CHAPTER 4

New Thinking on Sustainable Development and Growth

There is abundant work by economists on sustainable growth and development. However, this chapter does not review what has been written so far in this voluminous literature. Rather, we discuss new, and as yet little explored, avenues. This chapter is deliberately not technical and is shorter than the others in the volume. Indeed, our aim is simply to review some new ideas and approaches that are emerging at the beginning of the twenty-first century on the question of the sustainability of growth. The concept of sustainable growth (or development) is usually used to study the interactions between economy and environment. However, it maps several dimensions, including sociopolitical stability, pathogenesis in societies, conservation of resources for future generations, and preservation of planetary balances.

A standard approach to growth for an economist is to ask what conditions allow capitalist economies to generate a flow of income (GDP) in the most efficient way, taking into account structural changes in the productive capacity of economies. This explains why their attention is focused on some specific aspects, such as technological innovations, the digital economy, the slowdown in productivity gains, the rate of accumulation of physical capital, the role of demographic factors, and the contribution of finance. But all productive activities take place in an environment of increasing uncertainty: the increase in natural disasters, global warming, the resurgence of viral epidemics, the spread of metabolic diseases across the planet (hypercholesterolemia, diabetes, overweight), and so on.

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To approach the notion of sustainability of growth and economic development, we must therefore not only reason in terms of efficiency in the transformation of capital, but also in terms of opportunities in the perpetuation of the productive capacity of economies. An important issue is understanding under what conditions future generations will have the same opportunities as present generations to be able to produce, to have a good quality of life, to have sufficient natural resources, and to choose new technological paradigms. These opportunities are measured by net wealth: the difference between the value of the assets that we accumulate and that can be mobilized in productive activity, and their devaluation caused by today's activities. The concept of sustainability states that the rate of transformation of existing assets into income flows (i.e., the rate of growth of GDP) can only be maintained if net assets grow at a sufficient rate (which implies that their depletion over the decades and centuries should not be too rapid).

The notion of assets (the term "capital" is also used) must be understood in a generic sense. There are different forms of assets: natural capital, produced equipment, buildings, human capital, social capital, monetary capital, freshwater resources, food, ecosystem balances, and so on. The question of sustainable development (this term is more neutral than "human progress") has become central for macroeconomists today. Indeed, for good reason, we have spent the nineteenth and twentieth centuries asking ourselves what is the best way to improve our productive efficiency thanks to technical progress. There is a new question on the table for the twenty-first century: How can we do this while preserving as much as possible of the resources that will have to be equally available for all future generations? There are several possible answers.

A first angle is to consider that there is no issue at all because there are natural mechanisms for regulating these resources: cycles of oxygen, water, geochemical elements, and so on. Our concern could therefore be to continue to deal with efficiency (because to live we must continue to generate income flows) by considering assets as constraints whose reproduction cycles and risks of depletion we must internalize. This philosophy is one of the foundations of the idea that other ecosystems could represent "constraints" and limits to growth. Classical economists (e.g., Ricardo, Smith, Malthus) were very much afraid of such a perspective. As a result, this philosophy also helped to shape the debate among economists, with attention focused on technical means to circumvent its limits and prevent growth from running out of steam. The foundation of the neoclassical

endogenous growth models of the 1990s was to understand how the productive apparatus could generate non-decreasing returns to scale. Schumpeterian economists believe that technical progress can help push the limits of growth, for example by finding innovations to trap greenhouse gases, or to have technologies that are more carbon efficient.

But this reasoning has a flaw. It does not take into account conflicts of temporalities. This means that the short period of human production activities is the opposite of the longer period of the regulation of ecosystems and social organizations. The intensification of production methods and consumption thanks to technology can cause breaks in equilibrium. This is the thesis of scientists who defend the idea of the Anthropocene (economic activity, since it "oppresses" the various ecosystems, modifies the duration of natural cycles, and increases the chances of tipping points occurring). For this reason, it is not enough to internalize the dynamics of non-economic ecosystems. It is also necessary that the growth process be "co-determined" with the realization of other natural, sociopolitical equilibria.

Our attention must therefore focus on the following points. First, sustainability implies focusing on a global approach to investigate the interdependencies between economic activities and other ecosystems. In this perspective, a statistically interesting method to measure the wealth of nations in a context of sustainable development is the United Nations' Inclusive Wealth Index (IWI) (see below). Secondly, since the economy is necessarily embedded in social organization, we cannot ignore the phenomena of poverty and discrimination inherent to capitalism. A dazzling growth of GDP is not necessarily socially sustainable if it generates and accentuates social disparities and situations of precariousness. Indeed, such situations cause wars and conflicts and degrade the social climate, and thus the stability of social organizations. Finally, sustainability implies a better understanding of the relationships between macroeconomic and epidemiological equilibria. A country can have dazzling growth rates with a deteriorating human capital (because access to quality health care becomes difficult, since part of the population suffers from human metabolic diseases, because access to education is expensive, or because the population is aging).

4.1 A Global Approach to Sustainable Growth and Development

4.1.1 Economic Ecosystems Interact with Other Ecosystems

Sustainable development has two dimensions that require a global approach to growth. The first refers to the viability of interdependencies between human activities and other ecosystems. The second dimension refers to the polarities generated by the growth processes of capitalist economies.

One of the greatest challenges for researchers investigating sustainable development and growth in the twenty-first century will be that of a global approach to economic growth. Indeed, economic activities interact with the equilibrium of other ecosystems, whether geophysical, environmental, or animal. The economic activities can disrupt these equilibria, but such disruptions can also generate "feedback loops" that can threaten the viability of the fundamental functions that a strong economic growth should fulfill: producing to give people food; curbing demographic growth; managing the natural resources that are essential to human life; enhancing soils to facilitate agricultural productivity; preserving the workforce's health; and improving people's living conditions by facilitating access to clean water, decent housing, breathable air, and so on. Figures 4.1 and 4.2 help to visualize a global approach to sustainable growth.

To understand why economic growth and the activities it generates have several dimensions (environmental, material, epidemiological, etc.) we must bear in mind that humans coexist with other worlds (see Fig. 4.1), each of which forms an ecosystem. These ecosystems interfere with each other, and this is how local and global balances are defined. In these ecosystems, geography is important: Humans have taken over much forest space for agriculture and housing. Humans and animals serve as a vehicle for millions of micro-organisms, bacteria, and viruses to move around the world. The epidemiological equilibrium of a country and the world reflects these balances. Sometimes, this coexistence is difficult: Some viruses and bacteria kill people and animals (see Fig. 4.2).

Therefore, there can be a struggle between humans and these micro-organisms for their survival. Sometimes, things function very well: The immune system of wild fauna (e.g., bats) is highly acclimatized to viruses that are dangerous for humans. Soils provide services to human beings. They allow the supply of drinking water (purification of rainwater during

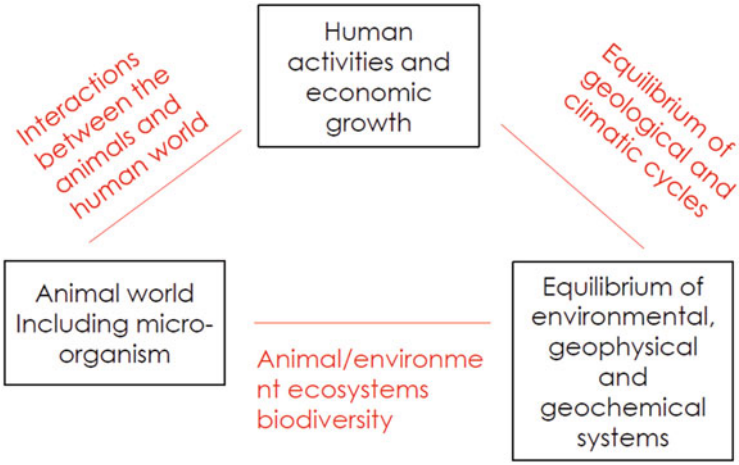

Fig. 4.1 The interference of the worlds: everything is linked

its infiltration to the water table), facilitate agricultural production, and provide medicinal remedies (plants). Geochemical, geophysical, and ecological cycles also illustrate the services provided to human beings by other ecosystems. The oceans and forests absorb carbon dioxide and bacteria. The Earth decomposes organic matter, providing a home for millions of micro-organisms, allowing fauna and flora to find living spaces.

Economic growth since the beginning of the nineteenth century has had the following characteristics: (1) It has taken place in a context of massification (mass production and consumption), (2) it happened within a thermo-industrial civilization (through the intensive use of carbon-based energies), and (3) it has been based on a strong geographical expansion (first by states, then by multinational companies with the multiplication of value chains). It has therefore entailed several costs:

- Deforestation to favor cash crops and livestock (oil palms in Asia, timber in Africa, soybeans in Brazil,…).
- Increase in maritime, air, rail, and road transport that accompanied the multiplication of value chains (crushing costs) has contributed to global warming.
- Intensive livestock farming and agriculture to meet demographic growth and the strong increase in demand for animal protein. Inten-

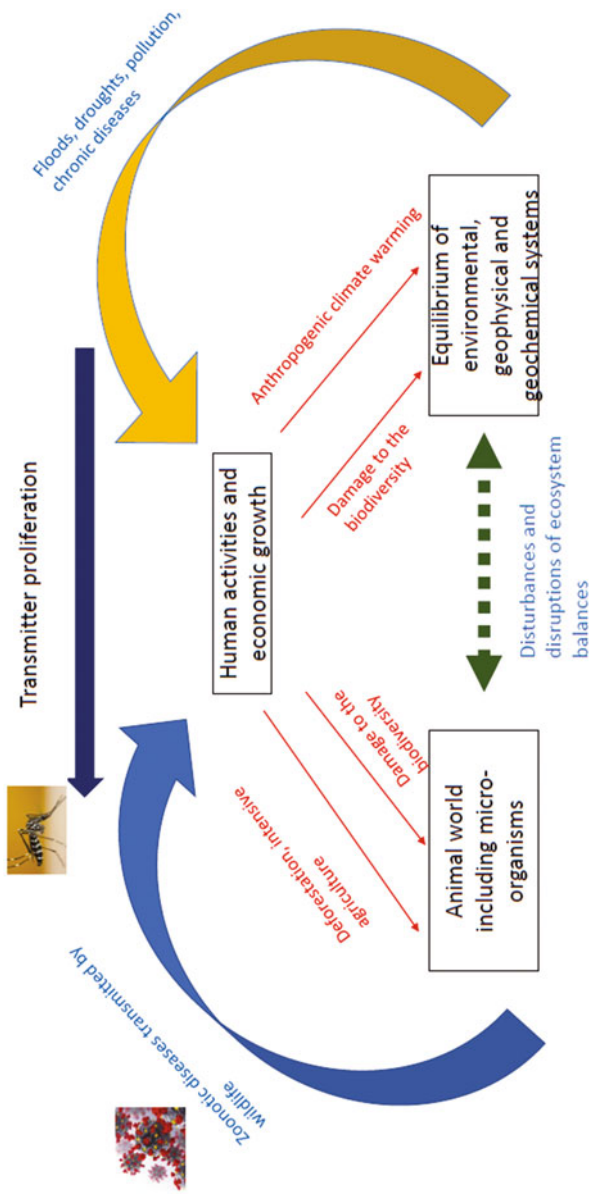

Fig. 4.2 Disturbances in the global equilibrium

sive agriculture has increased yields, but it has also caused environmental pollution.
- Damage to biodiversity.

