RESOURCE SCARCITY FROM AN APPLIED ECONOMIC PERSPECTIVE

Jose Cuesta[*]

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[*] Affiliated Professor, McCourt School of Public Policy, Georgetown University; Senior Economist, Poverty Reduction and Equity Unit, World Bank.

I. INTRODUCTION

Fellow economists' views on natural resource scarcity range from fear of catastrophic consequences to an unsettling lack of apprehension, something not uncommon in economics. Malthus hypothesized at the turn of the eighteenth century on recurrent cataclysms caused by population growth exceeding food growth.[1] Two centuries later, theorists of new growth economics consecrate knowledge as the solution to the quandary of diminishing returns that natural resources pose as factors of production.[2] Optimistic and pessimistic views over resource scarcity have alternated throughout history, and interest has recently reignited as increasing and volatile prices of food emerge as a new norm.[3] This has certainly been the case for economists across multiple disciplines, adding to previous discussions of how natural resources affect economic growth—and, to a lesser extent, how economic growth impacts natural resource availability—found in Barnett and Morse[4] and revised in Simpson, Toman, and Ayres.[5] The effects of natural resource abundance, dependence, and competition are increasingly being studied by economists interested in conflict, poverty, political stability, and governance.[6] These new interests add to the

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[1] THOMAS MALTHUS, AN ESSAY ON THE PRINCIPLE OF POPULATION (1798).

[2] Joseph Cortright, *New Growth Theory, Technology, and Learning: A Practitioner's Guide*, REV. ECON. DEV. LIT. & PRAC., No. 4 (2001), at 4.

[3] The World Bank, FOOD PRICE WATCH (Nov. 2012), *available at* http://siteresources.worldbank.org/EXTPOVERTY/Resources/336991-1311966520397/Food-Price-Watch-November-2012.htm.

[4] Harold J. Barnett & Chandler Morse, *Resources for the Future, Scarcity and Growth*, *in* THE ECONOMICS OF NATURAL RESOURCE AVAILABILITY (1963).

[5] R. DAVID SIMPSON ET AL., SCARCITY AND GROWTH IN THE NEW MILLENNIUM: SUMMARY (Resources for the Future Discussion Paper 04-01, 2004), *available at* http://bscw-app1.ethz.ch/pub/bscw.cgi/d170325/Simpson_etal_2004.pdf (revisiting and revising Barnett and Morse findings).

[6] *See generally* THE INT'L BANK FOR RECONSTRUCTION & DEV., THE WORLD BANK, NATURAL RESOURCES AND VIOLENT CONFLICT: OPINIONS AND ACTIONS (Ian Bannon & Paul Collier eds., 2003); Richard M. Auty, *Natural Resource Endowment, the State and Development Strategy*, 9 J. INT'L DEV. 651 (1997); Markus Brückner & Antonio Ciccone, *International Commodity Prices, Growth and the Outbreak of Civil War in Sub-Saharan Africa*, 120 ECON. J. 519 (2010); Paul Collier & Anke Hoeffler, *On Economic Causes of Civil War*, 50 OXFORD ECON. PAPERS 563 (1998); Philippe Le Billon, *The Political Ecology of War: Natural Resources and Armed Conflicts,* 20 POLITICAL GEOGRAPHY 561 (2001); Päivil Lujala et al., *A Diamond Curse? Civil War and a Lootable Resource*, 49 J. CONFLICT RESOL. 538 (2005); Michael L. Ross, *What Do We Know About Natural Resources and Civil War?*, 41 J. PEACE RESEARCH 337 (2004); JEFFREY SACHS & ANDREW WARNER, CENTER FOR INTERNATIONAL DEVELOPMENT & HARVARD INSTITUTE FOR INTERNATIONAL DEVELOPMENT,

mainstream focus of agricultural economics on agricultural production, international development, resources and environment, and agribusiness.[7]

