Greening Economy, Graying Society

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GREENING ECONOMY, GRAYING SOCIETY

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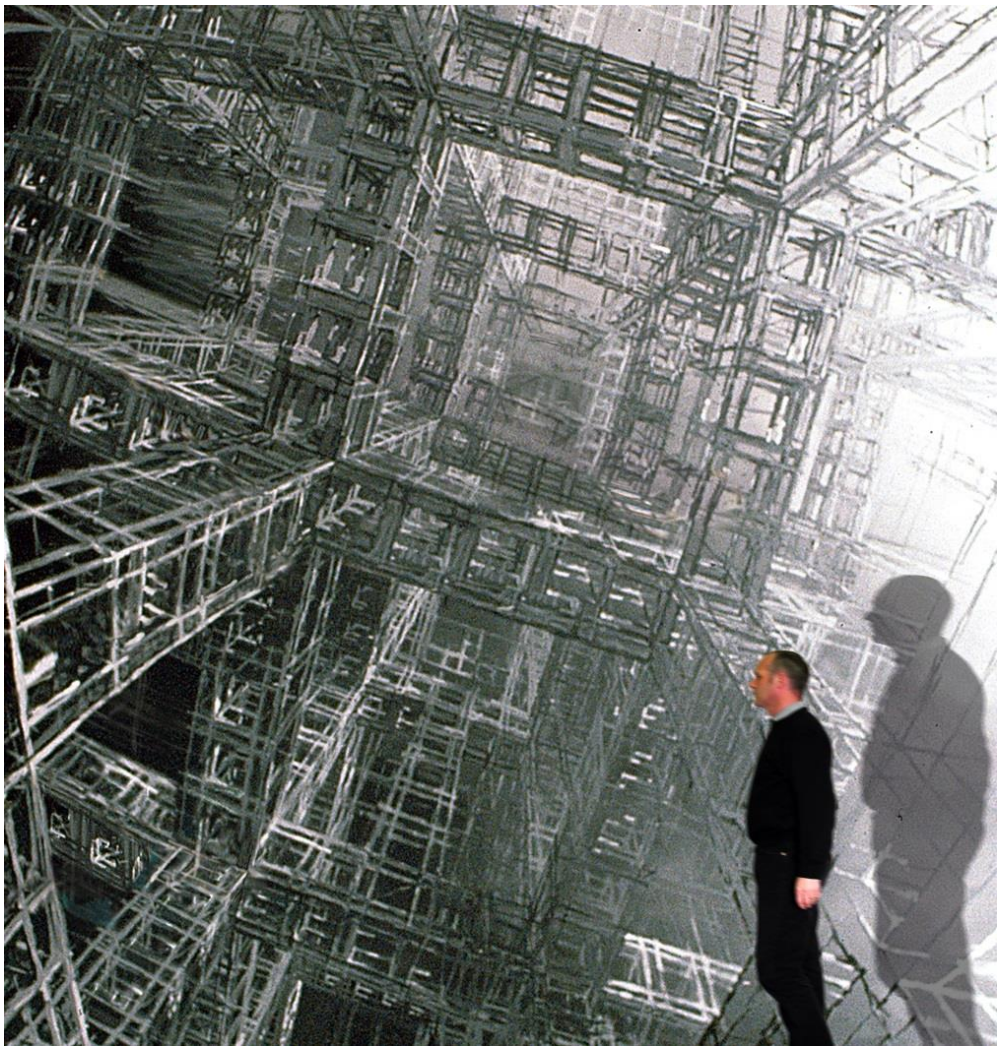

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Contents

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Common sense is not so common.

Voltaire

Preface

The world economy is affecting ecosystems in a way that puts future living standards at risk. Important issues include global warming, fading resource stocks, scarce water supplies, and decreasing biodiversity. It is broadly accepted that the future of our planet should be one of our major concerns. But when it comes to concrete policies, most clearly those related to climate change, grave difficulties arise. This may come as a surprise. In fact, it should not be surprising. Forward-looking and green policies have always proved to be demanding and controversial. At the global scale, national policy difficulties are only compounded. There is not sufficient consensus across the different countries.

World society is not very dynamic in problem solving. Rather, it is graying and inertial, cultivating conservative views and institutions. Economic interests and political perceptions diverge widely across countries. While the potentials offered by green technologies are huge, institutions have not yet adapted to meet the challenges. The political debate lacks sufficient focus; it includes very diverse opinions and notions on admittedly complex issues.

It is true that the most prominent sustainability policy, climate policy, combines the most difficult and complex conditions for policy making in a single subject. Correction of a big market failure, international consensus building, long-run planning, major uncertainties, huge equity concerns, and very heterogeneous country interests are ingredients that would bedevil any political decision.

On the bright side, concepts such as "green economy" and "sustainable development" have prominently entered the political debate, documenting the rising number of bridges between economy and ecology. Resource-efficient technologies are increasingly being developed and applied. Yet, while everyone would highly welcome political solutions to the climate

problem, accepting their consequences is much less widely embraced. These include significant reductions in natural resource use, especially with fossil fuels. They also entail acknowledging responsibility for past emissions and obligations to other countries and future generations. Consistent sustainability policies require a framework and an institutional setting that has yet to be built and globally implemented. Such a framework would enable policymakers exploiting the huge potentials for greening the economy.

Many scientific and applied contributions on sustainability have already been published. But the majority of the advocated policies have not been implemented; major problems such as global warming have not yet been properly addressed. It appears that sustainability policies are not attracting sufficient political support. By pointing to the profound problems inherent in policy making in this area, this book explains why this is the case. It also provides the elements needed to increase general understanding and to find political consensus.

Compared to the much broader scientific contributions on sustainability, some authored by large numbers of international researchers in different disciplines, the present book takes a more modest approach. It draws on selected research results to explain the most important sustainability issues from the point of view of economics. The book points at central underlying problems and misperceptions with the aim of increasing ambitions and rationality in political decision making. It reflects the high complexity of reaching sustainable development, which will require the contribution of social sciences involving many different perspectives.

The book uses neither formal models nor mathematical equations. These can be found in the underlying original academic works cited in the references. The approach follows that of the famous economist Alfred Marshall, who advised using formal analysis until the results were fully derived but then to "burn" the mathematics, translate the conclusions into normal language, and illustrate them by "examples that are important in real life." In following this procedure, this book aims to make the economic approach to sustainability attractive for a broader audience and a useful input to policy making.

PART I

Transition towards sustainability

Chapter 1

Big challenges, small efforts

The overuse of natural resources is the major impediment to sustainable development. But implementing new ways of production and consumption to reduce the environmental impacts of our economies poses big challenges for the world society. One of the broadly accepted mechanisms for changing fundamental economic relationships is technical progress. Innovations are not only crucial for development; they also have the potential to direct an economy towards a greener and more sustainable future. Many efficient solutions to green transportation, heating, and industrial processes already exist or are close to market maturity.

However, letting the economy float in a direction entirely dictated by technical progress will not necessarily prove fruitful; progress is not per se guided in a sustainable direction. Moreover, progress also has a destructive side, harming existing structures in order to create room for new activities. To provide useful guidelines and incentives for innovators, a set of sustainable conditions has to be provided by policy. In this way, the efficiency of natural resource use and fairness towards future generations can be better ensured.

Referring to the huge potential of new technologies and the required guidance by policy, Nobel laureate Paul Krugman concluded his famous New York Times essay on the green economy by saying "all we need now is the political will." Unfortunately, however, the will to meet the big challenges of sustainable development is still very limited. Relative to the size and importance of the sustainability challenges, efforts still remain relatively small on a global scale. There are several major reasons why current

political efforts are often lacking; the present book aims to explain them in detail in twelve chapters.

The first main issue preventing the implementation of green policies is the complexity of underlying matters. Sustainability is a highly demanding topic. It requires actively seeking a balance between the needs of present generations against the needs of future generations. It presupposes long-run thinking, involves many uncertainties, necessitates international agreements, and affects the distribution of world income and wealth. To build a sustainable world economy involves many different tasks and can only be approached gradually, through continuous efforts. It requires consistency of political conditions over a very long run, which is difficult to achieve in modern societies. The question to be addressed is how the world economy can further and durably improve human well-being on a finite planet. Many ideas have already been presented, many policies advocated, some measures implemented. But how do we start the process really going, how do we choose the best policies for the future?

In the past, the world economy mainly developed along a quantitative direction. More inputs were used, more output got produced. But recently, several sectors, regions, and countries have started to redirect the economy; they point towards development with a constant or decreasing input of natural resources such as fossil fuels. In this way, wealth is becoming increasingly reliant on inputs such as technology, knowledge, and skills. Less material is used, but in a more productive way.

Another major problem of green policies is expected economic costs associated with a long time horizon and non-negligible uncertainties. To illustrate the task for stylized economic development, let us compare the different avenues to economic success with climbing in a mountainous region. One can imagine two specific routes for gaining altitude. The first route relies on abundant and cheap natural resources, the second one on capital formation, education, and technical progress.

Changing an economy from a resource-intensive route to a resource-extensive one naturally entails several doubts and questions: is the second mountain to be climbed of equal height? Can the second route be climbed as fast as the first? And is the traverse to the new route technically feasible

and economically viable? There is still widespread belief that in changing the routes, we face substantial economic losses. However, more optimistic assessments are increasingly emerging in science and in the public. Various researchers predict that the second route leads to an even higher mountain and that, between the two routes, there is an ascending traverse. In this case, sustainable development is both an efficient and fair choice for present generations.

Another important obstacle to achieving sustainable development is the need for internationally agreed-upon policies. How can decisions be reached, how can good agreements be favored? In an ideal economy, good decisions are rewarded, suboptimal decisions get punished, and all this happens through competitive markets. The market mechanism is anonymous and relies on the autonomous actions of a large number of market participants.

The corrective force of competition also applies, but to a much lesser extent, to politics and political decisions in a democratic system, because elections provide a reward and sanction mechanism. However, the intensity of competition is relatively low. Governments, parties, and coalitions are limited in number and are elected only once in several years; they usually provide bundles of different policies in which green policies may be subordinate. Unfortunately, corrective forces definitely do not work in the context of sustainability, because excessive global market failures and severe common goods problems are at play. We have only one planet; there is simply no competitive mechanism that can cure bad decisions.

Referring to these main sustainability issues, explanations have to start with the question of the quantity of natural resources used by the economy to produce a given level of well-being. If a relatively small quantity is used, capital, knowledge, and education have to compensate for lower resource use. Our perception that lowering the resource intensity of economic development is costly has to do with our strong focus on current conditions, which we often take to be persistent. Put differently, we have to highlight that our intuition and our capacity to build expectations about dynamic changes of the economy in the future are in general very limited.

Because economic relationships analyzing sustainability are difficult to model and understand, mechanistic and purely static rules of thumb are often used. They provide a simple framework for thinking about the issues and communicating them. For example, the rule of thumb of so-called "growth accounting" suggests that when one input is decreased, we get less output. This is not wrong as a hypothetical exercise but by no means describes reality in an accurate way. The main reason this diverges from reality is that when one input is decreased, the other inputs do not remain constant but do in fact change as well.

As an example of the problems with mechanistic rules, consider the case of fossil fuels, which are currently an important input. When such a central input is reduced, growth accounting predicts high output losses. But the analysis remains purely static and partial. It is not considered that other inputs are affected by lower use of fossil fuels as well. Notably, energy reductions make it more attractive to build and use more capital. Yet, this kind of dynamic substitution — building on capital, knowledge, and structural change — is completely ignored with static growth accounting.

When mechanistic rules of thumb are adopted, attention of individuals and policy makers is focused on short-run costs and biased against dynamic gains. In this way, the flexibility of a market economy in the long run is heavily underrated. To get a feeling for the claim of high flexibility in the long run, we can compare different countries, because their current state is the result of country-specific development in the past. Through such an international comparison we see that living standards are not linked to resource use. For example, several European countries enjoy high income but exhibit relatively low per capita carbon emissions. By contrast, other countries use much more natural resources but do not reach European income levels.

More generally, it does not hold true that the countries with the highest abundance of natural resources generate the highest living standards. Quite to the contrary, many regions with only few valuable raw materials and rather unfavorable natural conditions host countries with high income and wealth. This may be termed a "scarcity paradox": When humans are not served abundantly by nature but have to start on scanty

ground they may, under favorable conditions, develop economies and institutions that are very successful in the end. By contrast, cheap ecosystem services can lead to a digression from a path to economic success.

Another reason for huge difficulties in implementing green policies is that not all countries and voters feel they are immediate winners; many remain uncertain about their relative position with and without the policy. There is enormous diversity of interests and value systems across the globe. Governments of many advanced countries argue it is expensive to redirect their economies, emerging economies aim at developing in the way they were shown by the rich countries, and developing countries are mainly concerned with getting support for necessary adaptation.

The international political process is neither very dynamic nor innovative. Of course, this cannot be expected given the complex decision process involving a multitude of different nations. Consensus building on an international level is thus quite naturally a very complex issue. At the present time, there is no forceful and reliable green leadership on a global level. For example, the big and politically strong countries are not the leaders in climate policy but rather the stragglers. This has fueled rather negative short-term expectations for substantial progress in fighting global warming.

A more optimistic vision of a sustainable future relies on the observation that technical, economic, societal, and institutional changes sometimes happen quickly. Examples are the use of smartphones and the internet, which changed the supply side of the economy; swift changes in public attitudes towards smoking is an example on the demand side.

Thus, development may become nonlinear, with small impacts gaining economic momentum and having large effects in the end. What helps such "speeding moments" is the effect of individual and country behavior on the behavior of other individuals and countries, so-called "network externalities." For example, with the proliferation of a new form of communication, people may adopt the new technology because they perceive an individual advantage from doing so. In a global world offering communication on a large scale, such speeding moments are even more pronounced.

Current climate policy offers a unique historic opportunity for reaching an ambitious international climate agreement. Once a new global framework is established, the dynamics of greening economies can be very effective. But achieving an international consensus is by no means trivial. International free-riding is still attractive whereby countries may try to rely on the efforts of the others. To prevent such behavior and to enforce a regime switch, increasing costs for uncooperative behavior could be considered.

Carbon tariffs for imports from non-participating countries is a currently available measure that has been discussed in the public as a means to enforce global carbon policy. This reduces the countries' gains from free trade but increases efficiency and fairness among domestic and foreign competitors, who then operate under the same conditions. Specifically, for the domestic market, the uniform conditions can be generated when taxing imports from countries with insufficient climate policies or from those lacking them altogether.