There are tolerable thresholds for other ecosystems (environment, animal, wildlife, Earth system) beyond which they can no longer provide the services necessary for the security of human life and production activities:

- Biodiversity becomes insufficient to protect against zoonotic diseases.
- Intensive breeding allows us to feed more people with animal proteins, but breeding sites are incubation sites for new viruses and create externalities (groundwater pollution).
- Global warming favors the proliferation of virus and disease vectors, for example mosquitoes, rats, and insects.
- Toxic substances and air pollution contaminate the water table and the air, causing health problems for individuals and the public.
- Deforestation increases the production and living space of human beings, but destroys the natural habitats of wild fauna and causes new diseases for domestic animals, livestock, and humans in the case of zoonoses.

4.1.2 Why Has the Global Approach Had Little Success with Economists?

Such a global approach to growth has long been neglected by macroeconomists working on growth, for several reasons.

The First Reason is Historical

We should remember that until the technological innovations of the industrial revolutions of the nineteenth century, a large part of the world lived in great misery and material poverty. The relationship with climate, micro-organisms, the Earth system, and the environment was conceived in a conflictual approach: The seasons gave rhythm to the periods of famine and abundance, while the epidemic and disease cycles regulated those of demography. The exclusively economic approach to growth during a good part of the nineteenth and twentieth centuries was justified, because the countries that are now industrialized-but that were underdeveloped until then-were emerging from several millennia of very low living standards. Production was the result of the interweaving of three cycles: that of agriculture according to climatic variations, that of wars according to the

moods of political powers, and that of diseases according to recurrent epidemics.

Figure 4.3 shows the share of GDP in the global GDP of select countries and regions from year 1 until 2008, based on statistics collected by the Angus Maddison Project. Until the nineteenth century, only two countries in the world had standards of living far above those of the others, that is, India and China. The changeover for Western Europe and the United States occurred "only" from 1870 onward. The downgrading of India and China took place with the rise of the technological and industrial revolutions, first in Europe, then in the United States. When countries emerge from very long periods during which means of subsistence have been lacking, it is not surprising that attention is mobilized on the question of how to ensure their sustainability, without the means of subsistence being subject to the vagaries of the natural elements. Long before the industrial revolutions of the eighteenth and nineteenth centuries, growth economists were already primarily concerned with the conditions that would guarantee sufficient yields from agriculture in the long term. Many economists, first and foremost the classics, were haunted by the idea that economies could in the long run converge to steady states because of non-

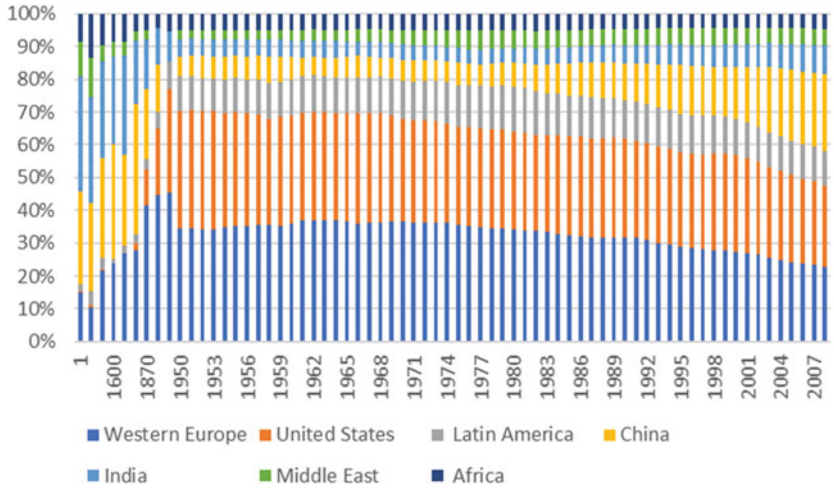

Fig. 4.3 Share of GDP in World GDP (%). Source: Historical Statistics of the World Economy 1-2008

economic factors: demographic behavior, land yields, diseases, or depletion of natural resources. With the industrial revolutions, the debates continued with the question of the best technology to achieve the highest yields while preserving scarce resources. During the periods following the two world wars, the urgency was to rebuild completely destroyed economies. The industrial boom was more important than the problems of externalities caused to the environment and other ecosystems.

The Second Reason Is due to Certain Misconceptions about Reality

The risks raised by the environmental externalities of rapid industrial growth were highlighted very early on. As early as the 1950s, there were heated debates on the ecological effects of growth within the civil societies of industrialized countries. In 1972, the Meadows report underlined the limits to this type of growth: depletion of resources and, above all, damage to the environment leading to additional human, physical, and financial costs.[1] An International Union for Conservation of Nature (IUCN) document from 1980 discussed the links between the global growth strategy and the issue and preservation of living species. The Bruntland Commission in 1987 wrote a highly publicized report on a reversal of hierarchies: Sustainable development and meeting the needs of the poorest is more important than the search for maximization of economic activities.

But these ideas, which today seem to be widely accepted by societies, were not in vogue for a long time. This is due to several misconceptions.

Economists have long believed that as countries succeed in raising their standard of living, the pollution generated by growth would decrease thanks to two effects: (1) a compositional effect due to the fact that countries specialize in the production of less polluting goods and services (richer consumers become more attentive to quality of life and therefore more demanding in terms of clean energy) and (2) a technical effect. Rising living standards lead to production changes (companies innovate in less polluting technologies because of regulatory constraints). These phenomena have never been observed.

[1] The first version of the Meadows report on the limits to economic growth dates from 1972 and evokes the possibility of a stationary state of the economies characterized by a growth rate that would become equal to 0, because of two factors, that is, demography in certain countries and the depletion of underground resources. The authors developed a planetary model, called World3, which includes several other dimensions in addition to growth: demographics, available reserves in the subsoil, pollution.

Another misconception is the result of ignorance. With the disruption represented by the industrial revolutions, the structuring of production and consumption patterns has progressively created conditions conducive to the acceleration of viral transfers: deforestation, the destruction of natural wildlife habitats during the conversion of land for intensive export agriculture, industrial livestock parks that are incubators for the spread of epidemics, excessive urbanization that favors animal migration zones, and excessive mining. Recent works show the existence of a correlation between the destruction of animal biodiversity and the appearance of emerging viruses from the animal world. This affects human capital, annihilates the demographic dividend, and can lead to a drop in activity in the event of major pandemics, as was the case historically before the micro-biological revolution of the nineteenth century and the progress made in medicine. We have not paid attention to the fact that global warming is likely to favor the adaptation of disease vectors and of a number of hosts constituting reservoirs for viruses at higher latitudes: insects, mosquitoes, birds, and ticks (in temperate as well as subtropical geographical areas).

4.1.3 Sustainable Development and Polarities

Industrial development has provided the means of subsistence and of living decently to millions of people. But this progress has a cost that is increasingly difficult to bear for societies and has produced polarities (see Fig. 4.4). On the one hand, we have overabundance (financial hypertrophy,

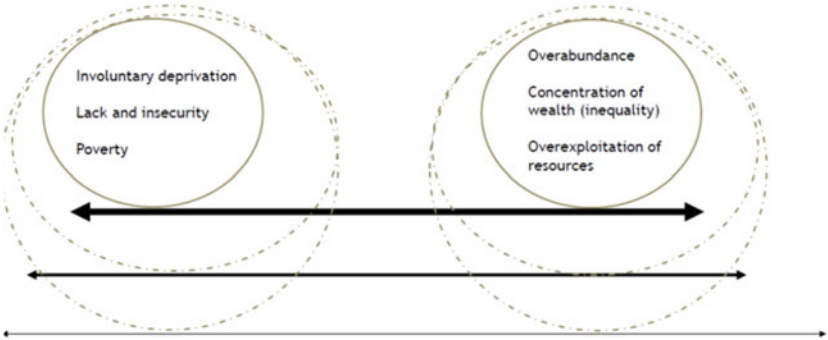

Fig. 4.4 Growth can generate excesses and shortages

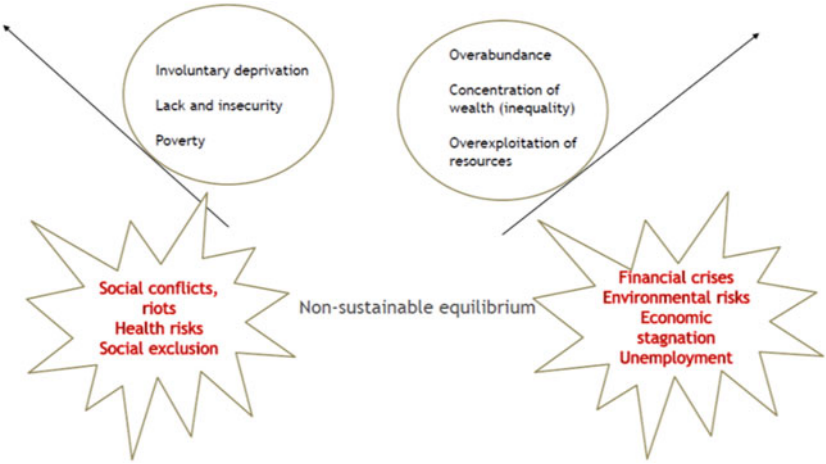

Fig. 4.5 Non-sustainable socioeconomic equilibrium

overproduction generating a proliferation of waste, over-exploitation of natural resources and the living environment, a high concentration of wealth creating inequalities). On the other hand, the productive systems have generated a proliferation of phenomena of "lack": Poverty still affects entire subgroups of populations, and there are involuntary deprivations reflected by the phenomena of precariousness. The social, political, social, and environmental equilibrium of a society cannot be achieved when the distance between these poles grows. It is as if two weights are placed at the ends of a wire and their mass increases more and more. At a certain point the thread breaks (see Fig. 4.5), and this break is materialized by various types of crisis (epidemic, social, environmental) that can call into question the viability of productive systems to maintain decent living standards for populations and future generations.