Part of the diversified attention has led to specific proposals beyond the traditional and somewhat unsophisticated menu of regulation and taxation of natural resource exploitation, formally developed a long time ago by Hotelling.[8] These include an earnest intention to stop counting "consumption of nature" as income, that is, as a free good.[9] For example, many national account specialists and public and growth economists call now for measures of economic product and growth that better capture natural capital availability and depreciation.[10] A practical example is the "sustainable budget index" in Botswana (credited as the most successful mineral-based economy in Africa), a policy rule that requires that all mineral revenues be reinvested.[11]

This recent renewed interest is perhaps a little surprising from a discipline defined as the science of scarce resources and how to use them efficiently. What is more surprising is the lack of a universally agreed upon definition of what scarcity is within the discipline, not to mention an operational classification of scarcity, similar to the geological classification of elements

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Natural Resource Abundance and Economic Growth (Nov. 1997), http://www.cid.harvard.edu/ciddata/warner_files/natresf5.pdf.

[7] C. Ford Runge, *Agricultural Economics*, *in* THE NEW PALGRAVE DICTIONARY OF ECONOMICS (Steven N. Durlauf & Lawrence E. Blume eds., 2d ed. 2008).

[8] Hotelling introduces his formal analysis by noting: "Contemplation of the world's disappearing supplies of minerals, forests and other exhaustible assets has led to demands for regulation of their exploitation . . . . Taxation would be a more economic method than publicly ordained inefficiency in the case of purely commercial activities such as mining and fishing for profit . . . ." Harold Hotelling, *The Economics of Exhaustible Resources*, 39 J. POL. ECON. 137, 137 (1931).

[9] William K. Tabb, *Resource Wars*, 58 MONTHLY REV. (2007), *available at* http://monthlyreview.org/2007/01/01/resource-wars.

[10] Natural capital is defined as encompassing land, forests, and subsoil resources. More specifically, Hamilton and Ley argue that national wealth shrinks if the proceeds from drawing down an asset are not invested. The picture that results from properly accounting for shrinking natural resources—large factor payments abroad and low investments in human capital—is a dismal trajectory of unsustainable macroeconomics and wealth dissipation in many resource-rich countries. Kirk Hamilton & Eduardo Ley, *Measuring National Income and Growth in Resource-Rich, Income-Poor Countries*, 28 ECON. PREMISE 1, 2 (2010); *see also* JOSEPH STIGLITZ ET AL., REPORT BY THE COMMISSION ON MEASURING ECONOMIC PERFORMANCE AND SOCIAL PROGRESS 17 (2009).

[11] In addition, Botswana follows another policy rule whereby the total amount of capital (including mineral assets and net foreign financial assets) should be maintained at the same level. GLENN-MARIE LANGE & MATTHEW WRIGHT, SUSTAINABLE DEVELOPMENT IN MINERAL ECONOMIES: THE EXAMPLE OF BOTSWANA 15 (CEEPA 2002), *available at* http://www.ceepa.co.za/dispapers/botswana_sustain.pdf.

as geochemically scarce or abundant. Geology considers elements that occur in the Earth's crust at average abundances below 0.1% as scarce.[12] A similar attempt to define land scarcity by an empirical threshold, that is when 70% or more of the arable land is under production, has not rallied a wide consensus.[13] Estimates of the value of subsoil assets by the World Bank simplistically assume a lifetime of only twenty years across a number of resources ranging from oil and natural gas to gold, bauxite, or copper.[14] In the absence of a practical and meaningful definition of scarcity in economics, Part II reviews different approaches that have been used to understand scarcity, from the traditional idea of a physical phenomenon restricted to natural resources to more complex concepts that include natural "amenities." Part III argues in favor of a pragmatic definition that avoids an elusive and complex conceptualization. The proposed definition will instead focus on the relevant features of resources. Part IV discusses the prospective trends of one of the most important scarcities that has recently attracted critical attention, namely food scarcity, despite the resource being renewable and inexhaustible. Part V reflects on the policy aspects of resource scarcity and provides concluding remarks.