Another less extensively discussed but probably more effective measure is taking legal action against free riders on international climate policy. Of course, this requires that the damages from global warming be sufficiently scientifically proven, but this might be increasingly feasible with steadily improving methods of measurement. The basis for possible litigation is clear, at least; the international goal to limit global warming has been decided on and confirmed by all nations globally and thus has international standing.

Even if rather unconventional for environmental issues, in other fields such as the financial industry legal action has proved to be effective for enforcing policies internationally and changing business behavior. The costs of legal cases for firms and possible arbitrariness may of course make such procedures problematic. But changing the worldwide direction of carbon emissions by establishing international legal standards is probably more cost efficient than restricting free trade by new cross-border taxation.

Considering these rather drastic options for advancing international climate policy, one might revisit the original problem of sustainability and fundamentally inquire into the right policy responses. In public debates

we will always be confronted with views that sustainable solutions are infeasible, very costly, unfair to the poor, or highly uncertain. The present book attempts to explain why and how these issues are the most crucial to understand when making political decisions. Redirecting a polluting economy towards a sustainable development path and the various elements of climate policy, as an important example, are subject of Chapters 2 and 3. They complete part I "Transition towards sustainability."

Part II presents different "elements of a sustainable future." Equity is developed as a major concern in implementing sustainability on a national and an international level in Chapter 4. Population growth and its relationship to sustainability are treated in Chapter 5. There it is shown that another mechanistic rule, the so-called "IPAT" formula, often used in this context is highly misleading.

A separate important topic in dealing with sustainability is uncertainty, which is addressed in Chapter 6. The complexity of this issue does not justify ignoring it, as is done in many mechanistic decision rules. The question is how to rationally deal with uncertain outcomes.

In general, individuals like to avoid risk and uncertainty. They are willing to give something up, that is they are willing to pay, in order to reduce the risks. That is the business rationale of the insurance industry. Global warming is an example of a case where laissez faire (not changing the economy) increases uncertainty, while reducing emissions actually reduces uncertainty at the same time. Hence, in order to limit environmental risks, more stringent climate policies would be warranted. The reason that this crucial insight is not yet broadly implemented in policy is discussed in Chapters 6 and 7. There, some reflections on more personal attitudes are summarized under the heading "sustainable lifestyle."

The third part of the book covers the important application of sustainability goals in policy. It first raises the more normative question of what should constitute economic development in the long run. It then treats the problem of short time for problem solving in Chapter 9. When climate policies are still politically challenged it is mainly because they are oriented towards the long run. Policies that generate costs in the present and benefits only in the distant future are not embraced by policy makers.

Moreover, like all policies, climate policies change economic structures, usually creating winners and losers. Even if losses are not particularly high, they can generate significant political resistance.

To balance gains and losses of green policies and to put forward adequate redistribution schemes, good institutions and a deep societal consensus are needed. Complex policy problems should be addressed by good governance. But what is often problematic on a country level is even more difficult on a global level. Even when it becomes increasingly clear that existing economic development is unsustainable, political decisions remain highly inertial. Given that the potential for greening is huge, the willingness to adopt sustainable solutions should be supported more forcefully by political decisions. However, these remain rather inflexible in a world society, which is often driven by habit persistence, short-run orientation, uncertainty, and failure to take responsibility

It has been found that nations fail because of bad institutions; world society might fail for the same reason. But interestingly, what can be successful on a country level may be harmful on a global level. In particular, when national institutions favor domestic investment but at the same time an overuse of the global commons, the country model is not a role model on the global level. Explanations for this are offered in Chapter 10.

The final chapter of the book is dedicated to the most important part of sustainable policy making. Recent voter surveys in Europe have shown that people would like to change virtually everything without amending anything. However, one cannot change the world by doing nothing; this attitude and behavior are highly inconsistent. When it comes to sustainable development and climate policy, many seem to act and talk in a contradictory way. While most support the general necessity to undertake sustainability policies, concrete political measures are rarely adopted.

Increasing general knowledge of the basic economic fundamentals and clear presentation of the consequences of the different policy measures appear to be effective in decreasing the ambiguities. Once the dynamic aspects of the problems and a rational response to uncertainty are better understood, the chances of achieving necessary agreements can be improved. In climate policy, the time to build international consensus is

very limited. One can even speak of an historic window, which is small but offers an immense new dimension to international policy making.

This book is a contribution to possible solutions for long-run sustainability problems using modern economics. It aims to show that the economic contribution to sustainability is much broader than commonly assumed and includes moral aspects of life and social responsibilities. In addition, the book applies and clarifies important issues of resource use, which are at the heart of economic science.

It might be interesting to note that in classical economics, natural resources were usually treated as a crucial input to the economy. Accordingly, the natural environment was a central part of the entire economic system. Hence, the current sustainability debate actually follows a long tradition. However, in the course of time, and especially with increasing industrialization, the role of natural resources was increasingly ignored, and so matters remained for a long time.

The space exploration programs after the World War II first suggested it might be possible to escape Earth's resource limitations. Only with the oil price shocks in the 1970s did the natural environment reappear as a major economic topic and political challenge on the general agenda. The first photographs of Earth taken by spacecrafts in the 1960s suddenly visualized the physical limits of the planet, giving rise to the idea that the Earth itself is just a spaceship with clear physical boundaries.

The book analyzes the effects of these boundaries in economic terms. It explains the basic substitution principles guiding economic dynamics, revealing that static and mechanistic frameworks are not useful as guidelines for policy. The book explains how excessively low prices for natural resources are neither optimal nor sustainable. The transition to a sustainable economy should be gradual and steady, avoiding major economic shocks. As sustainable solutions should be based on fairness and equity criteria, good governance anchored in reliable institutions is key.

Because scientific conclusions have to be ultimately communicated to a broad public and appeal to common sense, the book avoids the difficult modelling language which has become an integral part of standard economics. Nevertheless, the arguments and conclusions are based on

such formal models. The interested reader is referred to the cited literature appearing at the end of each chapter.

The challenges in reaching a sustainable economy are big; political efforts thus far have been rather limited. Given the long-run and inertial effects of today's decisions in energy and climate policy, it seems worthwhile reconsidering the basic problems involved with and prospects for building a world economy that is intrinsically compatible with its natural environment. The book concludes that a smooth transition to sustainability is possible, but that it needs time, steady efforts, and stable guidance.

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Chapter 2

Redirecting a polluting economy

It is widely accepted that sustainable development requires better protection of the natural environment. To save the world's ecosystems, voluntary actions by individuals and firms are useful and necessary. But they are neither sufficient nor effective enough without government regulation. If the private sector did enough on its own there would be no problem of sustainability. Free access to the use of natural resources induces an overuse, harming ecosystems and, with them, the economy. For this case of so-called "common goods," markets alone cannot deliver acceptable results because property rights are not well defined.

When some costs of private activities are not included in market calculations, we have so-called "negative externalities." Environmental pollution is a typical example; those who bear the cost of pollution receive no compensation through the markets. Hence, private costs of polluting activities are lower than costs for society so that markets alone cannot provide optimal results.

The provision of common goods and the elimination of externalities require common action. Climate change is a classic problem of a global commons whose solution lies in collective decisions. Public policy must establish rules for resource depletion and pollution control; it needs to further incentivize firms and individuals to increase their efforts for sustainability, ensuring that those contributing to common goods are rewarded.

Regulations of markets include pollution standards, taxes, and permits or subsidies of alternatives to natural resource use such as carbon-free technologies and materials. Mitigation of climate change requires sig-

nificant reduction of greenhouse gas emissions. From a macroeconomic perspective, the relevant question is how the use of natural resource affects income and economic growth. Despite increasing awareness of possible "green growth," it is still widely believed that green policies, in particular climate policies, generate significant economic costs.

Of course, it is the duty of economists to remind policy makers that most policies come at a cost. Pure win-win situations are rare; it is usually not possible to generate only winners from green policies. Achieving a green economy necessitates consideration of possible downsides. However, it has become commonplace to exclusively focus on possible problems and costs of sustainability policies and to neglect chances and opportunities, which actually increase as the time horizon is extended.

To understand the costs of green policies, it is indispensable to understand the scope and effects of substitution. In the present context, substitution shows how natural resources, especially fossil fuels, can be replaced in the economy. A widespread misperception is that only energy can substitute for energy. This mechanistic view ignores the far-reaching flexibilities in production and consumption. For the substitution of fossils, other inputs such as capital and labor and more general mechanisms such as new technologies are available. The insulation of a home involves substitution of capital for energy, while improving vehicles' fuel efficiency is substitution of knowledge capital for energy. These examples also make it clear that using more energy does not generally increase the use of the other inputs such as labor.

A deep and crucial issue, which is related to substitution, is the impact of energy use on income and growth. It has been broadly noticed by the general public that the oil price jumps of 1973-74, 1978-80, 1989-90 and 2004-08 were all followed by a worldwide economic downturn. Many have thus concluded that high oil prices are a threat to global prosperity.

But, in fact, the widespread perception that economic growth is closely and universally linked to intensive energy use does not hold true. First, all the mentioned economic downturns were caused by a multiplicity of factors; the collapse of the Bretton Woods system in the early 1970s and the financial crisis in 2007/8 were at least as important as the price of

oil. Second, recessions are short- and medium-term phenomena; analyzing growth effects requires looking at a longer time horizon. In the long run, capital buildup and technical progress are the crucial drivers of development. Third, overnight energy price shocks as in the 1970s have to be distinguished from gradual, steady price increases, which can be better included in planning. Interestingly, in the period 2004-08, the drastic increase in the oil price accompanied a booming world economy, which was ultimately hit by a financial, not an energy, crisis.

At first sight, increasing carbon and energy prices appear to be a curse, certainly not a blessing. Accordingly, it is widely argued in public debates that cheap and abundant energies fuel the growth process while low energy input harms both living standards and economic growth. In this respect, there is much agreement between highly disparate players such as oil companies and limits-to-growth proponents.

Because the link between energy and growth is very complex, it has been suggested to simplify matters by applying an accounting procedure, so-called "growth accounting." The rule mechanically decomposes economic growth into the growth rates of the inputs labor, capital, and energy. It predicts that if everything else remains unchanged, energy growth is good for economic growth. Although this is not incorrect, it does not explain anything; it is a tautology. There are several major objections to thinking about the issues in this way.

First, the assumption that "everything else is equal" is not innocuous; it even misguides our way of thinking. Most importantly, energy use has a direct impact on investments and innovation as described by one of the most influential economists of the 20th Century, Nobel laureate Sir John Hicks. Very early on, in 1932, he identified an effect he called "induced innovation." A change in input prices, he found, is a spur to invention, and furthermore innovations are directed towards the factor whose price increases over time. Applied to the sustainability problem, induced innovation suggests that rising resource prices foster additional innovation, which improves resource and energy efficiency. As not only innovations, which reflect an increase in knowledge capital, but all kinds of capi-

tal can raise resource efficiency, the generalized term "induced investments" can be used in this context.

The purposeful use of capital, i.e. the shifting of consumption into the future in order to increase the productivity of the other factors such as resources and energy, is a main contribution of economist Eugen von Böhm-Bawerk. In his book “Capital and Interest,” first published in 1921, he calls this "roundabout production." Better known but along the same lines is Michael Porter’s more recent so-called "Porter Hypothesis." His essay on “America's Green Strategy” states that stringent environmental regulation can increase social welfare and net benefits of firms. It is assumed that high prices for environmental services induce innovatory activities which increase the firms' competitiveness.

Second, a steady increase in energy input over a long time period starting now is not a relevant option; rather, we have to think about how best to use the available energies. The mechanism that is unambiguously driving economic growth is the accumulation of capital. In fact, capital is growing over long periods of time in the form of physical, human, knowledge, and social capital. But could the economy grow in other ways than by just accumulating capital? With the recent shale gas boom, the dream of unlimited, cheap, domestic, and reliable energy has experienced a revival. There is nothing wrong with the dream. But there is no such thing as a free lunch. Natural resource use and energy conversion are costly; the correct price should include the social costs of resource use, in particular the pollution of the environment.

For consumers, a low price is obviously nice. For society, cheap is not always best, because there are also the producers and the common goods. It is certainly not best when part of the private costs is not reflected in market prices. Also, induced innovation effects supporting growth will not arise when energy is cheap. It is, however, possible to support innovation with separate specific policies. An increase in energy use has been observed in the past, but a steady and permanent increase in energy use is neither a likely nor an attractive option for the future. For importers of fossil fuels, another effect becomes important: if they spend less for imported energy, they have more left over for other inputs, for example for

investment in research and infrastructure. Finally, resource booms have often had negative effects on the quality of political institutions, which has been referred to as the "resource curse" in the literature. Because good institutions are crucial for development, it has been observed that many resource-abundant countries have experienced relatively lower growth instead of higher growth.

We conclude that using a simple link between input and output to show that energy is "good" for growth is highly misleading. Like other energies and the factors labor, capital, and technology, fossil fuels are an input providing services to an economy. If energy input decreases while the other inputs remain constant, it is true that an economy cannot avoid a declining income level. Using less of any input decreases the output. Known as the static or level effect, this effect is intuitive and well understood.

What short-run analysis and growth accounting completely ignore is what changing energy use triggers in the economy, in particular in connection with capital investments and innovation. Capital formation itself depends on important variables such as energy and should therefore be fully explained by theory. To get the full picture, one has to include the dynamic effect of energy, that is, the effect of energy use on the capital build-up. Relating the issue to the substitution of energy inputs, it is crucial to distinguish between the short and long run. The more demanding question pertains to the dynamic or growth effects of energy use. For the sustainability debate we have to understand whether and under what conditions the economy experiences a positive growth effect that counteracts the negative level effect. Level and growth effects of energy have to be carefully distinguished.

Analyzing the effects of energy on long-run development requires looking at a cross section of countries. Substitution, capital buildup, and energy-efficient innovations need time. The state of an economy today is the result of specific long-run development under given conditions for energy supply and prices. Cross-country comparisons show that various countries with low energy use and high energy prices have performed economically well, while many low energy price countries, especially less

developed oil-producing economies, persistently show low growth rates. In particular, Scandinavian countries are doing very well economically, where fuel prices are not low but relatively high.

In my paper “Energy Prices, Growth and the Channels in Between” I look at many developed countries over different growth periods and find support for the result that higher energy prices do not hamper the growth process. In the long run, increasing energy prices and decreasing energy use even have a positive impact on capital accumulation and growth. Put differently, high energy input discourages and crowds out investments, which are central to the growth process. This corresponds to the previously introduced "scarcity paradox," which is due to distinct effects: lower energy use leads to a reallocation of inputs toward capital accumulation and higher capital accumulation entails higher growth, which may be associated with higher welfare. As growth is costly, it is not directly related to social welfare and economic well-being. But because of positive learning effects with capital accumulation and pollution associated with energy use, for example the greenhouse gas emissions of fossil fuels, a positive relationship is very likely in this context.