One of the reasons why this phenomenon has gone unnoticed is that economists are very optimistic about the role of technology in economic development, based on the historical experience of European countries. There is a strong belief among some economists that innovations contribute to reducing inequality and poverty when they become accessible to the greatest number of people. Economists such as Baumol, Okun, and Schumpeter have defended this idea (productivity gains leading to higher

real wages). However, this is not what we have observed: Since the 1980s, the evolution of wages and productivity gains has been uncorrelated, and poverty and inequality have increased in countries located on the global technological frontier (e.g., the United States and Japan).

Moreover, the technological discoveries of the end of the twentieth and beginning of the twenty-first century have been obtained through the creation of oligopolistic rents and through an increase in the concentration of capital (digital and communication sectors, pharmaceutical sector, etc.).

What Are the Implications for the Study of Growth and Sustainable Development?

There are several ways to model sustainable development taking account of the elements outlined above.

The first approach is the most difficult. It can be described as a "general equilibrium" analysis in the sense that it requires a global model that summarizes the mechanisms of each ecosystem (human, land, marine, animal, environmental) that captures the interdependencies and is interested in the co-determination of equilibria. This implies interdisciplinarity and transversality. This scientific approach is recent, dating back barely 20 years. It appeared in health disciplines (One Health approach) and in the Earth sciences. In economics, the so-called integrated approach (meaning "with other disciplines") is embryonic in some fields (e.g., regarding the role of economic behaviors in the spread of epidemics and the effects of these on macroeconomic indicators, models have recently been developed in a literature devoted to the macroeconomics of Covid-19; see Eichenbaum et al. 2020). In other fields, advances have been made for a longer period of time, for example on the links between economic behaviors and climate change. The aim is to define, within a consistent framework, the causal interactions and feedback loops between greenhouse gas emissions, the effects of climate change, and the repercussions of these. Such models require skills in environmental sciences (climatology, oceanography, ecology), in economics, and in the sciences. William Nordhaus has played an important role in proposing integrated models to assess the impacts of climate change on the economy.

The second approach, the most widespread, consists of internalizing the equilibria of environmental, animal, land-system, and epidemiological ecosystems in macroeconomic models, without necessarily exploring in detail their dynamics, whose complexity is summarized by simple relationships. Symmetrically, partial equilibrium models from other disciplines

may favor a geophysical, medical, biophysical, or environmental approach, reducing the complexity of macroeconomic and social relationships to simple mechanisms.

Thirdly, as we pointed out earlier, one of the causes of a growing interest of civil societies in sustainable development is that crises, whatever their nature, are caused by breaks. Approaches that can be described as "indirect" therefore aim to agree on and construct indicators in each discipline, to identify thresholds beyond which the equilibrium of each subsystem is called into question, and finally to look at the links that exist between the indicators of the various disciplines and the thresholds crossed. Economists have their indicators of sustainable development but they are also interested in indicators developed by other disciplines. Each time thresholds are crossed, we identify "limits" to growth, to development, or to the planet, in the sense that we enter zones of uncertainty concerning the viability of ecosystems due to a deterioration in their functioning.

Since 2009, sciences outside of economics have defined the concept of "planetary boundaries", that is, thresholds that must not be exceeded to maintain the environmental, epidemiological, ecological, and social conditions of the Earth system in which human life can develop. The crossing of thresholds increases the risks of chain reactions that we want to avoid imperatively. Today, there are nine indicators that are particularly scrutinized and that define the equilibrium of the biosphere: (1) the water cycle, (2) chemical pollution (including plastics), (3) greenhouse gas emissions and their effects on the ozone layer, (4) biogeochemical cycles (phosphorus and nitrogen), (5) the degree of ocean acidification, 6) the erosion of biodiversity, (7) climate change, (8) changes in land use, and (9) the increase of aerosols in the atmosphere. It is difficult to deny that human activities have some influence on the evolution of these indicators, and that in turn the latter affect the economic variables (see Rockström et al. 2009).

The challenge for macroeconomists is to define a growth rate that avoids approaching the planet's frontier and to define a sustainability space for growth, that is, a minimum distance from ecological thresholds. The complexity of the topics lies in the fact that we cannot be satisfied with aggregate production functions, because they do not allow us to account for the interactions with other ecosystems. Any model must integrate production processes built on green innovations, and behavioral mechanisms that promote pro-environmental and "pro-Earth" behaviors, and that take into account the services provided by other ecosystems. The notion of

well-being then consists in retaining growth and economic development trajectories that reduce the risks of bifurcations, of disruptions in the planetary physical equilibrium, because these are the bearers of extreme events harmful to human life: Climate disruption accentuates periods of drought, floods, and extreme cold; severe pollution has high costs for human health; melting ice favors the emission of methane, and so on.

In addition to environmental factors, we should also consider some additional indicators to monitor and ensure a sociopolitical dimension of sustainable development. We can take up some indicators retained in the objectives of sustainable development such as access to drinking water and energy, decent housing conditions, free education, food, gender equality, and the reduction of poverty and sociopolitical indicators such as social peace and security. We can also add indicators of reduction of inequalities, poverty, and social discrimination.

With the global approach, the interesting point is that the different regimes of capitalism in relation to the states of equilibrium of the various ecosystems can be defined from the economic decline of the Anthropocene. This concept is debated among scientists. But if we retain it, the Anthropocene designates recent periods in the history of the Earth during which human activities have begun to have an influence on biogeochemical cycles, climate change, ocean acidity, and so on. This definition can be generalized to all ecosystems. This means that the regulations of non-human ecosystems are no longer on a long time scale, but on an increasingly shorter one. Furthermore, it is assumed that this change is related to human activities. In this perspective, the Capitalocene designates historical periods during which different modes of production and exploitation of natural resources have begun to play a role in modifying the temporal scales on which the equilibrium of the biosphere, geophysical, geochemical, lithosphere, and other living ecosystems is defined.

If we go back to the industrial revolutions of the nineteenth century in Europe, we can distinguish two eras that followed one another rapidly, both marked by an intensive use of carbon-based energies. These periods are always part of a context of hegemonic stability-to use Kindleberger's term-where one or more countries impose their vision of the world and modes of production on the hierarchy of nations. This power is based on a combination of technical innovations and the discovery and large-scale exploitation of new energy sources. The first corresponds to the domination of the United Kingdom over the world, whose industrial superiority was based on the large-scale exploitation of coal from the

middle of the eighteenth century, at a time when transport costs were high. The development of the iron and steel industry, the textile industry, and transportation was based on the exploitation of coal mines. The second era is the one that established the hegemony of the United States from the end of the Second World War, because the country was able to access cheap carbon resources: oil, gas, and coal. The central role of these resources would be confirmed in the early 2000s, when the United States embarked on a program of energy independence because its dependence on oil imports from foreign countries was analyzed as a problem of national security (in 2007 the Energy Independence and Security Act was passed). Behind these dominant nations, the other powers emerging in their wake have also used the same modes of production based on carbon energies (Germany, France, Italy, Australia, Japan, the United Kingdom, etc). More recently, the rise of China and its global role, and its dazzling economic growth rates, have also relied on the combination of technological innovations and an intensive use of carbon-based energies (coal, in particular).

One of the difficulties in studying the consequences of the exploitation of carbon resources corresponding to different eras of the Capitalocene is that we do not yet have complete theoretical models that take into account all the interdependencies between economic and ecological variables in order to establish causalities and identify the underlying mechanisms. The current models (e.g., those of the IPCC) are simulation models and are based on hypotheses (these models have a predictive purpose by giving ranges on the probability of evolution of key variables). Those who contest their conclusions and refute the idea of anthropogenic climate warming rely on the fact that we cannot theoretically differentiate the effects due to human activities and those due to the functioning of the Earth system. At best, the empirical data we observe are correlations.

What do the scientific data on anthropogenic warming during the twentieth century show us? First, the concentration of CO_2 in the atmosphere has increased by 49.6% compared to the pre-industrial period between 1850 and 2020, from 278 ppm (parts per million) to 416 ppm (according to data from the US Earth Systems Research Laboratories). This is the stock resulting from the part of the emissions not absorbed by the natural carbon sinks (lithosphere, biosphere, and hydrosphere). Second, the evolution of the global annual mean temperature between 1850 and 2019 is described by a convex increasing curve with a flat part. Indeed, between 1850 and 1940 the increase was modest, but then accelerated

from this date. Taking the decade sliding average, between 1850 and 1950, the temperature anomalies remained around zero and were even negative between 1900 and 1920. Between 1940 and 1960, these figures became positive between +0.20 °C and +0.40 °C. In 2020, the anomalies were around +1.20 °C. Third, the average sea level has risen since 1900 (until 2010) by 1.7+/−0.3 mm, and the increase has accelerated to reach between 1993 and 2019 3.3+/−0.4 mm/year.

