexploitation of resources at market prices that are below replacement costs, due to the lack of well-defined property rights in developing nations prior to industrialization). Natural resources are inefficiently over-extracted, leading to the overexploitation of the global commons such as overuse of fossil fuels, minerals, and forests causing severe degradation of atmospheric water bodies and biodiversity degradation. Both state policies and private sector approaches lead to over-exploitation of natural resources beyond what is efficient, with severe degradation of the global environment and the satisfaction of basic needs in the planet. The solutions that Chichilnisky-Heal proposes for permeability, for example, limiting the Bretton Woods' Institutions' "seat at the negotiation table" of resource extraction contracts, could help resolve the global environmental crisis, including climate change, which arise from the overextraction of global resources.

Part II of the *Handbook* covers "Integrated Assessment Modelling". To understand the connections between individual elements of the climate and the economy, climate scientists and economists have developed models for the integrated assessment of both. These help researchers and policy makers better understand the effects of climate change and how mitigation and adaptation policy can avert damages and make the economy more resilient. The chapters of this section introduce the most prominent models used in climate policy and show how they can be improved to include important complex geophysical phenomena, distributional aspects, and sectoral, institutional, and behavioral details or to provide simple policy rules for politicians.

In Chapter 6, entitled "Integrated Assessment Models of climate change", Chris Hope presents an overview of the development of the economic modelling of climate change by

integrating impacts of climate on the economy and of the economy on the climate. The use of the models in policy-making has been rapid and influential, and the development and use of the models under the scrutiny of critics is strong and ongoing. As it becomes clearer that carbon pricing must be a large part of the solution to reducing greenhouse gas emissions, the importance and influence of Integrated Assessment Models (IAMs) may continue to increase. IAMs are tools that help translate the current knowledge about climate change, including its profound uncertainty, into policy advice. Chapter 6 describes three IAMs of climate change: The Dynamic Integrated Climate-Economy (DICE) model developed by Bill Nordhaus at Yale University, the Policy Analysis of the Greenhouse Effect (PAGE) model, developed by Chris Hope, at the University of Cambridge, UK, and the Climate Framework for Uncertainty, Negotiation and Distribution (FUND) model, developed by Richard Tol at Sussex University, UK. The vast majority of the independent impact and estimates of the social cost of carbon that appear in the peer-reviewed literature are derived from these three models. This chapter discusses their origins, influences, and shortcomings.

In Chapter 7, William Brock and Anastasios Xepapadeas introduce a spatial dimension to a standard model of integrated economic assessment by explicitly tracing the movement of heat and considering polar amplification. This chapter, entitled "Climate change policy under spatial heat transport and polar amplification", is the first instance in climate economics that considers a combination of spatial heat transport and polar amplification. It simplifies the problem by stratifying the Earth into latitude belts and assuming that the two hemispheres are symmetric. The results suggest that it is possible to build climate economic models that include the very real climatic phenomena of heat transport and polar amplification, and still maintain analytical tractability and show that the effect of heat transfer and polar amplification on climate policy depends upon the interaction of climate component dynamics with the distribution of welfare weights, population, and productive capacities across latitudes. The chapter discusses optimal fossil fuel taxes in a competitive environment with income effects and shows that optimal taxes have a spatial structure and are dependent on each latitude's output. In addition, it characterizes the interactions between spatial transport and the competitive equilibrium price path of tradable permits. Using general power utility functions, the authors show that an increase in the coefficient of relative risk aversion will reduce the social price of the climate externality.

In Chapter 8, the focus is shifted from global to regional modelling. Authors Luis M. Abadie, Elisa Sainz de Murieta, Ibon Galarraga, and Anil Markandya discuss in "Progressive adaptation strategies in European coastal cities: a response to flood-risk under uncertainty" strategies for European coastal cities of adaptation to climate change. The authors describe a novel stochastic model of sea-level rise and show how risk measures can be applied to such rising sea levels and the way in which sea-level rise and socio-economic development has been integrated. They present the estimated damage costs for different cities under different IPCC scenarios and for different time periods. The authors then turn to the concrete example of Glasgow and illustrate an application of real options analysis for this city. Using their approach a certain acceptable risk level can be determined above which no city is willing to go. This threshold allows estimating not only how much adaptation is needed but also when adaptation should start. This important piece of information complements other data used in decision making. Using the

Glasgow example, postponing a decision until more information on the impacts of sea-level rise or until other climate policy becomes available has to be weighed against other possibilities such as building a flexible defense that will allow a greater degree of protection in the future.