That high energy prices can be good for growth might sound provocative at first sight. However, it is quite obvious that previous intuition relied overmuch on the business cycles, especially in the 1970s, and not on long-run growth experience. The energy-growth nexus is crucial for determining the costs of green policies. To properly calculate the costs of climate mitigation, one has to get the economic fundamentals right. Rethinking the issues in terms of theory shows that the result of a positive impact of energy savings on growth is directly related to many past contributions in economics.

Of course, empirical results should always be cautiously interpreted, especially in the context of macroeconomics. In the present case this interpretation contends that, in reality, there is no evidence for a positive causal relationship between energy and growth; rather, the evidence supports a negative causal relationship. This holds true at least for the wealthier countries, which are requested to reduce their carbon emissions in the future for solving the climate problem. Developing countries might need

relatively more energy to fuel economic growth, because basic infrastructure requires substantial energy input. But for them it would appear most promising to use a lot of renewable energies instead of fossil fuels; these transmit intensive stimuli for technological progress and thus allow for learning effects that are productive for the development of the whole economy.

Decreasing energy use and increasing fossil fuel prices will direct economic development during the transition to sustainability. In general, costs of green policies are much lower than often perceived. A main argument supporting this contention is that for long-run substitution processes, many dynamic forces such as investment and innovation help to moderate the costs of policies. The pure factor time is important for the whole process because capital formation takes time. Moreover, investments and innovations are known to entail positive learning effects, which support economic growth.

Taking innovation and investments into account, a sustainable development path becomes economically very attractive once it has gained sufficient momentum. But the process needs to get started and be consistently pursued. When learning effects are redirected quickly during the transition, the intensity of policy measures can be reduced after a first phase. The contribution of Daron Acemoglu, Philippe Aghion, Leonardo Bursztyn and David Hemous entitled "The Environment and Directed Technical Change" studies this topic in an economy with clean and dirty sectors and sector-specific learning. The authors show that sustainable growth can be achieved with a temporary taxation of dirty innovation and production. The transition is less costly if it is effectuated earlier, because then the clean sector gains early momentum and can better compete with a dirty sector which relies on a large knowledge base accumulated in the past.

Still, in many countries with low or very low energy prices and fuel subsidies, substantial price increases seem to be politically infeasible or at least very difficult, even when other countries have seen price increases with little adverse effects on their economies. Reducing the use of an important input like oil causes changes in consumption and production that

are certainly not negligible. However, many powerful new technologies are readily available as substitutes, for example for mobility and heating. It thus appears that especially for the developed countries, the required adjustment is feasible and the costs of implementing it are limited. The next chapter on climate policy extends these conclusions by focusing on the sustainability problem of global warming.

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Chapter 3

Climate policies

An internationally leading newspaper writes that at the climate summits, the international community has to show where its priorities lie: economic growth or the protection of the climate. Based on the results of the previous chapter, we conclude that this is not a relevant trade-off. It is necessary to distinguish between short-run effects of climate policy, where substitution possibilities are low, and the long-run effects, which include induced capital formation and technical progress.

Here, the crucial issue is whether substitution of fossil fuels is sufficiently effective and not harmful to the economy in the long run. This has to be measured against the backdrop of the benefits of sound climate policies, which are the reduction of climate change and its negative consequences for the economy. The strict limitation of global warming is now an internationally agreed upon and confirmed target.

It is the duty and the merit of the Intergovernmental Panel on Climate Change (IPCC) to provide the world with a scientific analysis of the current knowledge on climate change and its environmental and socio-economic effects. Thousands of scientists from all over the world contribute to the IPCC by assessing the most recent information produced worldwide; objectivity and completeness are ensured by broad and regular reviews.

Further integrating the contribution of economics, the "Stern Review," produced by a team led by Lord Nicholas Stern, concluded that inaction in climate policy will entail high economic costs in the future. Stern has framed the expression of climate change as the "largest ever market

failure." One of the strengths of the study was the forceful communication of its message to the broader public. The Stern Review recommended carbon taxes and carbon trading to reduce greenhouse gas emissions. It found that the world economy can lower carbon emissions at a significant but manageable cost. The Review concluded that early emission reductions are needed to reduce excessive climate change.

A large number of diverse economic contributions on climate change have been published before and since the Stern Review. A pioneer among climate economists is William Nordhaus, who developed broadly known integrated assessment models, labelled "DICE" and "RICE," capturing the interplay between economics, energy use, and climate change. Active climate policy is generally recommended in climate economics literature, but the stringency of "optimal" policies varies across the different studies. In fact, accepting the internationally agreed upon target of maximum 2 degrees Celsius global warming actually implies the size of global climate policy. In this case, economics has to concentrate on providing the knowledge of how to minimize the costs of climate policy and how to frame international patterns of burden sharing. This alone is difficult enough.

In order to assess the policy costs we can build on the analysis of substitution and induced investments of Chapter 2. To continue the previous discussion, it is instructive to relate climate policy to traditional resource economics, analyzing effective and optimal depletion of resources such as fossil fuels. In their seminal contribution entitled "The Optimal Depletion of Exhaustible Resources," two leading resource economists, Partha Dasgupta and Geoffrey Heal, show how capital accumulation can compensate for decreasing natural resource use. They find that for continuous growth to be feasible, capital and natural resources need to be good substitutes as inputs in production. This means that is not too expensive to produce the same amount of output with less and less resources but more and more capital. In this case, the gradual replacement of fossil fuels is smooth and the costs of carbon policies remain moderate.

However, many empirical studies estimate that capital and natural resources are complements rather than substitutes, suggesting that the

substitution process is not straightforward and carbon policies would become costly. If these included the entire effects of climate mitigation, this would indeed be grounds for broad pessimism.

To shed a more positive light on matters, some authors have adopted a pragmatic solution. It consists of asserting that there has always been and always will be some technical progress, even when theoretical models do not cover the aspect. This reasoning is motivated by the seminal contribution of Nobel laureate Joseph Stiglitz entitled "Growth with Exhaustible Natural Resources: Efficient and Optimal Growth Paths," in which the positive effects of technical progress on growth with resource exhaustion are derived.

Recent theory has made a further central contribution in this context. It was derived how to effectively characterize and explain technical innovations in terms of economic theory, treating them as a specific type of investment activity. In so doing, economic predictions about sustainability in times of increasing fossil fuel prices and rising carbon prices become more precise and better founded.

Focusing on technology allows for tackling an additional problem of theory, which is to determine the type of capital that will still be abundant in the future. In fact, a problem of the substitution process in traditional models is that physical capital, like natural resources, is bound to the use of material. But material is ultimately limited in supply. In order to dissolve the link to material and to do justice to the increasing importance of technical progress for development, sustainability research has shifted the focus from physical capital to knowledge capital as a substitute for natural resources. Then, the concern over limits to the supply of materials on a finite planet loses its importance. The new modeling approach has yet another effect. Focusing specifically on the research sector in the economy, the analysis of the different economic sectors and structural change becomes crucial. What had earlier been considered complicated for modelers has turned out to provide important insights into an economy in transition towards sustainable development.

In the paper entitled "Sustainability and Substitution of Exhaustible Natural Resources," written by Sjak Smulders and myself, it is shown that

sectoral change supplements input substitution and technical progress very effectively in achieving sustainable development. We conclude that continuous economic growth can be achieved even with limited scope for input substitution. Notably, when prices of natural resources increase, we witness higher growth in resource-efficient and innovative sectors compared to those sectors which are intensive in resource use.

These insights from theory have been used to calculate the effects of envisaged climate policies in different countries. The quantitative models used for this purpose are more detailed than the ones usually employed in pure theory. They do not claim to predict the future accurately. Rather, the models are intended to show the net effects of policies such as the climate policies being simulated in this case. That is, they describe future development with and without climate policy, using expedient assumptions and taking advantage of all available information.

Because economic growth is crucial for well-being in the long run, it is instructive to compare the effects of climate policy in low-growth countries to such policies in high-growth countries. In the contribution coauthored by Roger Ramer and Florentine Schwark entitled "Growth Effects of Carbon Policies: Applying a Fully Dynamic CGE model with Heterogeneous Capital," we look at a wealthy country with relatively moderate growth rates, Switzerland.

We derive that in such an economic environment, substitution between sectors and inputs caused by ambitious carbon reduction targets is relatively smooth, such that the economy can cope with the changes relatively well. Compared to development without climate change and in the absence of energy scarcities, active and ambitious climate policy generates moderate but non-negligible costs. The annual growth rate of income is lowered by a very small and insignificant amount, even when decarbonization is undertaken at an ambitious pace.

The study result - that it is possible to meet relatively stringent reduction commitments with moderate economic costs - is mainly obtained because induced innovation and investments counteract the negative effect of lower fossil fuel input, as explained above. Furthermore, innovative and capital-intensive sectors are found to improve their position in the in-

ternational markets. Moreover, much innovative activity, a low share of heavy industry, and largely carbon-free electricity production help the transition process. If ambitious climate policy in a rich country is coupled with low economic costs and economic success, it sends a clear signal to those emerging economies considering undertaking climate mitigation. This is important because these countries are becoming increasingly central for global climate policy and an international climate agreement.

Can the result of moderate policy costs be directly translated to all emerging countries? Clearly not, but the methodological approach can be transferred and applied to different data and policies. China, a prominent case, has seen high growth rates of the economy over the last years. Accordingly, our results with respect to climate policy for China are somewhat different; see my paper coauthored by Lin Zhang on "Carbon policy in a high-growth economy: The case of China." In this economy, under normal assumptions, the costs of a drastic climate policy are significantly higher. This is because with high economic growth, a large amount of additional capital and induced innovation is needed to compensate for non-increasing energy input. Also, the country currently has less scope for energy-efficient sectors to expand at a rapid pace.

But it should be noted that the baseline calculations for the case of China are built on very cautious assumptions. If we have faster technology development in the energy sector or, alternatively, rising energy prices in the reference case without the policy, the net costs of active carbon policy are reduced significantly. Notably, an assumption of favorable technical progress in the energy sector allows welfare costs of carbon policy to be halved. The consideration of induced innovation has a major impact in a high-growth economy like China: with lower innovation effects, the cost of carbon policies rises significantly, while a high innovation effect can even entail economic benefits of climate policies in the long run.

It must be acknowledged that a general policy strategy relying on enforced quantitative growth like the one in China must in fact conflict with strict climate policies, because these require certain inputs to be used in constant or even decreasing quantities over time. If China's past growth strategy becomes a role model for other emerging economies, which will

make a large part of future world growth, one would indeed have to worry because of carbon emissions. However, as soon as quality aspects of growth gain in importance in emerging economies as well, for example in terms of better air and water quality, the tradeoff between carbon use and development is naturally moderated. Air quality in big cities in emerging economies, for example Beijing, has long been a cause of concern, but the effects of the extreme levels of pollution on daily life can now be seen more and more clearly. The extreme air pollution induces many inhabitants to change their routines to allow for a normal life to go on beneath the toxic shroud. Also, health problems are drastically increasing, making the benefits of active environmental policy become obvious.

An important aspect of climate policies is their strong impact on the relative position of North and South. Many lesser developed countries are more vulnerable to climate change due to their geographical location and their high dependence on agriculture. Adaptation to changing climate conditions is relatively easier for highly developed economies because capital and knowledge are more abundant there.

Given the unequal impact of climate change on developed and less developed countries, it has even been publically debated whether direct transfers from the North to the South would be more helpful for the South than climate mitigation. Assuming that climate policy is very costly and that foreign aid is effective in promoting growth, this could indeed be the case. But both these assumptions are not corroborated in the real world.

Accordingly, in the paper "Effective Climate Policies in a Dynamic North-South Model," Nujin Suphaphiphat and I use a dynamic model to derive that climate mitigation is actually more efficient for both North and South. Specifically, we find evidence that the North's climate mitigation policies are more efficient than direct income transfers for less developed countries, because they affect not only the consumption levels but also the growth rates of the economies. Moreover, there is a direct benefit of climate mitigation for the North. Also, transferring income between different economies generates efficiency losses which are absent in the case of climate policy of the North.

This is not to say that development aid is not a desirable instrument for many other reasons, e.g. humanitarian ones. But the paper shows that it appears useful to complement traditional policies with active climate policies to strengthen the support for less developed countries. The model results continue to hold when we extend the basic model by introducing international trade, polluting resources, and credit constraints into the model.

The North-South perspective reminds us that active climate policies have growth effects, which will be more important in the long run than the direct cost effects dominating the political discussion. First, climate mitigation will boost investment rather than consumption. People will put solar panels on their roof rather than go on holiday for example. Second, it will boost growth because it dampens the negative impact of climate change on production and consumption. The crucial thing to understand here is that this is in comparison to a development in which consumption is reduced by climate damages.

Effective climate policies are global and need to be decided through international negotiations. The task of reaching a new international climate agreement is immensely difficult due to the unequal costs and benefits for the different countries, the long time horizon, the involved uncertainties, and the difficult international decision process. The offer of side payments and the credibility of threats to restrict trade with non-signatory parties are more complex in the climate context than for other international frameworks. In the literature on international environmental treaties, the search for self-enforcing agreements has dominated. However, according to the Durban platform climate agreement, the climate coalition now encompasses the whole world community; it explicitly says that the new agreement will be "applicable to all Parties." For the development of a common policy for all countries, equity and fairness principles have proven to be an important issue, to which I turn in the next section.

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Part II.
Elements of a sustainable future

Chapter 4

Equity, a major concern

Equity lies at the heart of the sustainability problem. Most importantly, sustainability aims at avoiding unequal treatment of different generations. By taking responsibility for long-run development, we intend to care for future generations in an equitable and fair way. This implies a path of the economy with constant or increasing living standards in the future.

Considering current generations, another huge equity concern is world income distribution. It turns out that whether or not active green policies are in place strongly affects individual living conditions. Notably, it is especially striking that without appropriate climate policy, less developed and vulnerable countries will suffer disproportionately; conversely, with strict climate policies, highly polluting countries and income classes will have to carry a larger burden, depending on the effective policy scheme.

The recent report of the Intergovernmental Panel on Climate Change (IPCC, Working group III) summarizes why equity plays a crucial role in formulating international climate agreements. Equity is related to ethical principles constituting a useful foundation for burden allocations in the context of climate polices. Also, sharing the burden of policies equitably relates to already existing international treaty commitments, providing a legal justification for equity. Finally, a fair arrangement is more likely to be agreed upon internationally and implemented domestically. Equitable

burden sharing on a global scale will thus be necessary if the climate challenge is to be effectively met.