It is difficult to establish the existence of a correlation between pollution and global warming using econometric models that are necessarily simplified and that do not take into account the complex feedback loops specific to the Earth system and between different ecosystems. By relying only on data, we risk encountering a problem of selection bias. To see this, one only has to look at the evolution of temperatures before the industrial boom in Europe, that is, during periods when anthropogenic CO_2 emissions were lower. An important fact is that, historically, large temperature cycles have existed and have been characterized by periods of warming and periods of cooling. For example, between 900 and 1250, average temperatures were higher than in 2000. This period is known as the Medieval Warm Period (or in scientific language, the Medieval Optimum Period, the term "optimum" referring to periods of warming that are considered more favorable to human life than periods of cooling). Apart from temperature, other climate-related disturbances were also observed during the same period (see, e.g., Bradley et al. 2003; FollC et al. 2001; Jones and Mann 2004; Le Roy Ladurie 1988).

Will another capitalocene emerge in the coming years and decades, following the one based on the use of carbon resources? This is an important question. Indeed, the economically hegemonic nations are faced with the risk of downgrading in a context where the objectives of reducing greenhouse gases and mitigating the effects of global warming require a drastic reduction in the use of carbon-based energy.

The decision of the United Kingdom from the middle of the nineteenth century to base its economic, commercial, monetary, and geopolitical hegemony in the world on the carbonaceous resources of the subsoil took place at a time when the country had high growth rates but was in danger of being stopped by the depletion of organic resources, in particular precious metals, forestry resources, and wood. The potential costs of a halt in growth were all the more important as the country was also experiencing high demographic growth, an increase in agricultural productivity, and an

advanced division of labor. The standard of living of the population was higher than in the rest of Europe (the other country in the world that was in the same situation of prosperity at that time was China). It is by imagining the potentially high costs of stopping growth that the English decided to base an economy on a new resource to which they had unlimited access: coal (and later oil thanks to territorial wars). They also had the formidable steam engine and a vast colonial empire that helped them establish an industrial model based on coal (see Malm 2016; Wrigley 2010).

Energy transitions occur whenever hegemonic nations face constraints. During the 1980s, fossil fuels were referred to as non-renewable energy sources. A popular theory was Hubbert's peak, and each country estimated an end date for its assumed carbon energy reserves. But, in addition to the fact that more and more new deposits of high-quality oil and gas have been discovered in the rocks of the oceans, shale oil and gas have allowed the United States- a hegemonic nation-to pursue its growth model by ridding itself of its dependence on other countries, particularly those in the Middle East. The constraint today does not come from the unavailability of underground resources, but from the environmental disturbances linked to the intensive exploitation of these energies and the negative effects caused to the different ecosystems. A new technological paradigm must therefore be found, and this requires a transition toward the exploitation of new energy sources.

A new hegemonic race based on the capture of new resources has been under way for at least 15 years. It has prefigured an orientation of productive systems toward a new model of digital economy. Countries are gradually entering a new capitalocene, that of metals and minerals, whose strategic nature has become obvious. These are both abundant and rare metals: iron, silver, copper, nickel, cobalt, berylim, tungsten, bauxite, niobium, etc. There are at least 100 of these. These minerals and metals, which are supposed to have a low carbon footprint, are used in the technologies of the future: batteries, solar panels, televisions, computers, electronic circuits, lasers, robots, nanotechnologies, traction motors, drones, and so on. The strategies for capturing these resources reveal a dominant nation, sub-dominant nations, and "secondary" nations. The dominant nation is China. In addition to the strategies of monopolizing these resources from all the countries of the world (thanks in particular to extensive foreign direct investment policies), China has many of these minerals in its subsoil. But above all, this country has taken control and a dominant position in the mineral refining sector. The "sub-dominant" nations are the United States

and the European countries (if we include polymetallic nodules). The "secondary" nations are made up of countries which, although they have certain strategic resources, are not hegemonic powers on the geopolitical, economic, or financial level. On the contrary, the fact that they have these resources has made them dependent on China and the industrialized countries: Brazil, Chile, South Africa, the Democratic Republic of the Congo, and Australia. This is a new capitalocene because the extraction and refining of these metals and ores are highly polluting for the environment. Indeed, in addition to the release of radioactive elements during the separation stage for rare metals, their exploitation implies the use of vast quantities of water, and can lead to the pollution of water tables and soils and to the degradation of biodiversity. Moreover, the transition to the digital economy is not necessarily a low-carbon strategy. The raw material is the trillions of data and the necessary equipment (computers, servers) are sources of greenhouse gas production.

4.1.4 What Are the Directions for Future Research?

Attempts to propose a global approach to the links between economies and the equilibria of other ecosystems date back several decades, although this path has been little followed. However, several important contributions, both old and more recent, should be mentioned.

During the 1970s, an interdisciplinary team of 70 researchers from a wide range of disciplines (meteorology, economics, oceanography, law, ecology, atmospheric chemistry, biology, physics, etc.) was interested in global climate change and the environmental effects of human activities. The study was sponsored by MIT. Their work resulted in a report entitled *Study of Critical Environmental Problems.* The authors were already highlighting the effects of transportation- which was booming at the time, especially in the airline industry-on the rates of carbon dioxide accumulation in the atmosphere (especially the part not absorbed by the oceans and forests). They relied on a mathematical model showing the interactions between economic activities and the atmosphere–land balance. In the conclusion of their report, the authors called for a precautionary principle and for corrective measures in the pace of economic growth.

However, the report was subject to two major criticisms. The first was that it was too abstract (because it was complex), that is, not sufficiently accessible to non-specialists to attract attention from policymakers. The second criticism was that the predictions made for the long term seemed

exaggerated, even though their simulations showed that in the 100 years from 1970, the probability of climate change directly linked to the concentration of CO_2 in the atmosphere was low.

William Nordhaus has made a significant contribution to the development of multidisciplinary models to study the interactions between economic growth, geochemical cycles, greenhouse gas emissions, and climate change. Some seminal contributions are Nordhaus (1991), Nordhaus (1992), Nordhaus (1994), and Nordhaus and Yang (1996). The models proposed by this author (DICE and RICE models: Dynamic Integrated model of Climate and the Economy, and Regional, Integrated model of Climate and the Economy) have given rise to numerous extensions in the literature (see, e.g., Nordhaus and Boyer 2000 and Traeger 2014). But one of the criticisms of this type of modeling is that it remains very economy-centric. The models are not global in the sense that we have defined above, but they integrate climatic and ecological modules into the functioning of the economy by looking, for example, at the costs generated by damage to the environment. Their principle is to have a module tracing the dynamics of the economy by integrating a damage function (harmful to growth) and a climate module that models the cycles of geochemical elements (notably carbon) as well as the dynamics of the climate (with a link based on the fact that atmospheric carbon concentration rates have an impact on the climate). An important limitation of these models is that the welfare function of different regions of the world or globe is defined according to different trajectories of future per capita consumption with economic and geophysical constraints. Given the issues related to the balances of all physical, natural, and other living ecosystems, summarizing well-being as what people want to consume or invest optimally in the future is very limited. It does not take into account the concept of the planetary boundary mentioned earlier.

Recent work based on a truly global approach allows for modeling the services provided by other ecosystems (see Boehnert 2021; Daw et al. 2011). The interested reader will also find abundant references on socio-ecological Earth system models to study the dynamics of the Anthropocene in Bates and Saint-Pierre (2018) and Verburg et al. (2016). The branch of economics that currently seems most open to the global approach is ecological economics. It was born in the 1980s and includes various currents of thought. But all of them have in common that in their models the economy is inserted into the other ecosystems of which it is a component and not the final goal (for a synthesis, see Costanza 1989,

2020; Harris et al. 2006; Lagrue et al. 2012; Melgar-Melgar and Hall 2020; Pushpam 2010, and Washington and Maloney 2020).

4.2 Economic Well-Being and Sustainable Growth

We must remember that the objective sought by one of the founders of GDP, Simon Kuznets, was to find an indicator measuring social well-being. This is the purpose, beyond understanding the determinants of GDP growth over time. The goal is to find indicators that allow us to live decently for present and future generations. In the literature, there are two approaches to measuring wealth (and the theoretical models that follow from them).

On the one hand, one can reason in terms of flows and ask what use human beings get out of the income flows they generate (the GDP that is produced with capital): They consume, but must keep some of their income (savings) in order to continue to produce an income flow continuously over time. Growth models are interested in this: How to create wealth by satisfying various criteria (maximizing the well-being derived today from consumption, allocating consumption and savings in an optimal way over time, arranging for the flow of income that is generated to grow at the same rate as the resources that allow it to be generated-this is balanced growth). This flow approach can take into account demographic constraints and constraints related to the availability of natural resources. Theoretical models can also take into account the environmental externalities caused by productive activities, as well as the optimal rate of exploitation of natural resources (fish, minerals, etc.). There is an abundant literature, for example, on the economics of natural resources and ecological economics. However, this is not what interests us here.

An alternative approach is based on stocks. Welfare is measured by the-intertemporal-utility that one derives from the fact that a country has a capital that is multiple. What matters here are assets and liabilities. Capital cannot be understood only in the sense of growth theories (equipment, infrastructure, intangible capital, total factor productivity, human capital), but also consists of natural capital (forests, arable land, non-renewable and renewable resources, subsoil water resources) and the biosphere (ocean and atmospheric resources). In order to give them a value, one is obliged to take into account the services rendered by the different forms of capital, but also the costs incurred by their use. Sustainability refers to the fact that

the damage caused to ecosystems, and the losses of natural capital induced by economic growth, must not be greater than the gains from the use of resources for production. Otherwise this means that present generations cannot pass on to future generations a productive base that ensures a decent standard of living. Capital must also include certain common goods such as peace, stability, and social justice, and the reduction of poverty and inequality. Strong growth that is accompanied by rising inequality or increasing poverty is not sustainable if it increases the risk of future social conflicts and degrades the social capital necessary for productive activities.

The investigation of sustainable growth thus responds to two different objectives. In the first case, the focus is on the capacity of economies to transform capital into income flows. We study the efficiency of this transformation and the conditions that allow it. In the second case, we are more interested in the capacity of today's generations to pass on to future generations a productive capacity that is not degraded and that gives them the same opportunities as previous generations to continue to generate income flows to live, but also to have a decent quality of life.