In Chapter 9, Armon Rezai and his co-authors Frederick van der Ploeg and Cees Withagen contribute in "Economic growth and the social cost of carbon: additive versus multiplicative damages" to recent debates on how fossil fuel emissions should be priced and whether there are simple rules which policy makers can follow. They therefore discuss optimal carbon pricing and derive simple policy rules for the cases of additive and multiplicative damage. In a calibrated integrated assessment model of Ramsey growth and climate change in the global economy, they investigate the differential impact of additive and multiplicative global warming damages for both a socially optimal and business-as-usual scenario. Fossil fuel is available at a cost that rises as reserves diminish and a carbon-free backstop is supplied at decreasing cost. If damages are not proportional to aggregate production and the economy is along a development path, the optimal carbon tax is smaller than with multiplicative damages. The economy switches later from fossil fuel to the carbon-free backstop and leaves less fossil fuel in situ. By adjusting climate policy in this way there is very little difference on the paths for global consumption, output and capital, and thus very little difference for social welfare despite the higher temperatures. They show that for all specifications the optimal carbon tax is not a fixed proportion of world GDP but rather follows a hump shape.

In Chapter 10, Mark Budolfson and Francis Dennig study how income inequalities across and within countries affect the optimal response to climate change. In "Optimal global climate policy and regional carbon prices" they find that, rather than impose one global price, heterogeneous prices are warranted with potentially large disparities if society's aversion to inequality is considerable. It is often stated that optimal global climate policy requires a single carbon price throughout the world. Chichilnisky and Heal (1994) have argued, however, that distributional issues or lump-sum transfers break this theorem and a policy in which different regions face different carbon prices can become superior to the uniform one. The chapter calculates utilitarian-optimal carbon prices under zero cross-regional lump-sum transfers in the multi-region IAM NICE, an adaptation of the DICE model introduced in Chapter 6. The resulting optimal global climate policy has differing regional carbon prices. Regions with the lowest levels of income start at lower prices, while richer regions face higher prices. This entails significant welfare gains over the standard single price optima commonly reported, which, as outlined briefly in the concluding remarks, can be improved upon still by allowing international trading in the corresponding emissions' allocations. Budolfson and Dennig show that the welfare gain from optimal differential prices is always positive for all their simulations and provides theoretical insights on monetary transfer necessary in concrete climate negotiations.

In Chapter 11, Alessandro Tavoni and Doruk İriş in "Tipping and reference points in climate change games" take a closer look at the dynamics of energy transition that carbon pricing can help usher. Once a tipping point for investment in low carbon technologies has been reached, and constituencies with stakes in the nascent markets have been formed, standard economic forces could sustain the transition to a carbon-neutral economy. The chapter reviews some of the recent literature that provides clues about when such reinforcing dynamics take place and the transition takes off. Given the wide scientific uncertainties

surrounding the location of thresholds, the role of expectations and reference points are crucial for their formation and in supporting cooperation. The chapter reviews both theoretical and experimental literature featuring tipping points and reference dependence, with the aim of extending the understanding of potentially game-changing impacts on climate change cooperation. To this end, Tavoni and İriş examine the role of thresholds and reference levels in public goods and coalition formation games, which capture important features of dangerous climate change and its impacts on human behavior. The existence of ecological tipping points associated with abrupt and catastrophic, rather than gradual, climatic change has important behavioral repercussions in terms of the incentives to cooperate on mitigation efforts. Key insights emerging from the literature are that strong leadership in mitigation efforts induces cooperation by others; the reasons for why countries' high expectations about others' abatement efforts could have detrimental effects; and the reasons why developing countries have been relatively reluctant to exert even limited abatement efforts.