One of the most drastic economic consequences of climate change is that its negative impacts are highly unequally distributed between the different world regions. Countries with an exposed geographical position and little capital for adaptation measures will suffer most. In fact, the costs of global warming are severely biased against the less developed economies.

The main reasons for this are significant differences in climate vulnerability and the internationally unequal availability of capital and knowledge for climate adaptation. Warm and coastal areas are particularly affected by climate change in the form of droughts and floods. Specifically, with increasing damages from hurricanes, a small number of countries, especially islands, will suffer much more than the rest.

Environmental disasters and weather shocks reduce agricultural productivity and damage capital, especially infrastructure. Capital is a crucial factor for both growth and climate impacts. For example, the 2010 floods in Pakistan damaged some of the most fertile agricultural grounds, causing losses of land, cattle, and crops, and they destroyed railway networks, canals, villages, infrastructure, roads, barrages, and other essential facilities. The Philippines had similar huge damages because of storms and flooding. Many geographically disadvantaged countries are less developed. They have little capital and technological know-how to protect and adapt infrastructure and agriculture. They are expected to have to make special efforts well over more than a decade to replace the capital that was destroyed by the recent storms.

Accordingly, there is empirical evidence for many developing countries that anomalously warm years reduce both their income level and subsequent growth. If developing countries have to use an ever-growing share of their scarce capital for the protection of the economy against rising temperatures, their development prospects become severely limited.

Because climate change will have a strong impact on the growth of less developed countries it is a major topic not only in environmental science but, at the same time, in development economics. It is often argued

that poor countries must first build up a minimum amount of capital to grow independently. If this threshold is not reached, the country remains in stagnation, a so-called poverty trap. In a joint paper with Simone Valente "Climate Change and Uneven Development," we show that because of increasing climate change, economic development is becoming even more difficult and the likelihood of poverty traps is greater. In this way the fight against poverty, disease and hunger is being jeopardized in many regions. Rich countries can better escape the climate-related capital loss through the use of new technologies or more effective protective systems.

With the emergence of new poverty traps, a particularly significant distributional impact of global warming is becoming visible: low-income countries that contribute the least to climate change are most affected in their economic development. Global climate change mitigation, therefore, not only contributes to improved intergenerational equity but also to combating poverty and global inequality. Studying the impact of climate policy on international income distribution is thus at least as important as doing sophisticated cost-benefit analysis, which is far more commonly used.

According to the different impacts of warming, efforts in climate change mitigation are indicated both for development and environmental reasons. By the reasoning above, they help to improve growth prospects in less developed economies. It is of course rational to ask whether growth and development targets could also be met by different means.

The strategy to give more direct aid as a substitute for active climate mitigation has had a clear effect on some countries' positions at recent international climate negotiations. But as described in Chapter 3, citing the paper authored by myself and Nujin Suphaphiphat, we show that active climate policies are preferable because they positively affect economic development in the long run.

Just as with unabated climate change, active climate policies involve major equity concerns. The long-run equity issue is: Do we want to be fair to our grandchildren? Moreover, do we want to be nice to the grandchildren of those who live in different parts of the world? The short-run equi-

ty issue is: Are climate policies perceived to be fair enough to be politically acceptable?

In general, the political acceptability of policy measures has much to do with their effects on income distribution. Distributional impact is always a prominent issue in politics but is certainly crucial in a world economy that is deeply divided in terms of wealth and pollution history. International carbon policy should be considered fair and equitable by the negotiating parties.

The Montreal Protocol on the Ozone Layer of 1987 is often seen as a successful implementation of the principle of equality in an international environmental agreement. But climate agreements are more complex, because the use of fossil fuels and their substitution in the economy are central. In the recently agreed-upon ”Lima call for climate action” in paragraph 3, it has been underscored that the aim is ”reaching an ambitious agreement in 2015 that reflects the principle of common but differentiated responsibilities and respective capabilities…” In paragraph 14, it states that each country will have to explain ”how the Party considers that its intended nationally determined contribution is fair and ambitious, in light of its national circumstances, and how it contributes towards achieving the objective of the Convention ...”

How can we determine whether a contribution is fair and ambitious? Naturally, we have to restrict the complex nature of the problem to a few crucial arguments. Nobel laureate Thomas Schelling developed the notion that so-called “focal points” can facilitate the negotiations on a complex problem, such as global warming, which is natural, special or relevant. He explains that these focal points are useful for reaching agreements as they are part of general expectations and thus suitable to building trust and confidence among the negotiating parties. In this sense, equity principles can be highly useful. But one has to carefully look at them and select and combine those principles which are appropriate for international climate policy.

An obvious equity principle is the “Egalitarian” Principle, which stipulates that every inhabitant of the planet be treated in an egalitarian way. But to which aspects should it be applied? The proposal for equal

rights to atmospheric resources has attracted considerable interest in the past. It was put forward by a group of emerging economies called BASIC. However, despite its simplicity and immediate intuition, the use of the principle in this form has major drawbacks. It can be argued that if it is applied to the atmosphere, it could also be applied to the all the other natural (and also man-made) resources, which is not a generally accepted conclusion. Markets and policies usually have different objectives; countries allocate their own resources in different manners. Hence, a principle not currently applied anywhere on a national level can hardly be the main guideline on an international level.

Even more importantly, an equal use of atmospheric resources does not consider the context of the fossil fuel use. With increasing availability of carbon-efficient technologies, carbon emissions are becoming less related to income and human well-being compared to earlier time periods. Every individual should be treated in the same way, but crucially with consideration of the context of his or her actions. In applying equity principles to climate policies, one should compare like with like.

In this respect, a central but often neglected issue for an equitable solution in climate policy is the impact of economic development, in particular technological progress. Notably, carbon emissions should be evaluated with respect to the technical opportunities available at the time of emission. Equity principles should be applied to allow for equal access to sustainable development, which crucially depends on the availability of technologies, in particular carbon-efficient technologies, but not on absolute emission levels.

To rephrase the basic insight here: the notion of an equal right to atmospheric resources does not consider the context of the resource use. In particular, over time, carbon emissions become less important for economic development due to technological progress. Therefore, fair burden sharing does not involve equal access to carbon space but rather equal access to sustainable development.

An important equity principle in politics is the "Ability to Pay" Principle. It states that the more one can afford to contribute the more one should do so. This is how most countries set their taxes, e.g. by progres-

sive income taxation. Applied to global warming, the countries' contribution capacity to solve the climate problem should have an impact on their real contribution to policy. Expressed in terms of the allowed emission quantity, the so-called "carbon budget," this requires the allocation of carbon emissions to be inversely related to the ability to pay for carbon emission reduction.

According to the broad and elaborate survey by James Konow entitled "Which is the fairest one of all? A positive analysis of justice theories," another important equity principle is the "Desert" Principle, which is also known as the "Merit" Principle. It identifies factors that justify higher individual claims, generally on economic income and wealth, in our context on the international carbon budget. Differences in rewards which are attributable to individual effort are generally considered to be fair. In the context of climate policy, efforts relate to contributions to carbon efficiency and carbon-saving technical progress. Some benefits of technology improvements are internalized, that is they create profits and employment in the innovating region. But this is by far not a sufficient reward; otherwise, the climate problem could easily be solved using market incentives only.

Finally, as every policy entails costs, the equity principle of policy cost sharing has to be employed in sustainability policy. It says that those who have to carry a higher cost of complying with the rules have to get some compensation. In climate policy, this is to do justice to the global distribution of abatement costs.

In applying these principles to international carbon policy, several side conditions have to be met. First, especially with international trade, one has to determine whether producers or consumers are liable for the consequences of resource use. The standards of income accounting and international law suggest that producers are responsible, but economics shows that in this case as well, consumers carry (part of) the burden of climate policy through (higher) prices of (imported) goods.

A related issue is whether we should apply the same equity principles in distributing the burden involved in mitigation and adaptation policies. It is generally agreeable to suggest that, for adaptation, we should more readily apply the ability to pay and the polluter pays approach, but

the present chapter is mainly concerned with more urgent mitigation policy.

In terms of timing, one has to agree on a date when the period of "excusable ignorance" stops, which means the point when historic responsibility and thus accounting for emissions start. For climate policies, the most obvious starting date is 1990, because then the international community agreed that active policy definitely be required. Currently, the period ends in the middle of the twenty-first century, because climate sciences have calculated feasible world carbon budgets up to this point. Additional climate services in the areas of land use and forest management should be included in calculating the entitlements, while fossil fuels for transnational traffic should be subtracted. A specific issue is future population growth. It seems natural to argue that responsibility for the future also includes sharing resources among a country's population.

What is needed to make equity principles operational in policy is a plausible mechanism for transforming abstract theorems into effective rules for international burden sharing. Ideally, we would use a common system or an indicator reflecting our views on equity. In my contribution in the journal ”Environment and Development Economics” entitled “Climate policy and equity principles: fair burden sharing in a dynamic world,” I have presented such a synthesis which allows us to eventually concentrate on a single variable, emissions per capita, and two parameters, the start of the “responsibility” period and degree of historic responsibility. The reduction of complexity is aimed at optimally supporting political decision making. This equity-based proposal can then be compared to the alternative solutions, which are, for example, equal access to carbon space or a carbon tax with tax revenue remaining in each country.

According to equal access to carbon space, every country receives a carbon budget proportional to its population, irrespective of the context of resource use. Another straightforward approach in international climate policy that avoids complexity is to impose a world minimum and uniform carbon price. This has recently been put forward by leading environmental economist Martin Weitzman in his broadly debated contribution “Can Negotiating a Uniform Carbon Price Help to Internalize the Global Warm-

ing Externality?" Following the proposal, and assuming full national use of tax revenue, every country receives a carbon budget proportional to its carbon tax revenues. Weitzman argues that this would avoid massive transfer payments between very unequal countries. Countries, especially high polluting ones, are more willing to implement climate policies in the form of a carbon tax if they are allowed to spend tax revenue domestically. On the other hand, from a more global perspective, it seems that high emitters should not necessarily be allowed to use the whole revenue domestically, because it is exactly these countries that mainly created the problem in the past. The implementation of a single world carbon price from 2020 on ignores any historic responsibility; greenhouse gas emissions prior to that date are ignored. Hence, there is a tradeoff for rich and pollution-intensive countries between their willingness to engage in stringent climate policies and their responsibility for past emissions. With the tax proposal, the earlier polluting richer economies get greater access to world carbon space than later developing economies. This will hardly be acceptable for the less developed countries, which are still a majority of negotiating parties.

In our recent paper (Bretschger and Mollet 2015) titled "Prices and Equity in International Climate Policy: A Broad Approach," we show that the equity-based proposal of the paper "Climate policy and equity principles: fair burden sharing in a dynamic world" constitutes a compromise between the purely egalitarian and the uniform tax approach. Compromise could be a good precondition for successful policy. What would it involve? In short, it seems fair that low emitters receive a moderately smaller carbon budget share than under the egalitarian regime, mainly because alternative green technologies are now available. Conversely, high emitters should get a higher than the purely egalitarian carbon budget share because they have to adjust most to the new carbon regime, that is they carry a higher cost of mitigation policy. The surplus is strongly limited, however, especially for very high emitters. This is the essence of my proposal which provides a solution in terms of simple numbers, yielding a clearly defined solution for the allocation of international carbon budgets.

A successful climate agreement will improve the chance for equal treatment of all generations. The aim of intergenerational equity is often linked to the goal of intragenerational equity. Notably, in their contribution "Human Development and Economic Sustainability," Sudhir Anand and Nobel laureate Amartya Sen argue in favor of "ethical universalism," that is an elementary demand for impartiality of claims, such that intragenerational equity becomes an equally important issue. In an ideal world, the coming decades would be characterized by convergence to a low-carbon society and to decent living standards on a worldwide scale. But to achieve reductions in the use of fossil fuels, an increase in their prices is needed. This, however, is often perceived as being unfair to the poor members of the present generations.

In his well-known book "Fuel Taxes and the Poor," environmental economist Thomas Sterner concludes that this fear is in general not warranted, basing his conclusion on many different country studies. It is found that fuel taxes are neutral or exhibit, remarkably, quite strongly progressive effects in emerging and developing countries. This means that richer individuals have to carry a higher tax burden than the poor, in absolute terms and relative to income. In fact, in less developed countries, the poorest households cannot afford to own a car; if the tax affects them it is mainly through prices of public transport. In some richer countries, like the US, taxes exhibit, however, very weak regressive results, which say that the income share spent for fuel is slightly decreasing with rising income. Here, the poorer households are also affected by a fuel tax in a noticeable way, but the unfavorable distribution effect is not very strong.

In many political debates, arguments are based more on biased anecdotal evidence of exposed individuals than representative numbers; the myth of regressive fuel taxes is very persistent. And in countries where fuel taxes are indeed regressive, the system could still be made progressive by a suitable use of tax revenues or by using other taxes. In general, one of the remaining tasks of economists is to inform policy makers that sustainability policies such as fossil fuel taxation need not be unfair to the poor of current generations. It depends highly on the design of the entire

tax system in a country; this system must be considered fair and equitable as a whole.

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Chapter 5

Population growth: What is sustainable?

At the end of the 18th century, Thomas Malthus predicted that population increase is limited due to a finite natural resource base; any population growth would sooner or later lead to "misery and vice." Accordingly, he thought there is a limit to population size, the so-called "Malthusian trap."

Since this famous and still widely cited contribution, historic development has shown that there is in fact no such trap. The principal factors that help overcome resource scarcity and food shortages are capital accumulation and technical progress, especially in the agrarian sector. World population is currently growing at a very high rate, the highest ever attained in history.

Of course, it is still true that society is confronted with an ultimately finite supply of natural resources and a limited atmospheric capacity to absorb emissions. More than the scarcity of arable land, the constraints on energy supply and the limited capacity of the atmosphere occupy the center of the current debate. Declining oil production in several regions, reports of proven reserves of natural resources that are lower than previously estimated, and the problems of global warming are clear indications of the boundaries set by nature.

The total use of natural resources and energies will have to shrink in future centuries, even though several energy and raw material deposits have not yet been fully exploited. This is a fundamental change in eco-

nomic history because until now the expanding world economy has relied on growing resource inputs. Hence, a classical theme of economics returns to the center of the sustainability debate: the relationship between population growth, the scarcity of natural resources, and long-run prospects for living standards.

The negative Malthusian perception of population growth is still broadly represented in the literature and policy debates. But, since the original conception that stressed the infeasibility of population growth, the tenor of the Malthusian argument in some quarters has changed to emphasize its undesirability. As a consequence, the question has arisen whether policy should actively limit population growth, even under the heading of supporting sustainability.