To illustrate this, Fig. 4.6 compares the average annual growth rate of wealth in certain countries, measured using three indicators. Data are

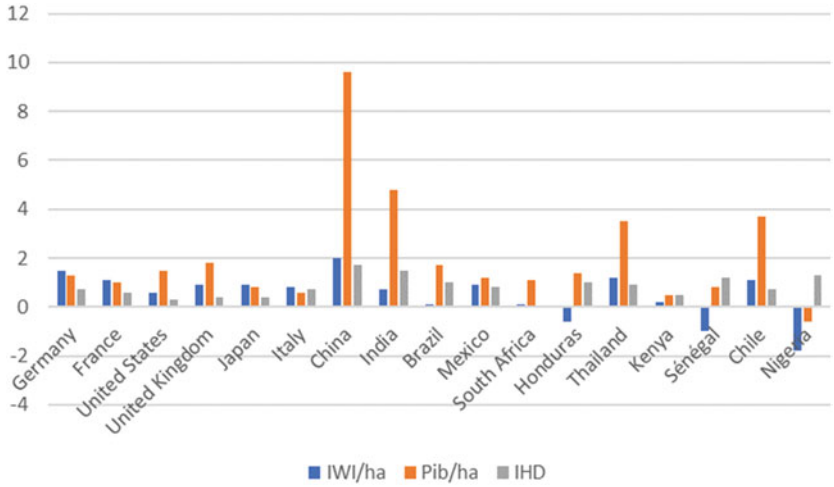

Fig. 4.6 Comparing growth per capita rates using three approaches

taken from the UNEP report on inclusive growth from 2014. The first indicator is standard GDP per capita growth. The second is the growth rate of the Human Development Index (HDI), which combines GDP per capita with a variable of life expectancy of the population and the level of education of those aged 15 and over. The third indicator is based on the IWI mentioned above. It is composed of three forms of capital: goods and services produced, but also human and natural capital. It has been proposed by the UNEP (UN Environment Programme as of 2012). The statistics concern a long period of 20 years between 1990 and 2010. The reader can refer to the 2014 Inclusive Wealth Report, measuring progress toward sustainability, UNU-IHPP, UNEP, Cambridge. The report presents data from 140 countries.

A country that experiences sustained per capita growth rates but at the same time "drains" its natural capital runs the risk of eventually running up against a natural constraint because the soil and subsoil resources will not have had time to renew themselves. The sustainability of growth depends on the management of natural resources and their availability for future generations. The figure shows that, according to the standard criterion of growth measured by GDP per-capita, the important performances are observed for emerging countries (notably, China, India, Thailand, and Chile). Countries such as Brazil, South Africa, and Honduras have per-capita growth rates very close to those of the industrialized countries (France, Germany, Japan, the United States, and the United Kingdom). However, per capita GDP growth does not always improve welfare growth, which, in addition to GDP, also takes into account the effects on human capital (health and education). We observe the large difference between GDP growth measured by GDP per capita and that obtained from the HDI. The changes in lifestyle and production implied by sustained growth rates cause damage to the environment and degrade the health of populations. Poor nutrition (overeating or nutritional deficiencies) has also shortened life expectancy through increased premature death. The differential is particularly striking in emerging and developing countries, and less so in industrialized countries (except in the United Kingdom and the United States). The same observation applies to the comparison of the growth rate of the HDI per capita and that of the IWI indicator. The difference is very marked in the emerging economies. In some developing countries such as Brazil, South Africa, Honduras, Senegal, and Nigeria, growth causes destruction of natural capital (negative growth rate of the IWI). In these countries, growth rates do not seem compatible with the

sustainability criterion based on the preservation of resources for future generations.

Factors change radically when we take into account the valuation (and destruction) effects of different forms of capital. For example, if companies build technologies to improve the energy efficiency of carbon-based energies (increasing the quantities produced with less coal, oil, or gas used), this increases production while decreasing the negative effects on the environment linked to the release into the atmosphere of fine particles and toxic fumes. In this case, the IWI is likely to increase. Another example is that the increase (decrease) in the price of oil on the world markets increases (decreases) the value of crude oil in the subsoil of a country.

Figure 4.7 takes into account several factors that may affect the measurement of IWI: environmental damage caused by carbon-based energy sources (Carbon), valuation effects related to oil price variations (Oil), and factor productivity (R&D). These figures show a world divided in two. In industrialized countries, the per capita growth rate is positive, while it is frequently negative in emerging and developing countries. The cases of China and Nigeria are an illustration. In most of these countries, the slowdown in factor productivity (the insufficiency of technologies

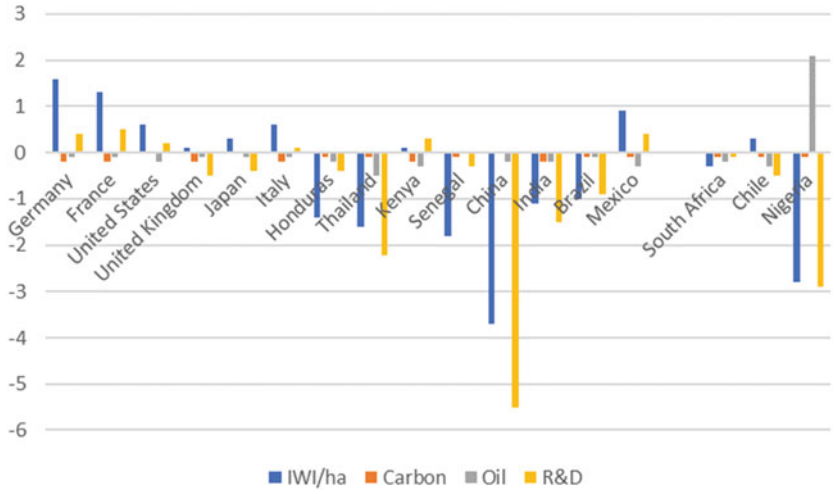

Fig. 4.7 Comparing the determinants of IWI

to safeguard human and natural capital) lowers the level of sustainable growth. In all these countries, the valuation effects of oil or the negative environmental externalities of the use of carbon resources have led to negative growth everywhere. In the industrialized countries, growth rates, even positive ones, are relatively low. There is heterogeneity between countries. For example, France and Germany have growth rates that are twice, and in the case of Germany three times, that of the United States, more than 10 times that of the United Kingdom, and four to five times that of Japan. The difference comes from technical progress, which is higher in these two countries than in other nations.

4.3 Sustainable Growth and Social Inclusion: A Trade-Off between Inequality and Poverty?

4.3.1 Fighting Poverty: The First Objective of Inclusive Growth

The notion of sustainable growth goes beyond preserving the balance of the various ecosystems. In social and political terms, it also implies that everyone benefits from economic growth. In recent years, there has been a voluminous economic literature on poverty and inequality, both theoretical and empirical. However, few works and models explicitly link these notions to the sustainability of growth (in the sense of "inclusive growth"). At best, papers focus on pro-poor growth. But theoretical and empirical progress still needs to be made on several points, which justifies the need to privilege a global approach, this time with the disciplines of the human sciences: sociology, psychology, and anthropology.

From a statistical point of view, a new multidimensional measure of poverty is now being proposed, based on the experiences of poor people (let us say that it is a behavioral approach). The method has nothing to do with experimental economics or randomized experiments. It is similar to what anthropologists do. Based on fieldwork conducted since 2016 by the OECD, ATD Fourth World, and Oxford University in six countries (Bangladesh, Bolivia, the United States, France, the United Kingdom, and Tanzania), a new indicator of non-inclusiveness of growth has been proposed by these institutions based on the feelings of people who are not beneficiaries of growth. This indicator has four dimensions.

The first dimension includes variables describing the core of the poverty experience and is related to disempowerment (in other words, the way in which the poor feel disempowered to act to improve their living conditions: psychological disincentives related to social suffering). The second dimension includes variables related to relational dynamics (social and institutional abuses, as well as unacknowledged contributions).

The third dimension deals with deprivation (lack of decent work, material deprivation, precarious income).

The fourth dimension includes "modifiers" (including cultural beliefs and the political environment).

This approach has several implications for theoretical modeling.

First, the experiences of people living in poverty suggest that work is not a service like any other. In economic analyses, it is a service from which both employers and those they employ derive income (a factor of production): On the side of firms, workers are hired for profit, and on the side of employees, a wage is received as compensation. However, when a significant number of people are unemployed, do not receive decent wages, and have precarious jobs due to the fragmentation of labor markets, the deprivation of these goods puts the social survival of individuals at risk. The work deprivation that accompanies poverty is, very often, correlated with situations of material deprivation, illiteracy, and social isolation, as well as with situations of opportunity inequality.

Second, there are implications for the way in which anti-poverty policies are designed. Field research (which extends beyond randomized experiments) shows a correlation between social inequality and poverty, in rich and poor countries. But poverty will not be eradicated through exclusively distributive policies, by heavily taxing the richest or capital. The solution is not only ex-post (through redistribution once the production of wealth has been achieved), but also ex-ante through the establishment of principles for the evaluation of social well-being that take into account the position of individuals in terms of access to primary goods and services: decent wages and employment, decent living conditions (access to good-quality health and education services, decent housing, equity in access to justice services), and today, the struggles against digital illiteracy and gender discrimination, as well as the search for more inclusive collective choice procedures. These are not ideological principles, but ethical ones in the sense of theories of social justice, notably those of Rawls and Sen. However, the reality on the ground suggests that one of the primary causes of poverty is inequalities in access to these primary goods and services. Indeed,

in recent decades, the trend has been toward greater fragmentation of labor markets at the global level, a nuclearization of work and a return to "task-based" remuneration favored by the uberization of economies, an accentuation of spatial segregation of housing due to land speculation (this phenomenon being observed throughout the world), and the deterioration of educational services in some of the world's poorest countries.

While field experiments have been gaining popularity among development economists and those working on inequality and poverty in recent years, there are several pitfalls to be avoided with this approach. The first is to think that a more accurate view of poverty can be obtained from subjective criteria derived from declarative data on the quality of life. We find here an old dilemma in social justice theories, between the welfarist approaches and the primary goods approaches of Rawls and the "capabilities" of Amartya Sen. Our societies will not be able to avoid a debate on what we choose, collectively and "objectively" (i.e., according to ethical principles), to consider as primary goods and services, beyond individual experiences. The second difficulty to overcome concerns randomized experiments. They do not allow the construction of general theories. Economists who use randomized experiments to test anti-poverty strategies have to fight against a strong temptation to seek consensus. This would be to forget that reactions to incentives vary from one group of individuals to another. The results of randomized experiments do not allow the formulation of microeconomic hypotheses that would serve as a basis for poverty reduction policies designed at the macroeconomic level.