The last part of the *Handbook* combines "Climate Change and Sustainability" by embedding the climate crisis in the broader study of sustainability and contextualizing it either historically and in previous environmental disasters or within broader equity considerations, be they intertemporal across generations or using developmental approaches across regions. The final chapter argues for an incorporation of recent insights from finance on how not to model complex systems and offers potential ways forward for climate change economics.

In Chapter 12, entitled "Climate change, Malthus and collapse", Norman Schofield examines the impending deleterious and catastrophic effects of climate change in the context of sustainability and previous environmental disasters and presents a way forward by drawing on the logic of the Condorcet Jury Theorem. This chapter points out that the Agricultural Revolution of about 10 000 years ago triggered the rapid growth of world population, but also created Malthusian traps where population outgrew the availability of food resources. The Roman Empire was apparently constantly faced with such a trap. The British Empire, in contrast, was able to expand its resource base using the innovations of the Industrial Revolution. The author draws a parallel between Rome and our global economy to suggest that climate change could induce a Malthusian trap for us unless we pay heed to Pope Francis's call for us to "Care for Our Common Home". Since this presents us with a common goal, it is possible that the logic of the Condorcet Jury Theorem may give us hope of wiser choices over our future.

In Chapter 13, Lance Taylor and Duncan Foley also frame climate change in the context of the Malthusian theory. In "Greenhouse gas and cyclical growth", they develop a demand-driven integrated assessment model in which ever-increasing energy demand to power growing labor productivity, is the key to achieving sustained economic growth. To highlight the role of growing energy use in economic development, their growth model incorporates dynamics of capital per capita, atmospheric CO_2 concentration, and labor and energy productivity. Taylor and Foley show that in the "medium run" output and employment grow rapidly and are determined by effective demand in contrast to most models of climate change. In a "long run" of several centuries, the model converges to a stationary state with zero net emissions of CO_2. Properties of dismal and non-dismal stationary states are explored, with the latter requiring a relatively high level of investment in mitigation of emissions. Without such investment, under "business as usual", output

dynamics are strongly cyclical in numerical simulations; there is strong output growth for about eight decades, followed by climate crisis, and output crash. Resources are the constraining factor in an economy generating endogenous growth as in the original essay of Malthus.

Chapter 14 by Robin Hahnel is entitled "Growth and sustainability" and discusses climate change, and more broadly, environmental sustainability in relation to economic production and labor productivity, arguing for a steady state economy and delineating what is necessary for achieving it. The relationship between economic growth and environmental sustainability has been the subject of much controversy. Hahnel argues that this has been in part due to lack of precision in defining terms and a failure to develop suitable models for studying the issue, both of which have been obstacles in developing understanding. The problem has been partly resolved in "What is sustainability?" by Graciela Chichilnisky (2011), which provided a rigorous definition and economic models to resolve this shortcoming. Following the earlier contributions, this chapter explains the difference between growth of production of goods and growth of environmental throughput, and it presents a model suitable for rigorously measuring changes in labor productivity and throughput efficiency. Hahnel formulates sufficient conditions for environmental sustainability, and helps to clarify how continued growth of production can be consistent with environmental sustainability. The chapter concludes with establishing linkages to the discussions on "steady-state" and "de-growth" economics, suggesting how the findings of this chapter can be extended to a world where nature is heterogeneous and parts of it are non-renewable, providing new observations about climate change policy and connecting it the broader questions of environmental sustainability.