With human beings constituting an important part of nature, the question is obviously very delicate. Furthermore, every living person is by definition part of the problem, especially if he or she uses natural resources intensively. It is thus highly appropriate to take a fresh look at the issue, which is done in the following by starting with arguments supporting population policy and then by arguing why a change of perspective is called for.

From a mechanistic perspective, per capita use of natural resources and limiting population are interchangeable. The simple decomposition done in the so-called "IPAT" formula captures this mechanistic perspective. It says that human impact on the environment (I) is equal to population size (P) multiplied by affluence (A) and by technology (T), formally $I = P \cdot A \cdot T$. It is argued that an increase in population P increases impact I if everything else remains equal, hence running counter to sustainability. Or, by extension, if there is an increase in P, T must change considerably in order to keep I constant or even to reduce it.

As in the case of growth accounting, discussed in Chapter 2 on the redirection a polluting economy, this reasoning is highly questionable. Affluence (A) is usually measured by income (Y) per capita (which is then Y/P) and technology (T) is measured by resource use (R) divided by income (yielding R/Y). Now, one immediately sees that income Y and population P cancel in the equation, because they appear both in the numerator

and the denominator on the right hand side. We are then left with the result that human impact on nature *I* equals resource use *R*: a tautology. It is always true but does not introduce a specific reasoning that adds to our understanding. Implicit in the equation, and highly misleading, is the assumption that population, affluence, and technology are independent of one other.

Rather, these variables are highly interdependent in many ways. A prominent one is the effect of "induced" innovation, as introduced above in Chapter 2 on the transformation of a polluting to a clean economy. Another important issue is the impact of income and wealth on fertility, the so-called "demographic transition." Wealthier countries tend to have more singles and smaller families on average than less developed countries. Public social security and increasing costs of child rearing are among the main drivers of the transition. Thus, as with growth accounting for energy use, the mechanistic decomposition of an important relationship does not provide sufficient intuition to explain the real effects.

A decisive issue affecting the impact of population growth is its relation to capital accumulation, because capital and knowledge build-up ultimately determine economic growth. Interestingly, in the traditionally used models of neo-classical growth, which include capital formation, population growth is not favorable for development. This is because only physical capital such as machines and infrastructure is considered whereas human, knowledge, and social capital stocks are disregarded. With a growing population, physical capital stocks have to be shared among a rising number of people, because they are so-called "rival" good. It means that the use of the capital by one person affects the use by another person. To have less capital per workplace decreases labor productivity and growth.

However, recent growth theories have argued rightfully that forces pointing in the opposite direction are at least equally important. Here, it is stressed that basic parts of capital come in the form of knowledge capital, which is not rival; it can be shared by everybody, as well as by an increasing workforce. If new ideas come up, everybody can use them without

diminishing the knowledge of somebody else. With knowledge capital, population growth thus does not decrease labor productivity.

In addition, knowledge is produced in organizations such as research labs, which are labor- intensive. Hence, labor not only uses natural resources but also builds substitutes, including clean goods and green technologies, which decrease natural resource use. More people generate more ideas and include more innovators, such that the size (and the education) of the labor force affects the intensity of knowledge creation and through this the economic growth rate. However, are these new elements influential enough to change the general perception of population growth and resource scarcity?

In my paper "Population Growth and Natural Resource Scarcity: Long-Run Development under Seemingly Unfavorable Conditions," I analyze in a general framework how it may be possible to obtain positive innovation and consumption growth under free market conditions, provided that the population is growing and resource stocks are bounded. In order not to be overly optimistic, I use very restrictive assumptions, such as poor input substitution, increasing resource prices, and significant use of resources in the research sector. Key elements of the model include resource scarcity, innovation, and the decision of families to have children, where the number is shown to decrease with rising wealth, in accordance with the predictions and the observations of the demographic transition.

Even assuming quite unfavorable conditions for sustained growth, I find that issues that have previously been described as critical (or even lethal) turn out to be surmountable, neutral, or even positive under the assumptions of the new approach, which explains the qualification "seemingly unfavorable" in the title of the paper. In particular, it turns out that population growth is not detrimental for growth but is even needed to ensure sufficient innovation. In fact, it may help the economy during the transition phase by increasing the chances of developing efficient technologies.

My results are in line with earlier contributions, in particular with those of Julian Simon, who in his well-known book called labor the "ultimate resource." The conclusions are also in accordance to the findings of

Esther Boserup, who in the book "The Conditions of Agricultural Growth: The Economics of Agrarian Change under Population Pressure" shows the positive impact of population density on development in (poor) agrarian societies.

Hence, contrary to the general belief that population size is a global problem, one can show that a growing labor force can be compatible with the natural environment, provided that the increasing resource scarcity is fully reflected in resource prices. Put differently, the planet can support a larger number of people if they correctly observe the restrictions imposed by nature.

To put this into the right perspective, the current per capita use of global resources is comparatively low in countries with high population growth, while it is much higher in rich countries; countries with high population growth usually feature a very low environmental impact per capita, especially relative to the global commons. If the debate centers around cutting emissions by restricting population in developing countries, this would not have much of an effect; rather, population size would need to be restricted in richer countries, a proposal which is rarely debated.

It turns out that the so-called population problem is rather a behavior problem: To ensure sustainability, we have to steadily decrease natural resource use and to provide sufficient technical change. A transition to a long-run steady state with constant population, sustainable resource use, and positive consumption growth can be obtained through a demographic transition based on individual responsibilities.

This conclusion suggests that population policy is problematic not only because it affects family welfare and easily becomes paternalistic toward less developed countries, but also because it might be counterproductive with respect to economic development. To promote sustainable consumption, it is more efficient to foster innovation, raise the prices of natural resources, and increase living standards to induce demographic transition.

The contra-Malthusian results of recent research do not suggest a laissez-faire policy; rather, by emphasizing central mechanisms for devel-

opment and resource use over time, recent theories indicate that the debate on population growth and the substitution of non-renewable resources should focus on issues such as resource prices, sectoral adjustment costs, and the formation of long-term expectations.

The results show that raising resource prices and facilitating labor reallocation from knowledge-extensive to knowledge-intensive sectors, like high-tech sectors developing and applying green technologies, are the best means to support sustainable development. The removal of subsidies to energy production (such as those for coal and even oil in certain countries) as well as shrinking and structurally weak sectors emerges as a desirable course of action. A steady increase in resource prices is not seen as detrimental; by contrast, the contribution "Population Growth and Natural Resource Scarcity" shows that it helps the economy to adjust in continuous small steps to a sustainable equilibrium. Population is expected to stop growing whenever all the countries have reached a decent living standard on average.

For some countries like Japan, it is a shrinking population that will shape future development, posing very different but perhaps really severe problems, especially for old-age provision. By increasing the share of the inactive population, the graying society constitutes a big challenge for the economic pillar of sustainable development.

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Chapter 6

Uncertainty

In the past, environmental policies were usually implemented after environmental damages had become sizable and evident. Voters became alert to the damages and requested governments to act by signaling political support for their actions. For example, natural disasters led Switzerland to adopt a very strict Forest Act in 1876, protecting forests in a rigorous way. The regulation is an early example of a sustainability policy. It is still fit for purpose and thus is still in place today.

With other dimensions of sustainability, especially climate change, matters are more complicated. Climate damages involve a large degree of uncertainty and mainly accrue in the long run. Of course, we already have indications of the direction in which things are tending. The recent Typhoon Haiyan in the Philippines was one of the strongest recorded storms ever to make landfall. The surge swept away entire cities and affected several million people, leaving them homeless, displaced, or even dead. The unexpectedly severe storms in China in 2008 stranded millions of rail passengers and caused food shortages and power cuts in many parts of the country. But these events are still smaller in scope than what is anticipated for the future. They have not yet fundamentally affected public opinion on a global scale.

The difficulties of long-run planning with an uncertain future are neatly captured in the quip "Predictions are difficult, especially when they concern the future." But in truth, we often lack sufficient foresight. The

economic logic behind building optimal expectations for the future is that those who properly do so will avoid suffering from negative effects like market share losses. But this mechanism does not optimally work in the sustainability context because the involved time horizon is too long.

It is of course an almost impossible task to foresee development in the very long run. Many states and empires in the past had a favorable development for some time and thereafter declined. Nature and technology are the main areas where shocks and surprises will always emerge. Similarly, with sustainability there are many more complex issues than simply the long time horizon, such as uncertainty, impatience, redistribution, and collective decision-making on a global level.

Uncertainty about the future is one of the reasons for discounting future events. It means that individuals value identical events differently, depending on the time when they arrive; every event in the future automatically receives less appreciation. This, of course, contradicts the sustainability target, which says that the well-being of future generations should have the same weight as the current well-being. Accordingly, it has been stated that society as a whole is not entitled to use positive discount rates and policy should correct for individual lack of orientation towards the future.

The main field of application for such a correction is climate policy. Given the uncertainty of disasters caused by global warming, how should an economy appropriately balance its expenditures on consumption, investment, production, and emission abatement? How should the optimal growth rate and the optimal emissions reduction in the uncertain environment be determined? And in which way do these key variables respond to changes in the fundamental conditions in an economy? Many economists have based their recommendations for climate policies on models ignoring uncertainties. Of course, economic models must of necessity reduce the pervasive complexity of modern economies to a small number of well-specified analytical relationships. Also, uncertainty is a very difficult issue to handle in formal theory. Nevertheless, and this is crucial, it has to be very carefully considered how uncertainty enters into

our policy decisions. Incomplete information definitely needs to be part of the economic research on climate change.

Both the economic and the ecological parts of the climate problem pose considerable modeling challenges, given the various sources of uncertainty over a long time horizon. One solution is to resort to numerical simulation models, which have provided many useful insights concerning costs and benefits of climate policies. But they have also produced diverging results, and because of the models' complexity, the reasons for the different outcomes are sometimes difficult to detect. Hence, to gain further insights about the central mechanisms at work, especially those related to the uncertain nature of climate change, a climate economic model that provides thorough solutions for future growth and optimum climate policy including all aspects of uncertainty is especially important.

In the paper entitled "Growth and Mitigation Policies with Uncertain Climate Damage" coauthored by Alexandra Vinogradova and myself, we calculate optimal climate abatement expenditures in a world economy subject to major climate shocks that are uncertain. Specifically, we look at a growing economy in which the occurrence of natural disasters is random. The magnitude of climate damages increases with greenhouse gas emissions. Unlike other contributions to the literature, here the world economy does not entirely collapse after a catastrophic event; we consider development with recurring but nevertheless significant shocks over time. This reflects the most likely pattern of climate-induced events in the future. We show that the optimal policy consists of devoting a fraction of output to emissions abatement, a fraction which is independent of time. We also derive that more frequently occurring natural disasters and higher damage intensity have a negative impact on the optimal growth rate and call for more vigorous abatement policies.

The optimal consumption rate and the capital stock grow at the same rate until an event occurs, causing a downward jump for the whole economy. Using the theoretical model, we can also derive quantitative results. Specifically, choosing accurate parameter values, we show that optimum growth and abatement react sharply to changes in the damage arrival rate and damage intensity. Assuming that future climate-related dis-

asters and their damages increase significantly, more stringent climate policies with more resources allocated to emissions reduction turn out to be optimal.

While different approaches and climate models yield different conclusions for climate mitigation policy, they all have one common feature: Once uncertainty is taken into account, we need to enact more stringent climate policies compared to the hypothetical case of perfect foresight. The reason for this is relatively simple and well established in economics. Individuals are risk averse, which means that they are always willing to sacrifice something in order to reduce risks and uncertainties. This constitutes the business model of the insurance industry. Big natural disasters are too big to be insured. Nevertheless, we aim at reducing the uncertainty of outcomes such as climate damages, which can be effectuated by climate mitigation policy.

It is instructive to look at individual behavior in times of pandemics with uncertain outcomes, such as the recent pandemics involving swine flu or bird flu. Interestingly, there were major concerns and many people took considerable pains to avoid bad outcomes, despite low probabilities of individual infection. Likewise, many activities of governments, for example in the area of internal and external security, aim to reduce economic and individual risk and to increase certainty. Hence, risk and uncertainty should not induce political indifference and inactivity. Rather, exactly because we are risk averse, climate policy is rational and thus in order.

But is the fact of uncertainty really guiding current mitigation policy towards a more stringent direction? Not necessarily, because there is another less manifest aspect of uncertainty which is extremely powerful: the basic and fundamental uncertainty of voters about the necessity for any climate and sustainability policy at all. Of course, we are aware of the massive support in favor of mitigation policies from climate scientists. We also know about an extremely strong consensus among researchers supporting significant climate policies. But some degree of skepticism always remains; it is a normal aspect of our general thinking and even a crucial attitude for any scientific approach.

Basic uncertainty opens the door to a possibly very strong impact on public opinion. It has become evident that in order to delay or prevent active climate policies like fuel taxation, a political party or a lobby does not need to prove that climate change is not happening or that it is not caused by human activities. It is sufficient to spread general doubt about climate change by claiming that scientists are not united or by producing evidence showing different climate patterns in the past. The effect of cigarette smoking on lung cancer is a well-known example where exactly this sowing of doubt in the public was sufficient to delay anti-smoking legislation for decades.

Why are doubt and basic uncertainty sufficient to convince part of the voters to oppose action on climate policy? The reason lies in a combination of the topics treated thus far in this book: climate policy is perceived to be expensive, country interests are very heterogeneous, and the impact of higher prices for fossil fuels is considered to be unfair to the poor. I have already treated the response to these concerns but have yet to address an additional aspect crucial for individual decision making: the impact of a greening economy on individual lifestyles. This is the topic of the next section.

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Chapter 7

Sustainable lifestyle

Political attitudes and individual decisions are largely shaped by personal experience. Green policies affect not only the business environment but also daily life. If a sustainable lifestyle is not in line with the current conception of a happy life, an important reason for the lacking political will to implement green policies becomes evident.

A related issue is habit persistence, the reluctance of consumers and producers to change their habits. The French publisher and politician Emile de Girardin famously said that "everybody talks of progress but nobody gets out of their routine" ("Tout le monde parle de progrès, et personne ne sort de la routine").

It is in general difficult but not impossible to change the routine of the average voter. This requires a major impetus, backed by a convincing scientific or technological input. As described in Chapter 1 in the example of the voter surveys, people would like to change virtually everything in politics but, crucially, always without having to move themselves. Obviously, one cannot achieve a sustainable economy on this basis. However, ambiguities and inconsistencies appear to be a durable component of the political process.