II. ECONOMICS OF SCARCITY 101: BEYOND PHYSICAL SCARCITY

Economics is the science of scarce resources and how to use them efficiently (or, in the jargon, how to optimally achieve an objective at the lowest cost possible). As such, scarcity is a concept as old as economics—perhaps older. Quintus Tertullianus wrote in A.D. 200 that pestilence, hunger, war, and floods were all consequences of resources being "scarcely adequate to us," the human race. He enumerated deforestation, loss of

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[12] Based on this criterion, there are twelve abundant elements and ninety or so known scarce elements, with aluminum, iron, magnesium, and manganese accounting for 99.23% of the mass of the earth's continental crust. Robert Ayres, *Resources, Scarcity, Growth, and the Environment* 10 (Ctr. Mgmt. Env't Resources, Working Paper No. 2000/31/EPS/CMER, 2001). *See also* JAMES R. CRAIG ET AL., RESOURCES OF THE EARTH: ORIGIN, USE, AND ENVIRONMENTAL IMPACT 279–333 (3d ed. 2001).

[13] *See* THOMAS F. HOMER-DIXON, ENVIRONMENT, SCARCITY, AND VIOLENCE 63–64 (1999). Burns points to the absence of tests or any systematic analysis to come up with the 70% threshold, suggesting that it might be an educated guess. Thomas J. Burns, *Environment, Scarcity, and Violence by Thomas F. Homer-Dixon*, 7 HUMAN ECOL. REV. 76, 76 (2000), *available at* http://www.humanecologyreview.org/pastissues/her71/71bookreviews.pdf.

[14] WORLD BANK, WHERE IS THE WEALTH OF NATIONS? (2006) (the exact list of assets includes oil, natural gas, hard coal, soft coal, bauxite, copper, gold, iron ore, lead, nickel, phosphate rock, silver, tin and zinc. Some 127 countries are covered; estimates refer to 2000 values.).

biological diversity, farming unsuitable land, and urbanization as observed effects of scarcity.[15] Food shortages are believed to have contributed to the demise of early civilizations like the Sumerians and the Mayans, whose food systems were brought down by soil degradation.[16] Scarcity was at the center of the widely known arguments popularized by Malthus's 1798 *Essay on the Principle of Population*. He argued that populations tend to grow geometrically, while food production grows arithmetically, resulting in increasing population pressures on resources, leading often to catastrophic consequences.[17] David Ricardo's theory of rent rests on the very principle that resources (he originally referred to land) are of different quality and in short and unequal supply.[18] Among the gloomy views on scarcity, another of the fathers of modern economics, Alfred Marshall, wrote that "[t]he world is really a very small place, and there is no room in it for the opening up of rich new resources . . . . When new countries begin to need most of their own food and other raw produce, improvements in transport will count for little."[19]

Doomsday views are also common in current times. It is fairly common these days to read news such as the killings of dozens in Kenya as a result of tribal fighting triggered by confrontation over scarce pasture for livestock.[20] In the case of oil, Tabb argues that as China's income levels get closer to those in the United States, the ownership of cars will increase and may reach one billion by 2031: if they all need to run on gasoline, Tabb argues, there would not be enough oil to power them.[21] Brown predicts that the depletion of underground water is even more threatening than depletion of oil resources.[22] Some eighteen countries (including China, India, and the United

[15] SIMPSON ET AL., *supra* note 5, at 5.

[16] LESTER R. BROWN, FULL PLANET, EMPTY PLATES: THE NEW GEOPOLITICS OF FOOD SCARCITY 6 (2012).

[17] MALTHUS, *supra* note 1.

[18] So lands endowed with plentiful resources benefit from higher prices as population and, consequently, demand increases until marginal lands are tapped. Development, accompanied by increasing demands on food, will increase prices and create rents for landlords, which Ricardo considered a waste to society (ignoring the possibility of such rents being invested), and increasingly so as land becomes more scarce. SIMPSON ET AL., *supra* note 5, at 5.

[19] *Id.* at 6 (quoting MEMORIALS OF ALFRED MARSHALL 326 (A.C. Pigou ed., 1925)).

[20] Reuben Kyama, *Clashes Kill Dozens in Kenya*, N.Y. TIMES, Dec. 22, 2012, at A9.

[21] Tabb, *supra* note 9. Tabb argues that oil reserves are largely exaggerated because OPEC (Organization of the Petroleum Exporting Countries) quotas are based on proven reserves so "members exaggerate their reserves to pump more." *Id.* at 5. Tabb cites Sarkis' estimates of 40% of true reserves being exaggerated. *See* N. Sarkis, *Addicted to Crude*, LE MONDE DIPLOMATIQUE, May 4, 2006.