In Chapter 15, Frikk Nesje and Geir B. Asheim discuss whether altruism is necessarily to the benefit of future generations, asking "Intergenerational altruism: a solution to the climate problem?" In an application of the theory of second-best, they show that in the presence of an uncorrected climate externality, greater utility weight on future generations can harm future generations by exacerbating the climate externality. Intergenerational altruism may induce more economic growth today to provide future generations with the means to weather the deleterious effects of climate change, thereby spurring climate change itself. Only when the climate externality is addressed by pricing carbon effectively, increased intergenerational altruism reduces the threat of climate change. Put differently, in a second-best setting with insufficient control of greenhouse gas emissions in the atmosphere, increased transfers to future generations through accumulation of capital might result in additional accumulation of greenhouse gases, and thereby aggravate the climate problem. In contrast, transfers to the future through control of greenhouse gas emissions will alleviate the climate problem. Whether increased intergenerational altruism is a means for achieving accumulation of consumption potential (through accumulation of capital) without increasing the climate threat depends on how it affects factors motivating the accumulation of capital and the control of emissions of greenhouse gases. Nesje and Asheim provide reasons for why increased intergenerational altruism aggravates the over-investment in brown capital and under-investment in green capital, that is, the atmosphere.

In Chapter 16, John M. Hartwick and Tapan Mitra also consider sustainability in the context of intergenerational justice in their essay "On intertemporal equity and efficiency in a model of global warming". They study equitable paths in a model where

irreversible global warming is produced using an exhaustible resource. Global warming is assumed to affect both production and instantaneous welfare of society, both adversely. Global warming is generated by the use of an exhaustible resource, and they establish three equivalence results connecting the concepts of equity, Hartwick's Rule of investing the resource rents, and a suitably extended version of Hotelling's Rule, which takes into account the externalities caused by global warming and provides as an explicit solution an equitable path which satisfies Hartwick's Rule of investing resource rents. Consumption and global warming are bounded and the path is asymptotically similar to the maximin path obtained by Solow (1974) in a model without global warming. When the global warming function is strictly concave, they provide an explicit solution of an equitable path in which consumption and global warming exhibit unbounded quasi-arithmetic growth. This path follows an extended version of Hartwick's Rule of investment, and attain the maximum sustainable utility among all equitable paths that have a constant savings rate.

In Chapter 17, Penny Mealy and Cameron Hepburn approach sustainability in the context of the Sustainable Development Goals in "Transformational change: parallels for addressing climate and development goals", and focus on climate change and poverty alleviation which, as Stern (2016) has stated, are "the twin defining challenges of our century". Historically, efforts to address these two challenges have been conflicted. Adverse impacts of climate change are likely to hit the poorest of this world hardest, but traditional industrial routes out of poverty are dangerously emissions-intensive. At the same time, climate policy must not impose the same abatement burden on the poorest as argued by Budolfson and Dennig in Chapter 10. In fact, such tensions have been major impediments to emissions reduction in earlier climate negotiations and largely underpinned the failure of the 2009 Copenhagen COP to reach a global climate agreement. The authors argue that the UN Paris Agreement (UNFCCC, 2015), which has now been ratified by the large majority of countries, provides a promising new international platform to progress a unique collective framework for global climate cooperation. The confluence of these global agendas represents an historic opportunity to marry efforts on climate and development fronts and drive significant progress on sustainable development. Against this encouraging backdrop, Mealy and Hepburn draw attention to the twin climate and development challenges: both require societies to navigate and manage system-wide transformative change. Transformational change processes, particularly as they relate to climate and development contexts, need to be better understood and the authors attempt to draw these fields together, highlighting key commonalities and shared learning opportunities. There are clear advantages for both research and policy. In relation to research, climate and development economists have traditionally studied the process of transformative change in separate fields and with differing emphases. However, identifying key commonalities in respective change processes may not only improve shared learning outcomes, it could also illuminate a more generalized theory of transformational change. For policy, a lack of integration in climate and development initiatives can lead to outcomes that are myopic, at best, and detrimental to their intended objectives, at worst. In terms of methodological tools for analyzing and modeling transformational change, the chapter reviews four different approaches that have been used in both climate and development contexts. Network analysis provides a useful framework to investigate relationships across economic sectors and allows scholars and policy makers to better

understand technological diffusion and industrial transition possibilities for a socially and environmentally more sustainable future.