In his book "The Conquest of Happiness" the mathematician, philosopher, and Nobel laureate Bertrand Russell states he does not aim at contributing to a profound academic discussion. Rather, he wants to compile some observations inspired by common sense in order to reach a broader audience; readers should be enabled to rethink established posi-

tions and explore new opportunities. The same approach is taken in this chapter, in a more narrow and modest context. I only summarize some thoughts from an economic perspective which may be crucial to understand individual attitudes towards green policies. Nevertheless, these attitudes translate into the costs of green policies, as individual valuation is the guideline in cost benefit analysis often used to evaluate public policies. Sustainability is similar in some respects to happiness. But as sustainability requires common action, it cannot be an individual target; rather, sustainability aims at providing durable happiness through a collective and steady provision of basic services such as those of ecosystems.

Countries are very heterogeneous, particularly in terms of resource abundance and economic wealth. Individuals also differ widely from one another. People adopt or develop a lifestyle that seeks to improve individual and social well-being and helps them craft an individual identity. It has been argued that international environmental agreements must not threaten typical national lifestyles and identities. National sovereignty has even been stylized as a basic principle for determining countries' climate policy. But this is not particularly helpful. Rather than national separation we need a broad international consensus on an acceptable attitude towards sustainability. If this eludes us, not only the lifestyle but the entire economic existence of vulnerable countries may be threatened.

Changing fossil prices will indeed affect individual consumer behavior in most countries. Yet in the individual microeconomic context as well, changes need not happen overnight. Time and adjustment over time are important factors. Transitions can be made over several decades. What are the individual costs of the long-run transition? If individuals have strong preferences for certain types of consumption, for example carbon-intensive heating and mobility, limiting this consumption implies high perceived costs.

The behavior of habit persistence is well known in consumer theory. Habit persistence argues for not changing consumer habits too quickly, while environmental damages and the involved uncertainties require the opposite: action directed towards changing consumer habits. Hence, there

is a major tradeoff in incentives. Thus far, the effect of stickiness has mostly trumped the demand for change.

A liberal attitude suggests not judging individual behavior by strict general ecological standards. Asking for voluntary action of an unwilling in public is a delicate matter, not well received in general. But, as is well known, individual "free" decisions depend on other people's evaluations; they may change as the context changes.

It has been noted that one of people's motivations in working and consuming is to seek higher status and improve their perceived social position. In this case, the outcome for society as a whole is not optimal, because these individuals impose negative externalities on others. In such positional competitions, people work harder, consume more, and pollute more extensively than they would under optimal conditions. Decreasing consumption and probably limiting their carbon-intensive lifestyle is then less costly in such a context, because individuals and their peers are affected to the same extent.

Here we encounter another interesting aspect of modern consumption, which is related to imitation, another characteristic of individual behavior. Increasing social integration, globalization, and new communication technologies have increased the size of the relevant peer groups for many people considerably. Consumption peers now include individuals from virtually the whole globe, all income levels, and all professional fields. For example, the preference for individual fossil-based mobility has been gladly adopted by consumers in emerging economies.

A faster adoption of a new lifestyle could also happen with a more sustainable consumption pattern, for example, with passive or even active energy houses, which produce rather than consume energy. But given globalized attitudes, in order to have a truly meaningful impact on individuals by changing their role models, it requires an immensely large scale and thus needs sufficient momentum. Still, it is true that carbon pricing comes at a highly visible cost while the benefit is much less evident. Exactly the opposite is true of the tiny hand computers anybody willingly carries around all over the globe. With these, nicely provided services come first, the bill comes later. This example neatly shows, however, that

if enough people are attracted, we obtain network effects, and the change in consumption habits gains momentum.

The question is how to obtain the momentum for a change in the use of fossil fuels. A worldwide uniform carbon price on an efficient level appears to be a good solution. The policy of setting the correct price for a scarce good or service corresponds to the procedure that international organizations usually prescribe for less developed countries with distorted markets. The message is "Get your prices right." Prices should reflect scarcities.

An efficient worldwide carbon price affects fossil-intensive lifestyles. But households and firms are free to adapt individually, depending on their preferences. Even if some individuals still consume much fossil fuel, on average, over the whole world population, human behavior is both efficient and sustainable.

Working on the assumption that consumption habits are very sticky, people have started to consider possible alternatives. If individuals are unwilling to decrease fossil fuel consumption, geo-engineering solutions at the end of the process gain in attractiveness. These include carbon capture and sequestration, solar radiation management, and cloud reflectivity modification.

Unfortunately, many engineering options are not technically mature. In addition, their environmental impacts are highly uncertain. Geo-engineering may reduce or postpone climate change for a certain period of time. But measures cannot be stopped later; once implemented, they are locked-in for a very long time period. Hence, should environmental damages from geo-engineering become visible at a later stage, prompting public requests to terminate them, we are then in the worst of all worlds: unabated climate change and environmental damages from engineering.

Another option, which has been prominently discussed by the two economists Klaus Desmet and Esteban Rossi-Hansberg in their contribution "On the Spatial Economic Impact of Global Warming," is to consider the option of large-scale migration across countries in the face of global warming. The authors explain that in the medieval warm period, popula-

tion density in the Nordic countries increased and Iceland, Greenland, and parts of Newfoundland became populated.

Hence, it is argued, another mass migration toward Northern countries could alleviate the effects of climate change. However, matters nowadays are far more complicated. There is simply no hope that mass migration between countries would be politically acceptable on a large scale. Worldwide, we not only see strict immigration laws but also extensive walls and fences to forestall illegal immigration. Hence, "moving to Greenland" cannot be seen as a viable answer to the climate problem. Interestingly, the term "Greenland," implying a green, pleasant, and fertile land, was never really an appropriate descriptor for the island. Rather, it appears that the name was coined at the time as a marketing device to attract settlers for strategic reasons.

Emigration in general comes at a high personal cost. Current productivity largely depends on local institutional and innovation networks, which cannot be easily transferred to a new place. Even the sometimes predicted productivity gains from global warming in the agricultural sectors of Northern countries are uncertain, because natural countervailing forces in the form of fires, vermin, and the like might emerge.

The Greek philosopher Aristotle's ancient but still very attractive notion of conducting a "good life" may still be useful for shaping individuals' aims. According to Aristotle, happiness is the ultimate purpose of human existence; it is the activity of the soul in accordance with virtue. This tradition attributes a strong role to individual efforts to conduct a life deserving of this description; but the impact of luck and external forces is captured as well.

Good life is self-sufficient; hence it cannot rely on external factors. The exercise of intellectual and moral virtue requires action, for example by assuming public duties and responsibilities. In a democracy, politics are a specific form of collective action, shaping the frames for individual activities and lifestyles by setting appropriate conditions and guardrails. In Aristotle's tradition, individual contributions and efforts in public life and politics are considered important. This is the subject of the next part of the book.

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Part III.
Policies for a sustainable future

Chapter 8

What should grow?

The broad project of creating a sustainable future aims at achieving a state of economy and society that can be sustained in the long run. The well-known "Brundtland Report" defines sustainability as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." The perspective adopted here concentrates on human well-being, seeking a balance between the different generations. The famous growth theorist and Nobel laureate Robert Solow frames sustainability as the "ability to maintain a developed state or to grow toward a developed state that can be sustained for a very long time horizon." To operationalize these states, one usually looks at average living conditions over a very long time horizon. Declining ecosystem services and environmental risks are a threat to future living conditions. Accordingly, the natural environment is an important determinant of such a state.

This general framing of sustainability requires important qualifications. How should we develop towards a sustainable state, can the world economy still grow in a sustainable manner, and is further economic growth desirable? Providing answers to these questions clarifies options, limits, and trade-offs for the future. But the issues are so broad and fundamental that any attempt to provide thorough and definite solutions is likely to fail. Still, important general statements are possible and warranted. The first question is how we should develop towards sustainability. The long-run target for the world economy should indeed be a developed

state because poverty may also be sustained, which is obviously not desirable. The main question is then how economies can grow and even grow out of poverty while improving the basic conditions for development that can be sustained in the long run.

In ecological systems, evolution and regeneration are given by biological laws. Natural regeneration is the guideline for the concept of the ecological footprint, where development is said to be sustainable when natural capital remains constant. For an economic system, however, regeneration is not given but flexible, which makes the concepts much more complex. Nevertheless, the economic part cannot be ignored in considering future living standards. A comprehensive view integrating economy and ecology requires determining the appropriate sacrifices of the current generation necessary to improve future generations' living standards.

In their article "An environmental-economic measure of sustainable development," Robert Cairns and Vincent Martinet derive a valuable theoretical concept of the limits to current consumption. Applying their theory makes it possible to determine a moving target for consumption flows in each generation. Sustainability is then feasible, provided the current level of wellbeing is lower than or equal to this target value. Not only society has to consume less than what is sustainable, but proper investment can increase sustainability in order to reach a higher sustainable development level. On the contrary, bad investment decision can jeopardize sustainability even if current consumption is sustainable. As this is basic research, further operationalization, concrete application to real economies, and derivation of useful guidelines for practice still need to be developed.

Another question often raised in public debates is whether further growth of the world economy is feasible, given that the planet is finite and natural resources are limited. Since the 1970s there has been a broad debate over the existence and nature of putative "limits to growth." A famous quote by social scientist Kenneth Boulding says that "whoever believes exponential growth can go on forever in a finite world is either a madman or an economist." Gladly noting the "or," the growth economist should justify the reasoning behind faith in unceasing growth; the topic constitutes one of the core contributions of economics to the sustainability

debate. The answer to the question of whether we can grow forever on a finite planet crucially depends on the question of what can grow in the long run.

The supply of material is bounded on planet Earth. Hence, growth cannot be based on something that is directly linked to scarce materials. But this kind of growth is neither appropriate nor necessary. In fact, the whole approach of sustainability can be seen as a counter position to assuming limits to growth. It is appropriate to refer again to the term "living standards," which most people in the world would like to see improve for themselves. Living standards clearly do have a material component but they are not equivalent to simple material use. The concept is much broader, and nothing in it indicates that the use of material can or must grow forever. Rather, there are strong indications that with increasing living standards, the non-material components gain in importance. This also holds true for production, where improved technologies can gradually decouple economic output from material input.

Knowledge capital and education can indeed grow further without visible bounds, in order to increase productivity and well-being. Sustainability captures the notion that economy and ecology can be compatible, provided that the crucial ecological conditions and restrictions are well respected by the economy and growth is based on non-material factors such as technologies and human skills.

If we accept the view that we can, in principle, grow indefinitely into the future, is it equally true that a market economy must necessarily grow in order to avoid a collapse? Are we forced by the market system to either grow forever or to collapse? Like limits to growth, this claim often appears in public discussions, creating quite a bit of confusion and undermining the general sustainability discussion. There is an empirical and a theoretical answer to the idea of compulsory growth. Taking the examples of big economies like Japan or Italy, we have observed virtually no positive growth rates for two decades. But there has been no sign of an economic collapse in these countries whatsoever, just economic stagnation. Hence, the position of compulsory growth in a market economy is difficult to defend.

Still, policy and planning in both countries set a clear target to improve living standards in the future, which leads to the theoretical aspect of the answer. If a country aims to grow, it intensifies the accumulation of capital by investing in infrastructure, machinery, education and technical innovations.

These activities need to be financed by the savings of the individuals. Hence, by deciding how much to save, an economy has a direct and strong impact on its economic growth. Of course, other conditions such as openness to world goods markets, competition in markets, and lean governmental institutions are also important for growth, since they determine the productivity of the investments. For a certain period of time, savings can also stem from abroad, but the domestic economy has to be sufficiently productive and growing to attract the funds.

The deeper wisdom behind the issue is this: Macroeconomic outcomes like economic growth result from intended actions of the individuals. There are never inherent necessities in the economy forcing us to do things we actually do not want to do. If we want a different development we can have it. "The future we want" is the title of the document adopted at the United Nations' Rio+20 conference, accurately expressing the aim to actively shape development rather than arguing about practical constraints. If a society actually aims only to maintain its standard of living, it can of course pursue that policy. But if there is broad societal agreement on further economic growth, as appears to be case for most economies, we have to further save and invest. What may prevent us from doing this? Of course, there is no guarantee of success if, for example, our public institutions are not efficient. Also, it is true that coordination failures in policy can hamper the process. But if we do not trust policy to manage basic societal coordination, we cannot discuss sustainability policy at all.

If we have the liberty as a society to decide about future growth, would a better decision be not to grow at all because this would bring us more happiness in the end? Would it be better for sustainability to maintain or even decrease living standards?

Such questions typically arise in a satiated environment, where people are used to a high living standard. In emerging and less developed

countries, these issues are never in the center of peoples' minds; it is quite the opposite. There, the need for economic development is not disputed. In China, economic growth helped to bring no less than 500 million people out of poverty in a few decades. Globalization helped the process, as it did with other growth miracles in Asia. The high cost to China's environment reveals that development has not been on a sustainable track, however.

Of course, open markets are not automatically good for sustainability. If natural services are undervalued and thus overused in a country, international trade can worsen the situation. But trade is not the real reason for the problem; it just amplifies an existing domestic problem. If this domestic environmental problem cannot be fixed, because, for example, the political system is not ready to implement the necessary measures, restricting trade may be in order. But this is usually not conducive to increasing living standards; it is normally bad for economic growth.

A very different concern has been raised in the sustainability debate, namely that with ongoing growth, future generations will be richer anyway. In this case, current sacrifices, for example in terms of climate policies, would mean burdening the relatively poor rather than the relatively rich. But the claim that economies will always grow automatically, even with ongoing global warming, is hard to defend. Many countries will have severe difficulties developing economically if the predictions of climate science are accurate.

Only world models with a focus on economic growth can provide answers about growth on a warming planet. They indicate that ongoing growth is by no means guaranteed, and for many climate-vulnerable and less developed countries, it even becomes highly unlikely. Through international goods trade and capital markets, the world economy is quickly affected when one country or region is hit by a major natural disaster.

The views on what should grow in a society and how fast will never converge completely. They do not have to. The important thing is to make sure that current generations shape development in an intended direction and that future generations are an important part of the considerations. If there is a general perception that income per capita should shrink

("degrowth") or that economic growth is unimportant ("agrowth"), it can be implemented.

But the truth is that there are currently no political majorities in favor of "agrowth" and "degrowth." Rather, one has to concentrate on the more important issue, which is indeed how we should grow, in which way we should develop. The old distinction between quantitative and qualitative growth is still useful. Development should go in a direction that increases the quality of our life, not merely swamps us with more material gadgets we do not really want in the end.