How do we know whether a country's growth is socially inclusive? A common idea is that it should raise the average or median standard of living of the population. But we know that this criterion has its limitations, because it does not provide information about how what is produced is distributed. Nor does it provide information on the quality of life, let alone the thresholds at which income can be considered sufficient to live on. Inclusive growth improves people's quality of life.

The European Union, for example, uses a multidimensional indicator of material deprivation. Inclusive growth or development reduces people's deprivation. In Europe, poverty is defined as the inability of a household or individual to afford at least four of the following:

- Pay rent or utility bills,
- Keep the home adequately heated,
- Meet unexpected expenses,

- Eat fish, meat, or one protein equivalent every two days,
- Go on vacation away from home one week per year,
- Buy a washing machine,
- Buy a color television,
- Pay for one telephone connection.

Based on this criterion, it is estimated that 5.6% of the EU population is in this situation (24 million people). The populations at risk are young people, the least educated, and single-parent families. The countries with high rates of multidimensional poverty are Bulgaria (19.9%), Romania (12.6%), and Greece (15.9%).

Improvement in quality of life can also be seen in the fact that people's living standards are less subject to uncertainty. The European Union proposes an economic stress indicator that captures the vulnerability to shocks that can push people from a situation of precariousness to a situation of poverty. The dimensions of this indicator as follows:

- Difficulty in balancing the household budget given its income,
- Inability to meet unexpected expenses,
- Accumulation of payment arrears: rent, housing loans, credit purchases, water, electricity and gas bills,
- High burden of the total cost of housing.

Finally, it is necessary to have indicators of poverty. The at-risk-of-poverty rate is the proportion of people with an equivalent disposable income (after social transfers) below the at-risk-of-poverty threshold, which is set in the European Union at 60% of disposable income after social transfers. Based on these criteria, in 2019, the proportion of the population at risk of poverty and social exclusion was 21.1% in Europe (i.e., one fifth of the population). In 10 years (between 2008 and 2018) the risk of poverty has increased by almost 5pp in Luxembourg, 2.8 pp in both Sweden and the Netherlands.

4.3.2 The Question of the Trade-Off between Poverty and Inequality

Rampant inequality is another hot topic linked to the non-inclusive nature of growth in the industrialized countries and the rest of the world. In this chapter we do not address the extensive literature review that exists on this issue. Rather, we focus on a puzzle that has long been discussed by economists: Can economic growth reduce poverty and inequality at the

same time? Is this desirable? And is it possible? Kuznets (1955) was the first to suggest an inverted U-curve theory for inequality. In an initially poor country that industrializes, inequality jumps. It increases less and less rapidly as the country increases the standard of living of its population. Then, above a certain level of GDP, inequality falls. This was the case in most industrialized countries at the beginning of the twentieth century, reflecting the emergence of a pauperized working class. Some authors, such as Okun (1975), argue that a more equal distribution of resources can be disastrous for the production of wealth and therefore detrimental to the growth of average income because it reduces the incentives to work and invest.

But there is also a more anthropological reading. The forces that reduce poverty are technological and economic in nature. They are linked to the productive system, to technology, to the market, to trade, to business activity, to good business, and to industrialization. They correspond to the mechanisms that allow for an increase in wealth that could potentially be distributed in an equitable manner among all economic and social actors. The forces that reduce or increase inequality are sociopolitical in nature. Historically, they have emerged from the great societal demands for more equality, from sociopolitical compromises as in the regime of welfare states. According to a Marxist reading, inequalities are linked to private property and to the unequal ex-ante distribution of capital among social actors.

The answer to our question has been considered from several angles. The first idea is to try to find a link between the two phenomena (poverty and inequality) by focusing on a subgroup of the population. For example, statistically, there are indicators that measure both the poverty rate and its depth by taking into account the distribution of income among the poorest. These are the FGT indicators (Foster–Greer–Thorbecke):

$$P_\alpha = \frac{1}{N} \sum_{j=1(R_j \leq S)}^{K} \left(\frac{S - R_j}{S} \right), \tag{4.1}$$

where

N: population size,
R_j: income of individual j (earning less than the income corresponding to the poverty line$S$),
S: poverty line income,

K: number of poor individuals with income less than S,
$\alpha = 0, 1, 2, 3, \ldots$.: relative weights of the poorest among the poor inequality aversion parameter.

For $\alpha = 0$, we define the headcount poverty, which corresponds to the proportion of the poor in the total population:

$$P_0 = \frac{K}{N} = \frac{1}{N} \sum_{j=1(R_j \leq S)}^{K} 1. \tag{4.2}$$

For $\alpha = 1$, we define the poverty gap measure or depth of poverty, which provides information about the average location of the poor relative to poor people's average income:

$$P_1 = \frac{1}{N} \sum_{j=1(R_j \leq S)}^{K} \left(\frac{S - \bar{R}_L}{S} \right), \tag{4.3}$$

where $\bar{R}_L$ is the poor individual's average income.

For $\alpha = 2$, we define the severity of poverty, which considers the distribution of income among the poor captured by the standard deviation of income (denoted σ_L) in the following equation:

$$P_2 = \frac{1}{N} \sum_{j=1(R_j \leq S)}^{K} \left[\frac{S - R_j}{S} \right]^2 = \frac{K}{N} \left[\left(\frac{S - \bar{R}_L}{S} \right)^2 + \left(\frac{\sigma}{S} \right)^2 \right]. \tag{4.4}$$

Using the FGT indexes, one can also consider the Sen poverty indicator, which combines all three aspects of poverty: headcount, depth, and severity:

$$Sen = P_0 G_L + P_1 (1 - G_l), \tag{4.5}$$

where G_L is the Gini index computed for individuals' income below the poverty line.

A disadvantage of these measures of poverty is that they can produce surprising results, such as a decline in poverty when income falls, because it creates more deaths. On the other hand, in the opposite direction, the demographic effect is interesting. Even when income increases, poverty

may increase due to a demographic effect (poor families have more children). This problem is not solved by taking income per capita, because we do not have detailed statistical data on how deaths and births are distributed in the population according to income level. But they are widely used.

A disadvantage of ¶$_{a}$*lpha* indicators is that they focus on the poorest. For public policy, the question must be more universal: How to increase the average standard of living while reducing the dispersion of income within a population? To answer this question, we must not approach it in exclusively economic terms, but also in terms of political philosophy or social justice. Let us make the hypothesis that intra- and intergenerational solidarity is a condition for the viability of societies in the long term. A possible reason is that no social contract, no productive system, can last over the long term without the support of the population. But this adherence presupposes that the needs of everyone are taken into account. But how can we objectively construct a social welfare function? Economists have answered this question by highlighting a paradox: It is impossible if preferences are heterogeneous (Arrow's impossibility theorem). The solution can only be based on normative principles. According to Rawls, a fair society is one in which each member has access to primary goods, any deprivation being equivalent to depriving people of freedom. The fight against poverty is therefore a first objective to aim for (providing everyone with the minimum to live decently). But can it be achieved by fighting against inequalities?

In Fig. 4.8, we show poverty on the x-axis, on a scale of 0–1. This is any indicator that measures the average standard of living of the population. As we approach 1, poverty becomes important in the country. Conversely, as we move toward 0, it decreases. On the ordinate, we represent inequality. Inequality is high when we are close to 1 and low when we are close to 0. On this graph, small numbered circles illustrate different country situations. Circle 1 corresponds to an ideal situation where the distribution of income and wealth is not very unequal and poverty is low. This is the medium-/long-term objective toward which a government that puts inclusive, socially sustainable growth at the heart of its priorities seeks to move. Circle 2 represents a situation of egalitarianism in poverty. This was the case in China throughout the Mao period, and also in the USSR until Perestroika. It is still the case today in many poor countries in sub-Saharan Africa, Asia, and Latin America. Circle 3 describes a case where a few rich people rule in the middle of a mass of poor people. This situation

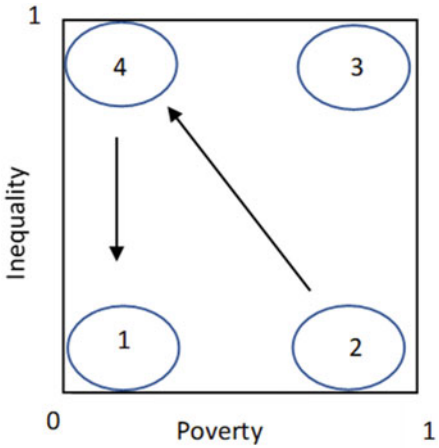

Fig. 4.8 Fighting inequality and poverty

generally characterizes "kleptocracies", that is, economies that function under the regime (autocratic or liberal) of exploitation of rents. Finally, circle 4 illustrates the situation of countries with a high average standard of living in a context of high inequality. This reflects the current situation in many industrialized countries.

The question we can ask ourselves is: Starting from a given initial situation, how do we get to circle 1?

Let's start from circle 2, taking two examples. This was the situation in the Communist People's Republic of China under Mao, between 1949 and 1976. The mass of the population, mainly rural and working class, was poor, but communism claimed to be different from capitalism in its ethics in favor of equality among all. The doctrine in vogue was an adaptation of Soviet communism to the Chinese reality. The policy of the Great Leap Forward until 1966 marked the collectivization of the means of production. The Great Cultural Revolution, from 1966 onward, aimed to give power to the masses (the proletariat and the youth) by eradicating all symbols of inequality (questioning the bureaucracy, the elites and all Confucian symbols of meritocracy). Even if daily life was devoid of comfort, the system drew its strength from an authoritarianism based on the zeal of the rulers to exalt the sharing of goods in common as an example of humanity. A similar situation prevailed in a small African country, Burkina Faso, between 1983 and 1987. Under the leadership of Thomas Sankara, one of the poorest countries in the world adopted harsh

policies of eradicating corruption, national emancipation, and repression of any opposition to the anti-imperialist struggle. The ideas were close to Russian communism, but were intended to be rooted in the African tradition. Typically, political regimes promote structures for participatory democracy, both politically and economically (e.g., participation in local management structures). In Burkina Faso, as in China, the aim was to give power to the masses. In China, a breakthrough came with Deng Xiaoping's reforms from 1978. The arrival in power of a new generation of leaders led to the following leitmotiv: The people of China want the same standard of living as those in Western countries. From then on, the objective was to create a middle class to which it was hoped to provide a standard of living comparable to that in Europe or the United States. In Burkina Faso, the arrival in power in 1987 of a president more in favor of close relationships with France and industrialized Western countries gradually put an end to the revolutionary experience. Before that, people were living in a country of "men of integrity" (as Burkina Faso means in the Moré language), but the vast majority of them were very poor.