In Chapter 18, Cameron Hepburn and J. Doyne Farmer in "Less precision, more truth: uncertainty in climate economics and macroprudential policy" draw on the existing knowledge of complex systems, particularly financial systems, to inform our understanding and modelling of climate change and climate policy. They argue that climate change economics is falling into the same traps that much of financial modelling did previously: parameters are expressed with too much confidence, important variables are omitted, and modelling of feedbacks, non-linearities, heterogeneity, and non-rational behavior are inadequately represented. Hepburn and Farmer, however, argue that while the climate and financial systems share various features – they are both "complex systems" – they also have important differences. The authors, therefore, carefully explore what lessons might be learned for climate system modelling from financial system modelling and macroprudential policy. Their key findings are: systematic data collection at a variety of scales is fundamental to properly understanding and modelling systemic risk; parameter values and the resulting model outputs need to treated with great skepticism due to the underlying uncertainty. In addition to parameter uncertainty, model uncertainty is likely to be large due to the fundamental difficulty of validation. Finally, since most economic models spring off the same set of narrow assumptions, significant variables, feedbacks, non-linearities, heterogeneity and non-rational behavior can, therefore, be easily overlooked. The authors argue for "conclusions that are less precise but more truthful" since they place emphasis on resilience as well as efficiency.

REFERENCE

Chichilnisky, G. (2011), 'What is sustainability?', *International Journal of Sustainable Economy*, **3**(2), 125–40.

We tell you how climate change affects the economy and its social impact, and the need to develop a new production model.Â This problem needs public-private sector collaboration to change the way we produce goods to other methods that guarantee and drive the development of sustainable economic growth. Economic impacts of climate change. How is climate change affecting the economy and society? #society #climate change #economy. Not only is it a serious threat to the planet and to people, climate change is also threatening the global economy. This problem needs public-private sector collaboration to change the way we produce goods to other methods that guarantee and drive the development of sustainable economic grow .. . Climate Change Handbook for Caribbean Journalists. According to the United Nations Framework Convention on Climate Change (UNFCCC), the term climate change is used to define a change in climate that is attributable directly or indirectly to human activity that alters atmospheric composition (UNFCCC, 2002). Another definition regards climate change as any systematic change in the long-term statistics of climate elements (such as temperature, pressure, or wind) sustained over several decades or longer (see http://www.ilrdss.sws.uiuc.edu). The economics of climate. 4 The Greatest Balancing Act Nature and the global economy David Attenborough and Christine Lagarde. 6 Carbon Calculus For deep greenhouse gas emission reductions, a long-term perspective on costs is essential Kenneth Gillingham. 12 Fifty Shades of Green The world needs a new, sustainable financial system to stop runaway climate change Mark Carney.Â 20 Straight Talk The Adaptive Age No institution or individual can stand on the sidelines in the fight against climate change Kristalina Georgieva 50 People in Economics City Slicker Chris Wellisz profiles Harvardâ€™s Edward Glaeser, who sees urbanization as a path to prosperity 54 In the Trenches Going against the Tide Brazilâ€™s Ilan Goldfajn explains why central bankers ought to follow. The Economics of Climate Change in the Asia-Pacific region. The shaded areas of the map indicate ESCAP members and associate members.Â While the knowledge base on the economics of climate change is still evolving, national best practices in the use of economic approaches are emerging across the region. Enhancing regional understanding in this area will allow policymakers to prioritise the optimal mix of low cost and efficient abatement and adaptation initiatives.Â Estimates suggest that the introduction of the new national ETS in China would potentially double the total value of ETSs and carbon taxes globally to about US$100bn. Additional economic benefits depend on how the revenue collected is used. Book description. There is now clear scientific evidence that emissions from economic activity, particularly the burning of fossil fuels for energy, are causing changes to the EarthÂ´s climate. A sound understanding of the economics of climate change is needed in order to underpin an effective global response to this challenge. The Stern Review is an independent, rigourous and comprehensive analysis of the economic aspects of this crucial issue. It has been conducted by Sir Nicholas Stern, Head of the UK Government Economic Service, and a former Chief Economist of the World Bank.