Economics has a role to play here; it can, for example, explain that long run predictions of increasing demand with decreasing supply do not make sense in a market economy. Markets are able to clear so that demand and supply go hand in hand. Moreover, economics should provide sufficient information about how different kinds of economic and social development can be achieved, so that the economy can serve the individuals in the best possible way.

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Chapter 9

Time for consensus

Achieving political consensus on framing long-run policies has always been time-consuming. Decisions in climate policies are necessarily directed to the long-run future. In addition, changing energy supply systems has long-run impacts. The choice of technologies today governs development for a long time; changing direction is costly because the economy is locked in with durable facilities and well-established networks.

Policies aiming at a sustainable long-run state are difficult, because in general governments tend to be pressured to deliver in the short run. This tendency has even increased recently. Business cycles, recessions, financial markets and employment are always first priority. This leaves limited room and time for sustainability policies and future-oriented actions. The French publisher Emile de Girardin's observation that "governing is foreseeing" ("gouverner c'est prévoir") has ceased to describe current reality because short-sighted voters, narrow political competition, and bad public management increasingly discourage the foresightful part of policy.

In a recent adaptation of Antoine Saint-Exupery's famous tale of the little prince, there is a planet of time where time itself is out of joint. It is described how the great Clockmaker, who was responsible for "keeping the planet's clocks set to the right time," had disappeared because he "has fallen victim to the evil promptings of the Snake."

As in this tale, planet Earth currently has a severe time mismatch. Current generations should make far-reaching decisions on global resource use, especially on climate policy, but it is questionable whether

they are really up to the task. It might be that reaching consensus will take considerable time, time we do not actually have. But it is also fair to say that without time restrictions, political decisions tend to be delayed to the indefinite future.

International climate policy is an urgent topic. Climate sciences have demonstrated that within a few years, we have to reverse global trends in carbon emissions. Cuts in emissions and emission peaks have to be effectuated soon if the target of a maximum global warming of 2 degrees Celsius is to be achieved, and of course even greater cuts are needed to reach the 1.5 degree Celsius target.

But the complexity of the negotiation issues, the asymmetric interests of countries, and the necessity to have all countries on board for a meaningful deal raise the concern that a forceful agreement will not be reached. A deal compatible with the 2 degree Celsius target may not be finalized within the internationally agreed time period. The current challenge is to propose a distribution of a given greenhouse gas budget across all nations that has the potential to be generally acceptable.

It is important that such a proposal does not involve overly high negotiation costs, because these might prevent the deal from being agreed upon within the remaining time period. Equity principles appear to be highly relevant as useful and time-saving guidelines for a feasible climate negotiation process. The 1987 Montreal Protocol on the Ozone Layer is often seen as a successful implementation of equity principles for an international environmental issue, but it is obvious that the costs and benefits in that case were also more favorable for reaching an agreement.

The earlier used “pledge and review” procedure for country abatement targets produced very unequal results between the parties, revealing strong tendencies towards free-riding. In addition, it was often unclear, specifically to the non-pledging countries, how the offers could be evaluated in an international comparison. Other options are to allocate carbon space equally per capita, following the proposal of the emerging economies of the BASIC group, or to implement a globally uniform carbon price, as proposed by Martin Weitzman in his paper “Can Negotiating a Uniform Carbon Price Help to Internalize the Global Warming Externali-

ty?" These plans are straightforward and would not need much time to be negotiated. But the discussion of equity in Chapter 4 described the distributional consequences of this, making clear that many countries will have reservations about the two proposals. As a compromise, Chapter 4 introduced the application of major equity principles. Ideally, this procedure generates an allocation of carbon budgets to the different countries which is considered fair and more broadly accepted.

The scientific logic with respect to timing suggests we first agree on the mitigation part of climate policy, that is the reduction of greenhouse gas emissions, and then find common rules for the adaptation to damages caused by the remaining emissions. But for a while the trend has run in the opposite direction: Policy has favored the path of least resistance. The reason is that decisions on the adaptation to the impacts of climate change are politically easier to achieve than decisions on abating greenhouse gas emissions. This is mainly since climate adaptation allows payments and costs to be delayed. Promises on future payments are not binding and are often not kept. Quite the contrary: emissions cuts are visible forms of political reorientation. Hence, it is a positive development that currently in climate negotiations the mitigation part of climate policy has regained priority. Naturally, it is valuable to further develop the adaptation mechanisms, not however as a substitute for climate mitigation but rather as a complement.

In general, to meet the given time constraints, it should be the aim to propose a solution for burden sharing in climate and other sustainability policies that is broadly considered fair, efficient, clear, and simple. What works within a country may possibly be delicate on an international level, however. All the major players, sovereign states in this case, must be onboard. A general rule for burden sharing, even if very sophisticated, can be seen as "dictatorial," insufficiently representing differing national circumstances. However, equity principles do in fact reflect national circumstances, but only those which are generally and globally accepted, like the "Ability to Pay" principle. Sovereign countries also typically feature impatient voters, special institutions, and conditions framed by their own history. It is truly questionable why these country-specific circumstances

should be acceptable to establish special country positions when it is about contributing to a global commons, where all individuals should be treated the same way. Nevertheless, in real politics there will always be pressure for not ignoring them completely, especially when major countries are involved.

The bottom-up approach currently taken in climate policy is a process with a pledge and review procedure for national contributions to international policy. This ensures that countries only commit to a global policy they are willing to implement on a national level. It fully respects national sovereignty. But it does not guarantee that the internationally agreed upon targets will be met. In fact, the current development suggests that the targets will not be met if the current plans for the pledges are not made drastically more stringent. Moreover, the procedure does not guarantee that countries will be satisfied with the contribution of the other countries, should some contributions be far below what is generally considered to be fair. As a consequence, convergence of country positions might take considerable time.

In our paper on "Prices and Equity in International Climate Policy: A Broad Approach" written by Janick Mollet and myself we show that the big emitters in particular need to become more ambitious soon if the 2 degrees Celsius target is to be met. What can convince the parties to do so? Most likely, it is public opinion and the public's conviction based on scientific information, which is credibly conveyed on a global level. To a lesser extent the motivation may be found in the possible threat of punitive measures like cross-border tariffs on carbon-intensive goods or legal action against free-riders of international policy efforts.

In conclusion, what is central to achieving a good climate agreement is a thorough review procedure for countries' contributions to mitigating climate change. The nationally determined contributions to global policy have to be made comparable in a systematic way. But this brings us back to the necessity for information that can be applied to all the countries, to the proposals that are universally accepted as fair, efficient, clear, and simple.

If a prescriptive top-down approach, framed by scientific input, cannot produce the worldwide consensus necessary for the provision of a public commons, it might be achieved through the indirect approach of a bottom-up convergence process. This consists of the country pledges of individual contributions on the one hand and a coherent international review procedure on the other. Of course, the review has to be based on scientific input, but it should also point at the relevant tradeoffs and policy options, so that political choices are still possible and can be based on accurate foundations. Policy ambitions can be raised by repeated rounds of pledges and reviews.

Such an international convergence procedure for policy targets will need intensive negotiation efforts. But it could ultimately produce more robust results than a pure top-down policy approach. In the ideal case, it should bring about what is really needed for the provision of a public commons: the consensus of a world as one.

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Chapter 10

Institutions matter, of course

Whenever we are confronted with correcting for major market failures and setting the basic prerequisites for market economies, we need efficient policies and smart public governance. This especially holds true when the global commons is involved. We strongly prefer institutions that establish accurate rules in a uniform and cost-efficient way. Good institutions have a major positive impact on wealth; bad institutions can block development decisively and for a long time.

In their well-known book "Why nations fail," Daron Acemoglu and James Robinson argue that "rich nations are rich largely because they managed to develop inclusive institutions at some point during the past three hundred years." By "inclusive" they mean institutions that enforce property rights, create a level playing field for firms and consumers, and encourage investments in new technologies and skills. The crucial point is that many nations past and present have failed because their extractive economic institutions do not create appropriate incentives needed for savings, investments, and innovations. Extractive political institutions support these conditions by cementing the power of those groups that benefit from extraction.

These results can be applied to the field of sustainability to yield important insights. Investments in new technologies and skills are at the heart of the sustainability debate, because knowledge is an important determinant of living standards. Moreover, green technologies need to be implemented in order to improve the compatibility between economy and

ecology. Thus far there is no contradiction between institutions good for growth and those conducive to sustainability. But in looking at institutions in the context of the global commons such as the atmosphere, it turns out we actually have to rethink the terms "inclusive" and "extractive." Where national playing fields encourage the overuse of global goods, institutions can no longer be naturally labeled "inclusive."

In fact, in terms of natural resource use, many successful nations have behaved in a rather extractive manner. By contrast, less developed countries use, on average, much fewer resources per capita; with fewer intervening technological systems in many developed countries, the population lives closer to nature. Friedrich Nietzsche's "transvaluation of values" concept is applicable here, if slightly highfalutin. It aptly points to the idea that so-called "inclusive" institutions happened to encourage a development which turned out to be "extractive" with respect to nature. What we ultimately need is "super" inclusive institutions that consider investments in private capital and investments in natural capital alike.

How then can international institutions be built and improved on in order to establish good policies for the global commons? In their book, Acemoglu and Robinson state that it would be "heroic" to formulate general recommendations for policies encouraging change toward inclusive institutions. But, ideally, these would be highly useful for the sustainability issue. In order to avoid a future transvaluation of values from inclusive on a national level to extractive on the global level, one should try to transfer success models of institutions from individual countries to a global level. Naturally, in the process, one should try to avoid making the sort of major mistakes that were made in the past on a country or international level.

Given the intensity and increasing globalization of trade and the rising importance of international environmental problems, global governance is one of the big policy topics for the future. Consideration of possible redesigns of global institutions is thus certainly warranted. It is not competition but cooperation between nations that has to be achieved. It is true that the United Nations provides a well-developed frame for international negotiations and decisions. But the process of debate and the proce-

dures of decision making within this institution and the subordinate units need to be carefully reconsidered and improved.

The currently dominant institutional system of international decision making at the United Nations is unanimity, which is inherently difficult to achieve. Assuming that all nations act in a selfish way, only policies ensuring that everyone is a winner can be approved. Economists have labeled this situation "International Paretianism," according to the contribution of Italian economist Vilfredo Pareto; see the contribution by Posner and Weisbach entitled "International Paretianism: a Defense." For climate policy, this would mean that every country without exception would have to achieve a more favorable benefit-cost ratio. This, however, is not acceptable for distributional reasons. It would involve a massive redistribution from less developed countries to developed and oil-producing countries. This would occur because less developed countries would benefit majorly from climate policy, while the others would incur costs of climate policies in terms of higher abatement expenditures and lower export revenues.

An equivalent massive redistribution in world income would be effectuated if countries with an interest in climate policy were requested to buy and shut down fossil resource stocks. Besides the distributional consequences, such a policy would also be critical with respect to the question whether future generations would comply with the obligation they inherit from their ancestors. Even if current generations agreed that resource-poor countries should buy resource stocks abroad and not use them for extraction, future generations in the formerly resource-poor countries might be tempted to nevertheless exploit the stocks. Moreover, future generations in the formerly resource-rich countries might be tempted to expropriate the stocks from the foreigners to extract again.

It is instructive to analyze global resource stocks with respect to the existence of legal property rights. Natural resources such as fossil fuels are usually national property. By contrast, carbon space and other international resources are global commons without property rights. Knowledge stocks, which are productive capital accumulated by firms and public in-

stitutions, are subject to property rights as far as they are protected by patents.

In general, markets can only deliver optimal results when property rights are well defined. In this case, there is no conflict between the self-interest of agents and public welfare. But establishing property rights for carbon space different from those for other resources is difficult because of a lack of consensus across countries. Neither property rights for resources nor those pertaining to knowledge are easily renegotiated on an international level.

Shifting the costs of climate policies to the less developed part of the world is also critical in terms of ethical principles of responsibility. All nations, especially rich nations, have to examine their historic responsibility for the state of the planet. Of course, rich nations have not made equal use of the global resources in the past. Also, developed economies host institutions that have advanced technical limits and contributed to global technological progress, which can be applied worldwide. But this is an expected aspect of development that has generated much revenue and income. Hence, it cannot be used as an argument against being held responsible and liable for the downsides of development, for example in the form of pollution.

A related challenging aspect of institutions and development with natural resource use is the phenomenon of the so-called "resource curse," which was already referred to in Chapter 2. It has been found that countries with abundant natural resources have experienced periods with lower growth than comparable countries without natural resource stocks.

A key reason for this finding lies in an additional effect of natural resource abundance, which is the impact of natural resource revenues on the quality of institutions. Institutions are mostly affected negatively when they are of critical quality in the first place. Specifically, in some oil-producing countries, oil revenues were used to establish and sustain undemocratic governments with "extractive" institutions. In other regions, resource wealth has created resource conflicts and wars, which also create unfavorable institutions and adversely affect economic productivity. In all

these cases, the causal chain goes from natural resources to bad institutions and from there to a bad economy.

The important paper of Christa Brunnschweiler and Erwin Bulte entitled "The resource curse revisited and revised: A tale of paradoxes and red herrings" shows that the resource curse is not something which is inevitable. In fact, a different development emerges when natural resource wealth occurs in a country with good and robust institutions. The examples of Norway and Botswana show the causal chain from resources to good institutions to a good economy.

Still, good general institutions are not sufficient for a positive economic outcome; this also needs adequate resource-linked institutions and good governance. The example of the Netherlands in the 1960s shows that even in an established democracy, intensive natural resource use might retroact to the economy, an effect that has been called the "Dutch disease" effect.

To prevent a resource-rich economy from following a suboptimal development path, appropriate public policies can be implemented. Most importantly, they have to regulate the way the returns on natural resource sales are invested. Regulation should also cover how natural resources are exploited, for example when the natural environment is negatively affected. For the demand side, that is resource use, various measures such as taxes, subsidies and permits have been discussed in earlier chapters. Furthermore, an extension of liabilities can be evaluated, assigning greater responsibilities to polluters with respect to environmental damages.

Well-suited institutions on a global level would ideally help implement adequate sustainability policies. Standard economics describes how it would be an efficient approach to get the prices right and thus to put an optimal price on carbon and other greenhouse gases. In terms of international trade relations, it would be preferable not to implement any further policies. But if a fair and ambitious climate agreement cannot be reached, cross-border measures may be evaluated.

The often hotly debated policy instruments are cross-border taxes or tariffs, levied on the carbon content of imports. If countries have largely different climate policies in place, such a system can restore equal condi-

tions for producers in the different countries. But the policy is quite costly. It requires applying many different tariffs for the different goods imported from various countries.