In the figure, arrows are drawn to indicate the case of a country that cannot move directly from circle 2 to circle 1, and that must necessarily join circle 4 first. This seems to be consistent with what the historical and empirical evidence suggests (even if it is only clusters of evidence with no theoretical basis).

Indeed, historical evidence suggests that the two phenomena (declining poverty and declining inequality) have often been decoupled. For example, Perestroika in the early 1990s raised Russian living standards above what they had been before, but it was initially accompanied by a sharp rise in inequality. Developing countries that experience catch-up growth rates of 5–8% for several years experience an increase in GDP per capita, but this is not immediately accompanied by an improvement in inequality indicators (Gini and Theil indices, Palma ratio, etc.). In the case of China, between 1978 and 2012, about 600 million Chinese people were lifted out of extreme poverty. Living standards have risen and a large middle class has emerged. But the meteoric growth has also increased income and wealth inequality. The goal of the Chinese leaders is now to move down to circle 1 by keeping the economy as far to the left as possible in the figure. The quest for a "harmonious society" is the stated goal of the Chinese Communist Party, which means that growth strategies over the next few years will be based more on social justice considerations (even though the country appears to be growing at lower rates than in the past decade).

What makes it difficult to reach both objectives simultaneously (fighting poverty and income inequality) is that the necessary conditions are often difficult to meet. Not only must economic growth be sufficiently fast (to bring about a significant decline in poverty levels), but inequality must not be too pronounced at the beginning and end of the process. This means that countries starting from an initial situation corresponding to point 2 are more likely to achieve these two objectives than countries starting from point 3. This can be easily demonstrated by using two concepts familiar to growth economists, that is, beta and sigma convergence.

Let us consider a population with N individuals $j(j = 1, \ldots, N)$ whose income y is measured between two dates t_0 and t_1. A usual measure of a decrease in income inequality is the σ-convergence, that is, that the variance of income is lower at date t_1 than at date t_0 $(t_0 < t_1)$:

$$V(y_{t_0}) > V(y_{t_1}). \tag{4.6}$$

The increase in average income between the two dates can be described by a β-convergence equation:

$$y_{t_1} - y_{t_0} = \alpha - \beta y_{t_0} + \epsilon_{t_1}, \tag{4.7}$$

where ϵ_{t_0} is a residual term. α and β are two coefficients.

If the average per capita income is negatively correlated with the cumulative average income gap between the two periods, this means that the average income has increased between the two periods t_0 and t_1, so beta is positive. There may be several causes. But it is not clear whether this income is increasing because the standard of living of the poorest has increased faster than that of the richest. We could even have an increase in average income if the income of the richest increases greatly and that of the poorest decreases somewhat. Ideally, we would like to see the standard of living of the poor rise faster than that of the rich.

Considering a general form of the convergence equation, we write

$$y_t - y_{t_0} = \beta(y_{t-1} - y_{t_0}) + \epsilon_t, \quad t > t_0. \tag{4.8}$$

Taking the variance of both sides, we obtain

$$\sigma_t^2 = \frac{1}{1 - \beta^2 L}\left[(1-\beta)^2\sigma_{t_0}^2 + \beta(1-\beta)cov(y_{t-1}, y_{t_0}) + \sigma_{\epsilon_t}^2\right], \tag{4.9}$$

where σ_t^2 is the variance of y_t,$\sigma_{t_0}^2$ is the variance of income at time t_0, $\sigma_{\epsilon_t}^2$ is the variance in income due to idiosyncratic factors, L is the lag operator. If $|\beta| < 1$, then we have β-convergence. Under this assumption, the limit behavior of $\sigma_t^2 - \sigma_{t_0}^2$ (when $t \to \infty$, $L = 1$) is given by

$$\sigma_t^2 - \sigma_{t_0}^2 = \frac{1}{1-\beta^2}\left[\beta(1-\beta)cov(y_{t-1}, y_{t_0}) + \sigma_{\epsilon_t}^2\right]. \tag{4.10}$$

Using the fact that, by the OLS (ordinary least squares) estimate of β,

$$cov(y_{t-1}, y_{t_0}) = \frac{1+\beta}{\sigma_{t_0}^2}, \tag{4.11}$$

We can write

$$\sigma_t^2 - \sigma_{t_0}^2 = \frac{\beta}{\sigma_{t_0}^2} + \frac{\sigma_{\epsilon_t}^2}{1-\beta^2}. \tag{4.12}$$

Inclusive growth must meet two conditions.

First, it must lead to the production of new wealth (growth), so that the average income initially observed in the population increases. The β-convergence condition must therefore be satisfied. Moreover, the poorest in the initial income distribution move to the right of the distribution, which implies a tightening of the left tail of the distribution. This does not necessarily happen, especially when the convergence is cyclical (when β is less than 1 in absolute value but negative). The β-convergence process is not necessarily monotonic. GDP per capita can increase cyclically around an increasing trend, which means that growth rates vary over time: Sometimes the economy grows rapidly, sometimes its growth slows down. When β is negative, there is σ-convergence (lower income inequality) if the variability of income due to idiosyncratic shocks does not exceed a certain threshold:

$$\sigma_{\epsilon_t}^2 < \left|\frac{\beta(1-\beta^2)}{\sigma_{t_0}^2}\right|. \tag{4.13}$$

If initially the income distribution is highly unequal (X large), then even a small variability in the growth dynamics can lead to a sigma-divergence in income.

Another way of dealing with the issue of trading off between poverty and inequality is to use the concept of poverty elasticity of growth, which has been extensively studied in the literature.

Let us take the FGT index, discussed above, in continuous time:

$$P_\alpha(S, R)) = \int_0^S \left(\frac{S-R}{S}\right)^\alpha f(R)dR, \tag{4.14}$$

where $f(R)$ is the density R which measures the distribution of income among the poor. The poverty elasticity of growth is defined by:

$$\eta_\alpha = \frac{\alpha(P_{\alpha-1} - P_\alpha)}{P_\alpha}. \tag{4.15}$$

To account for the effect of income distribution on the response of poverty indicators to growth, it is necessary to make assumptions about the distribution of the density function $f(R)$. In the literature, we often consider the case where this distribution is log-normal (see, e.g., Bourguignon 2000; Datt and Ravallion 1992; Kakwani 1993). The elasticity of the headcount poverty can be written as:

$$\eta_0 = -\frac{\Delta P_{0t}}{P_{0t}} \frac{1}{\Delta \ln(\bar{R}_L)} = \frac{2}{\sigma_L^2}\lambda\left[\frac{\ln(S/\bar{R}_L)}{\sigma_L^2} + \frac{\sigma_L^2}{2}\right], \tag{4.16}$$

where $\frac{\Delta P_{0t}}{P_{0t}}$ is the proportional change in headcount poverty, $\bar{R}_L$ and σ_L^2 are respectively the average and standard deviation of log-income among the poor, λ is the hazard function of the standard Normal distribution (i.e., the ratio of the density to the cumulative distribution function). S is the poverty line.

The equation shows the sensitivity of headcount poverty to a 1% increase in the average income, assuming that the inequality of income does not change (σ is given). The elasticity is an increasing function of the economic growth (captured here by $S/\bar{R}_L$). Indeed, a higher growth rate brings the average income closer to the poverty line. Elasticity is a decreasing function of inequality. In the case of a log-normal distribution, there is a relationship between the Gini coefficient and σ:

$$Gini = 2\Phi\left[\frac{\sigma_L}{\sqrt{2}}\right] - 1, \tag{4.17}$$

where Φ is the cdf of the standard Normal distribution. For a given level of elasticity, we can observe that there is an inverse relationship between poverty and income inequality. The level curves are decreasing and convex.

The elasticity of the poverty gap is written as:

$$\eta_1 = \frac{\Phi\left[\ln(S/\bar{R}_L)/\sigma_L - \sigma_L/2\right](\bar{R}_L/2)}{\Phi\left[\ln(S/\bar{R}_L)/\sigma_L + \sigma_L/2\right] - \Phi\left[\ln(S/\bar{R}_L)/\sigma_L - \sigma_L/2\right](\bar{R}_L/2)} \tag{4.18}$$

As shown earlier, for a given level of η_1, there is a decreasing and convex relationship between poverty and income inequality. To show the effects of changes in income distribution in the indicators, we can use the approach suggested by Datt and Ravallion (1992).

The assumption of a log-normal distribution of income can be criticized, and the literature has highlighted other distributions (see, e.g., Cowell and Flachaire 2007). But the derivation of previous elasticities under these distributions is still an open field of research. In particular, it would be interesting to examine the case of extreme distributions (where, e.g., there are large income disparities within the population of the poor).

Some empirical work argues in favor of the two-step sequence: first fighting poverty, then fighting inequality. Indeed, one of the stylized facts highlighted in the context of globalization over the last 30 years is that the opening up of economies has reduced inequalities between countries, but that these have increased within countries. The convergence of living standards between countries is linked to the phenomenon of economic catch-up and to the fact that the GDP per capita of the poorest countries has grown faster than in the richest countries. The increase in inequalities is linked to various phenomena: the technological shift (skill premium) and its consequences on the widening of wage inequalities, the greater flexibility of labor markets which have increased competition between workers and crushed wages, the decline of welfare states, and disparities in access to land, capital and opportunities, etc.) (see, e.g., on these aspects Autor et al. 2014; Bourguignon 2016; Brandolini and Carta 2016; Dabla-Norris et al. 2015; Milanovic 2016, and Rodrik 2018).