An emerging but even more controversial measure affecting firms' behavior is to involve another type of institution, the intervention of courts and judges. For private companies, the extension of litigation to fields such as environmental damages can become costly and risky. However, even according to existing law, if environmental standards are implemented, controlling the firms and punishing violators must necessarily be implemented as well. Could it also be used to push countries into adopting more rigorous climate policies?

This raises several concerns. In his well-known book "The Failure of Judges and the Rise of Regulators" Andrei Shleifer finds that judges have "weak incentives" due to job security and lacking rewards for good performance; furthermore, he explains, they "lack sufficient knowledge and specific education." But it is natural to ask whether this judgment of the judges is in fact warranted and, if so, whether this does not apply to all civil servants, especially those working in regulation. Conversely, one can credibly argue that the limited role of judges and regulators may systematically attract individuals with an ideological bias towards contributing to the common good.

Finally, the effectiveness and legitimacy of litigation in an international context can be discussed. In several cases in the past, national legislation has been enforced by taking legal action against foreign companies. That can be very effective but appears to open the door to certain arbitrariness and might even involve a touch of bribery. However, if climate policies are seen as vitally crucial when international agreements are implemented, but certain countries are not willing to contribute to the global common, such legal measures might remain an option for further consideration.

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Chapter 11

Sustainability policies

The task of identifying efficient and widely acceptable policies for sustainability is complex for many reasons. The global dimension of the different sustainability problems gives rise to substantial communication and coordination issues. In the most prominent case of climate policy, international cooperation to agree on a common policy has proven to be very cumbersome and difficult. Moreover, the global setup provides incentives for international free-riding, which means that every country can profit from actions of the others without contributing itself to problem solving.

On the international level it is thus advantageous for proposed policies to embody some countervailing forces against overly narrow self-interest of the different countries. Carbon tax revenues or initial allocations of carbon permits can be distributed in a way that provides incentives to countries to behave cooperatively.

The same applies for policies at the country level. Countries are not homogeneous but consist of different interest groups which have an interest to free-ride on the country's environmental policies. When tax revenues are retained internally, they can be used to compensate interest groups or to offset other taxes; similar goals can be pursued by distribution of permits.

Environmental and climate policies in particular are still generally perceived of as entailing substantial economic costs and uncertain benefits. Given the dominance of fossil fuels in the current energy systems, the perception of high costs is not really a surprise. But I have argued in

Chapters 2 and 3 that this view is mainly driven by calculations with a static economic framework, which hides the major part of the true context. In the medium and longer run, an economy can adapt to rising energy prices through increased capital and knowledge accumulation, which moderates the costs of policies on the climate and other environmental issues. As soon as the general perception of costs and benefits changes, agreements on international policies become much easier. A prominent example is the Montreal Protocol on the Ozone Layer, where the costs of protection were relatively small and the expected benefits large.

A further characteristic of sustainability policies is that economic costs and benefits are often asymmetrically distributed across the globe. Hence, the self-interests of the different countries are naturally very different. Specifically, the question of how to include historic responsibilities is especially critical for the high-income countries.

Moreover, sustainability requires consideration of a very long time horizon. Greenhouse gas emissions cause economic damages only after a major time lag, which presents a big challenge for largely myopic political decision making. Finally, economic and ecological development involves large uncertainties in the long run, which have to be appropriately addressed in the political decisions taken today.

Policies advancing sustainable development ideally have the following features. They should be cost effective, which means that a reduction of natural resource use needs to be reached at minimum economic cost. Also, as usual in politics, policies have to be considered fair and equitable. In most cases this means a policy should not be harmful to the poor or, at least, not harm them disproportionally.

Fairness is an equally big issue for international environmental agreements. It is crucial in a world economy that is deeply divided in terms of wealth and pollution intensity. A fair burden sharing in international climate policy is thus important. It involves equal access by all countries to sustainable development but, as explained in Chapter 4, not equal access to polluting natural resources. The mistakes of developed countries need not be repeated by the less developed, especially when better technologies are now available.

Looking more closely at the practical aspects, we see that environmental taxes and permit systems are not equal in terms of administration and transparency. Also, to verify that the effects of a global carbon price are not neutralized by national policies, some monitoring of energy taxation and subsidy policies across countries will be needed.

A greening economy is characterized mainly by a reduction in emissions, improving resource efficiency and the development of environmentally friendly technologies. A primary concern is the reduction of carbon emissions. Whether the quantities of natural resource use are limited or taxes on resource use are levied, the effect on prices is similar: the price of environmental services is forced to rise. This is not a negative development but allows the correct incentives to the economy to be transmitted.

Of course, overexploitation of nature is always cheaper for users, at least in the short run. Price increases will never be very popular, even if highly reasonable. However, if we really want to have stringent energy and climate policies, we should not argue against necessary price adjustments. Prices at levels below social costs are nothing more than hidden subsidies to resource users at the expense of safety, the environment, and future generations. Overuse of nature is removed or at least minimized when market prices reflect real scarcities.

We note it is foreseeable that energy prices will rise in the future, even without new energy policy. Supply of fossils is limited; environmental protection and security standards will further rise. Constant energy prices, therefore, do not constitute a reasonable determinant of the benchmark development.

Higher energy prices provide incentives for sustainable innovations and investments that support economic development. To provide the private sector with direct benefits as well, green taxes can be coupled with a reduction of income and corporate taxes. Another option is to provide direct public subsidies for sustainable investments, for example in the building sector, for specific types of construction. These are in fact quite effective, but they must be paid for with general tax money. With the exception of the poll tax, which is generally considered unfair, levying taxes usually creates distortions in the economy.

A more rigorous and holistic approach to guiding an economy towards sustainability, one that combines several different policy proposals, is ecological tax reform. Reforming the tax system in a more sustainable direction can potentially yield benefits on three levels, usually called the "three dividends."

The first and most important dividend of ecological tax reform is the improvement of the state of the natural environment, the primary task of sustainability policy. If the specific design of the tax policy is not substantially unreasonable, this dividend will naturally be positive.

The second dividend concerns the improvement of the efficiency of the entire tax system, following the maxim "tax what you burn, not what you earn." Taxing labor income reduces incentives to work, which decreases individual living standards. By contrast, taxing fossil fuels removes negative externalities, which increases overall well-being.

The problem with the second dividend is that energy expenditures only account for a small percentage of total income. Hence, if too high a tax burden is imposed on energy, the narrow tax base calls for relatively high tax rates. Provided that public expenditures are substantial, market distortion may arise. Also, environmental taxes may erode their own tax base, when individuals change their behavior in a more environmentally friendly direction. Finally, in reality the incidence of taxes can be shifted; for example, a company that has to pay a carbon tax may increase its sales prices, which shifts the tax burden to the consumers. Income taxation allows for a certain redistribution of income, which cannot in general be effectuated with energy taxes. To conclude, efficiency and fairness of the tax system are not necessarily improved. The second dividend is not expected to be high in general; it might even be negative.

The third dividend of ecological tax reform is again a potentially important one, very much in line with the reasoning of this book. It concerns induced innovation and investments, driving economic growth and development. It is expected to be positive; the size of the dividend depends on the sectoral structure of the economy and the concrete tax setup.

In policy, instead of proposing environmental taxes, it is often easier to convince voters of environmental standards and the regulation of

norms, because these affect everybody equally. In certain cases, standards and bans are very effective. For example, goods that are very toxic or endanger health in a direct way should be banned. Also, when the variety of consumer goods is large, the supply of the most polluting goods can be easily stopped by imposing minimum quality standards.

It is, however, a wrong perception of the public's that environmental standards have no costs or are cheaper than environmental taxes. Firms and individuals do have to change their behavior, just as with different prices. What economists usually stress is the fact that adjustment costs vary substantially across the various individuals and firms. Hence, if everybody has to act in the same way, the one permitted by law, individual cost situations are disregarded. By contrast, with a given price, every individual and firm can adjust according to their own preferences and technologies, which increases the degrees of freedom substantially. In a liberal and open society, this increased liberty should count for a lot. Moreover, it is a central insight of modern environmental economics that total abatement costs for society become minimal when using environmental taxes or permits.

Politics' preference for "command and control" measures is due to the sense of equity this imparts. Equity may not be furthered, however. Often it is possible to circumvent regulation while accepting to pay more money, which typically applies to the richer population. If, for example, traffic is restricted according to the last digit on license plates, wealthier people can still drive around unrestricted if they have several cars. Even worse, to circumvent restrictions, people may buy several cheap and inefficient cars with opposing number plates, which means that the regulatory scheme would even have an adverse effect on air quality.

By contrast, the adaptability of market economies is often underestimated in the public debate. In parallel, the impact of changed prices for environmental services is mostly evaluated too negatively. The virtues of prices as a decentralized and flexible control system for the economy are particularly relevant for the objectives of the green economy. When people refer to the "magic of the marketplace," they mean that decentralized mar-

kets can react to price changes in a cost effective way, inducing necessary innovations and investment.

For the smooth development of an economy, it is important that input substitution and the required sectoral change take place at low economic costs. If adjustment costs are high, there is a drag on the growth process and the development path may become non-sustainable. The lower the cost of the reallocation in the direction of sectors that generate considerable spillovers and do not use natural resources intensively, the better the chances of sustainable development. Therefore, the political aim to lower these adjustment costs is the best measure to achieve sustainable development by supporting the necessary changes in the economy.

To apply the theoretical concepts of sustainable resource use in practice, it is easiest to refer to certain rules concerning the use of natural resources. First, one should not use more renewable resources than nature is able to regenerate. Second, non-renewable resources can be used, but one must ensure that appropriate substitutes or alternative technologies exist or can be developed. In the course of time, a decreasing quantity of non-renewable resources will be available.

The various possibilities for substitution in a dynamic multi-sector market economy have been elucidated at different places in this book. If welfare is to be sustained or increased in the future, the lowered amount of natural resource inputs has to be sufficiently compensated for by the accumulation of man-made inputs consisting of different forms of capital. The greater the saving effort of the present generation, the easier the substitution of natural resources in production and consumption becomes.

But saving means that we have to sacrifice some current consumption possibilities, and this sacrifice is economically attractive only if the return on savings and investments is sufficiently high. In this way, the payment for capital is connected with sustainable development. To guarantee a sufficient return to man-made capital, including human and knowledge capital, the appropriate policies should be put in place.

Long-term problems require long-term solution strategies and appropriate decision making. Sustainability can only be achieved in the future if we provide sufficient and continuously new technologies as a sub-

stitute for limited natural resources. This is certainly a difficult task, but with sufficient foresight, it is ultimately a feasible one. To obtain the adequate quantity and quality of forecasting, scientific studies are increasingly important for the crafting of political opinion. There is little to be gained in speculating about future development paths if they are not predictable in some way by theory. Similarly, direct intuition about the dynamic consequences of the different policies is impossible unless something concrete is known about the properties of feasible development paths. Thus, a profound study of sustainable growth and associated policies are not possible without a sound theory of endogenous development.

One is tempted to ask: if it is so complicated to attain sustainability, how could we have ever been sustainable in the past? We were not always sustainable, of course: all past empires have collapsed at some point of time. Indeed, our grandparents had it easier. They were probably not less selfish and shortsighted than today's generations, but the way they acted enabled us to have a better life compared to them. So was it merely accidental? How long will it last? Already our grandparents started making more intensive use of fossil fuels, a use which lies at the heart of our climate and resource problems today. The climate problem has been called the biggest market failure ever. In this sense, the problems of any civilization always have deep roots.

The fact that current resource and energy markets are distorted and that many existing policies are not optimum but are restricted by political considerations needs to be at the center of our sustainability considerations. Since not only market incentives and policies but also market and government failures shape the incentives for transitions to green growth, there is no doubt that economics provides important contributions to solving current sustainability problems.

With these final remarks we come full circle to our main conclusions. The political will to implement green policies will rapidly intensify where costs of these policies are not perceived as too high, benefits are valued as essential, policies are considered fair, international asymmetries are not too large, and uncertainties do not undermine the credibility of the scientific foundation of sustainable development.

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Chapter 12

Epilogue

The world economy has witnessed significant economic development for several decades. Many countries have lived through an unprecedented rise in living standards. But the current development pattern is not sustainable in the long run, mainly because of natural resource scarcity and climate change.

It seems evident that investment and consumption need to be redirected to make economic development compatible with the boundaries of the natural environment and to ensure a transition to sustainable or "green" growth. However, it is far from clear how and at what speed this transition could and should be made. Much depends on how alternative climate policies, changes in the energy system, and new technologies interact and affect investment incentives.

Political decisions are made by individuals who are increasingly educated but are still often limited in their perception and creativity. The famous physicist Albert Einstein once said that "Only two things are infinite, the universe and human stupidity, and I'm not sure about the former." How then can rather unintelligent and short-sighted actors get something important done like forging an international climate contract?

One might be tempted to rely on an individual genius like Einstein to obtain a decisive breakthrough technology. But this is highly unsatisfactory. In addition, adopting a fatalistic attitude and claiming that too many things about the future are unknown is too easy and neither responsible nor intellectually adequate. Hence, the aim to achieve a consistent policy furthering sustainability can be viewed as a serious attempt of trying to prove that humans can indeed get something substantial done in the international policy arena that will benefit future generations. The 1987

Montreal Protocol on the ban of CFC gases may serve as a role model, although its scope and effects were much more limited compared with climate policy.

One of the most demanding tasks for a researcher is to actively engage in policy advice and to develop politically feasible pathways towards achieving sustainability, for example by proposing designs for a global climate treaty. Economists can best contribute to the process by providing clear and robust results on the different possible policy proposals and solutions. For example, it can be stressed and explained that predicted costs of climate policies are lower than generally perceived, once we consider appropriate dynamics and induced innovation effects.

In the process of international policy making, one also has to acknowledge that economic impacts of international agreements are likely to be major and certain to be asymmetric between the different countries involved; hence, the self-interest of the countries are naturally very different. Specifically, the question of how to include historic responsibilities is critical for certain industrial countries. Whether the final mechanism will be a quantity or a price regulation is less important, provided that the emissions targets are compatible with the agreed upon temperature targets and that the deal is considered to be fair to all the negotiating parties. These are indeed tough requirements, adding an enormous degree of complexity to the process of political decision making.

If the recent growth in the world economy were to continue far into the future, conserve the ecosystems, and redound to the less advantaged, the urgency of implementing policies would be moderated. But these assumptions on economic growth are not well founded. In studying growth carefully, one must acknowledge that future income levels and growth rates will be negatively affected by decreasing ecosystem services and declining natural resources. In the extreme, growth may become negative, for example in countries which are vulnerable to climate change and have little capital for adaptation. Hence, the assumption that future generations will be richer is simply unfounded. Sustainability policies remain central for future development.

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