The question of theoretical links (proven or unproven) between inequality and poverty remains open, even though the issue has been debated for

a long time. We have, for the moment, essentially empirical and historical answers (see, e.g., in a very extensive literature, Berg and Ostry 2011; Lopez and Serven 2006; Ravallion 2005, and more recently Berg et al. 2018; Lakner et al. 2022, and Seo et al. 2020). It is still not clear whether a better redistribution of wealth is an effective and sustainable policy to fight poverty, because it is also necessary to take into account the factors endogenous to the dynamics of poverty that are at the origin of, for example, poverty traps or recidivism phenomena. All we can say is that more equality of income or wealth is a factor of social stability (and therefore of sustainable growth) because it responds to norms of social justice accepted by the social actors. On the other hand, empirical evidence shows that fighting poverty is not a sufficient criterion for reducing inequality. All these questions are important because they condition the public policies to be adopted. Should policies be universal, or is it better to target subgroups of the population? The economist can approach this question by anchoring his or her reflections in other disciplines, notably sociology, where these questions have long been studied (see, e.g., the seminal paper by Korpi and Palme 1998). Theoretical contributions were first developed with reference to the seminal approaches of Kuznets and Kaldor, but were then abandoned because of the questioning of the empirical stylized facts put forward by these authors. Several authors suggest a new theoretical framework that links inequality to the increase in rents of different types (land, human capital, wealth and intergenerational transfers, distribution of asset ownership). We can add to this the rents accumulated by the GAFAM, whose business is based on the almost free exploitation of massive data collected from the users of their services. The same GAFAM order works to numerous subcontractors or employees in strong competition with each other. There is both an accumulation of rents and a concentration of capital. If there is a link between inequality and poverty, it may be, for example, dynastic inequality, which perpetuates inequality from one generation to the next through the transmission of wealth, but also explains the persistence of situations of poverty (see, e.g., Kanbur and Stiglitz 2015; Stiglitz 2016).

4.4 A Hot Topic for the Twenty-First Century: Should Inheritance be Taxed?

While the debate on inequality has focused on the unequal distribution of wealth and income, the issue of dynastic inequality is at the heart of the debate on what a fair society should look like. The sustainability of growth includes a dimension of social ethics, and this applies to relations between generations.

One of the reasons for the vehemence of the debate today is that recent work seems to show a return of rentier societies. In the United States, 10% of the population holds almost three quarters of the wealth, and the top 10% of the population holds 99% of the financial investments. In Europe, in France, for example, inheritance flows were 15% in 2010 and are projected to be 25% according to Piketty's data. Moreover, sociological data show that in most industrialized countries, the reproduction of elites is a phenomenon due to barriers (cultural, financial) to access to education. This phenomenon is even one of the causes of the slowdown in productivity gains in the United States: Higher education has become expensive and even unaffordable for many people. Does inheritance increase social inequality? The answer is yes, if we consider only movable and immovable capital. Indeed, real estate bubbles increase spatial segregation (by limiting access to city centers to people who do not own property). Moreover, according to Piketty, there is a dynastic reproduction of inequalities linked to the phenomena of rent extraction: monopolies, patents, and financial markets. Finally, real estate and movable capital is today concentrated in the generations born during the baby boom period. There is thus an inequality between generations, since the younger generations who would need capital to invest benefit from it late and often have to go into debt.

If we include public goods and services in the inheritance, the answer is more ambiguous. Societies in industrialized countries benefit from a public heritage, through the social protection systems that are a hallmark of political regimes based on social democracy: pension rights, health expenditures related to old age, and social transfers to senior citizens. This mitigates the effects of wealth inequalities, even if differences between countries may exist depending on the specific regimes (capitalization versus distribution, public versus private health systems). If we include human capital, there is no doubt that inheritance is a cause of dynastic inequality. Emmanuel Todd shows that in the United States, it is a tool for sorting out the elites.

Should inheritance be taxed? If so, should we tax the holding or the transmission? The transfer tax has been abolished in some industrialized countries (e.g., Portugal, Austria, Sweden, Italy, and Australia).

The arguments in favor of taxing inheritances are well known. On the one hand, it generates economic inefficiencies. This argument is put forward by Piketty, for example. If the interest rate is higher than the growth rate, then economic actors have been over-saving by building up financial rents and under-investing by limiting economic risk-taking. On the other hand, inheritance can have a negative effect on the supply of labor (and thus on economic activity). If there are wealth effects due to the revaluation of wealth following increases in asset prices, this affects the intertemporal trade-off between consumption and leisure over the life cycle.

Macroeconomists disagree on the following point. Some believe that wealth ownership should be taxed. Piketty believes that capital should be taxed whatever its origin (whether inheritance or capital gains) in order to fight against the phenomenon of capital concentration-one should tax rent extraction-and to avoid the capture of the state by the richest (lobbying). Other economists, such as Philippe Aghion, posit that we should not tax entrepreneurs (who innovate and take risks), but rather rentiers. Those who believe that it is better to tax inheritance have several motivations. First, there is a redistributive virtue. Inheritances are a source of inequality. Yet democracies favor meritocracy (equality of opportunity must be promoted). It is therefore necessary to correct the inequalities linked to initial endowments. Another argument is that there is an asymmetry of information between those who know how financial markets work and those who do not. Arrondel and Masson suggest that transfers at death should be heavily taxed, so as to encourage in vivo donations. The idea is to reward altruism in order to reduce dynamic inefficiency (accelerating donations during the life cycle alleviates the liquidity constraints of descendants). Readers interested in these topics can consult the following articles (among many others): Adermon et al. (2018), Blancher et al. (2022), Botta et al. (2021), Chancel and Piketty (2021), Corak (2013), Lindahl et al. (2015), Palomino et al. (2021), Piketty and Saez (2013), Piketty (2014), Piketty and Zucman (2015), and Piketty (2020).

4.5 Conclusion

The issue of sustainable growth goes beyond the question of limits to growth. We are in an era where scientists from other disciplines are putting forward the hypothesis of potential ruptures in the regulation of environmental ecosystems, micro-organisms, and biodiversity, but also ruptures in sociopolitical stability, the rise of dynastic inequalities, and the phenomena of the recurrence of poverty. Faced with this, the standard models of environmental economics, at the center of which is the economic sphere, have little to tell us. The right approach is that of global models whose purpose is to model what scientists call the Earth's boundaries. Of course, growth or GDP per capita and the allocation of available resources are included in the sustainability objectives, but they are objectives among others (non-economic).

This shows that the question of sustainability is one of the most complex of the many questions that economists face. It challenges our modeling habits. On the statistical side, it is the same. We have given an example here of the IWI indicator proposed by the United Nations to measure the growth of GDP per capita taking into account used and available resources. It is likely that this indicator will be completed in the future to integrate the availability of water resources, as more and more countries are suffering from water stress, as freshwater resources are decreasing, and as the evapo-transpiration cycle seems to be disrupted by human activities as well. We have also addressed the issue of the trade-off between poverty and inequality, to underline the difficulty of strategies trying to fight against these two scourges at the same time. A sequenced strategy seems more appropriate.

In any case, we realize that the question of sustainability of growth and development puts the homo economicus as an element at the heart of different sets: societies, animal, geochemical, and environmental ecosystems. One of the difficulties for economists is that of entering into this perspective by not thinking that growth is the final objective and that ecosystems-or society-are constraints to be taken into account.

PIONEERS IN THE FIELD

Joseph Stiglitz

Stiglitz is known for his theoretical contributions which earned him the Nobel Prize in Economics in 2001. In particular, his papers have contributed to a better understanding of the phenomena of asymmetry of information. In relation to the topic of this chapter, he can be defined as one of the economists with the most innovative theoretical proposals on the issue of the analysis and reduction of inequalities. With Jean-Paul Fitoussi and Amartya Sen, he proposed in 2008 that indicators of well-being should go beyond GDP alone and include ecological and social dimensions. Some of his ideas are summarized in his book *The price of Inequality published* by WW Norton & Co in 2013, where he analyzes the rise of wealth and income inequalities in the United States and the role played by rent-seeking activities and the destabilizing role of the financial cycle for socioeconomic balances. An important aspect of the book is that it shows that the fight against inequality is based on political choices. Stiglitz has contributed to advancing the ideas of redistribution policies through taxes on capital in order to fight inequality and poverty, working with another global specialist on these issues, Anthony Atkinson. Stiglitz can be compared to Joseph Aloy Schumpeter in his approach to economic processes that are embedded in the historical, social, and political dynamics of societies. Readers interested in a comprehensive view of his contributions to the field of social justice can read the book edited by Martin Guzman at Columbia University Press in 2018 entitled *Toward a Just Society: Joseph Stiglitz and Twenty-First Century Economics.*

Thomas Piketty

Like Joseph Stiglitz, this economist has made a major contribution to the analysis of inequality. In addition to Capital in the Twenty-First Century, his other book, Capital and Ideology, which has been translated and published by Harvard University Press, is worth reading. The author has an advantage over other academic authors: He uses statistics but above all his historical knowledge of societies

(continued)

to study past and contemporary inequality regimes, in industrialized and emerging countries. We can retain several key ideas from his work. First, while inequality has become rampant in industrialized economies (the breakthrough being meteoric in the United States), this has not always been so. The period between 1914 and 1980 was one of redistribution through progressive income and inheritance tax systems. This was one of the hallmarks of social democracy in Europe. An important point emphasized by the author is that the decline of this sociopolitical regime is due to the collapse of the USSR in the early 1990s. Among the author's original proposals for reducing inequality are a universal capital endowment equal to 60% of the average adult's wealth, the application of social quotas in access to education, and the restoration of progressive taxes with an increase in the marginal rates on the income of the richest. Piketty considers that in order to allow the least privileged to benefit from the highest standards of living, it is necessary to rethink property relations and the distribution of income and wealth. In his abundant work, the interested reader will find ideas on various subjects: the transformation of capital since the eighteenth century, the division of capital and labor over the long term, the evolution of labor inequalities in industrialized countries, the relationship to inequalities in meritocratic societies, the problem of public debt and its reduction, the constitution and evolution of the social state, and the history of the progressive income tax.

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