[22] BROWN, *supra* note 16, at 57. Brown eloquently argues that increasing population (at 80 million per year), consumers moving up the food chain, and the use of grains to fuel cars have

States) currently produce food by what he describes as overpumping their aquifers.[23] Partially related to this, the old practice of looking for land abroad—formerly restricted only to empires—has gained momentum in recent years alongside food price spikes. Citing Deininger and Byerlee's data, Brown reports 464 projects between October 2008 and August 2009 involving land acquisition of an area exceeding the land dedicated to producing corn and wheat combined in the United States.[24]

All of these views[25] are rooted in the concept of scarcity of natural resources as fundamentally a *physical* phenomenon. As physical resources become scarce, additional human workforce and capital will produce progressively lower outputs. This is the law of diminishing returns, which explains the concept of "marginal value." As eloquently explained in Simpson, Toman and Ayres, marginal value is the reason why a gallon of water, despite being fundamental for everyday life and exhaustible, is sold at a price much lower than a diamond, which is not critical for life. For any given period of time, there is plenty of water available or accessible, so an additional liter does not bear much of the marginal value compared with the very limited supply of diamonds.[26] Unfortunately, this marginal value is only part of a more complex story in which the prices of both water and diamonds fail to truly take into account the destruction of irreplaceable environmental capital.[27]

Ironically, it is also the concept of marginal value that explains the optimistic views of many economists. John Stuart Mill argued that the law

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led almost overnight to a doubling of the world's annual consumption of grain—from 21 million tons per year between 1990 and 2005 to 45 million tons per year from 2005 to 2011. This is taking place at a time when aquifers are being depleted in most populous countries; grain yields are hitting a glass ceiling; and the temperature is rising, which ultimately will also affect agriculture yields.

[23] *Id*. at 61.

[24] *Id*. at 103. Out of the 464 projects, in only 203 was the amount of land involved known. Land grabs in those projects amounted to 140 million acres—more than the area of the U.S.A. dedicated to producing corn and wheat combined, and only 37% of the projects involved food crops (of those for which information was available). *Id.*; *see also* KLAUS DEININGER & DEREK BYERLEE, THE WORLD BANK, RISING GLOBAL INTEREST IN FARMLAND: CAN IT YIELD SUSTAINABLE AND EQUITABLE BENEFITS? (2011).

[25] Interestingly, for each pessimistic view, there seems to exist an optimistic one: see Leonardo Maugeri, *Two Cheers for Expensive Oil*, FOREIGN AFFAIRS, Mar./Apr. 2006 (on oil reserves); GORDON CONWAY & KATY WILSON, ONE BILLION HUNGRY: CAN WE FEED THE WORLD? (2012), *available at* https://workspace.imperial.ac.uk/africanagriculturaldevelopment/Public/Policy%20Briefing%20paper%20-%20final.pdf (on food availability).

[26] SIMPSON ET AL., *supra* note 5, at 6.

[27] Ayres, *supra* note 12, at 9. This is a clear shortcoming in their pricing as it is equivalent to deny that an investment in reproducible capital is an increase in the capital stock. *Id*.

of diminishing returns can be "suspended or temporarily controlled, by whatever adds to the general power of mankind over nature and especially by any extension of their knowledge."[28] In effect, many economists saw knowledge as the solution to the Malthusian conundrum: Clark leaves no room for doubt when he argues that "knowledge is the only instrument of production not subject to diminishing returns."[29] Technological progress (first unexplained,[30] then the result of investments in research and development[31] and human capital formation in education[32]) would ensure either constant or increasing returns, allowing capital accumulation to infinity. Once the issue of diminishing returns is solved, physical scarcity of a given factor of production is no longer *the* fundamental constraint on growth and development.

In fact, Krautkraemer argues that evidence so far indicates a bias toward repeatedly underestimating the capacity of technology to overcome natural resource scarcity with "many predictions of impending doom" when it comes to natural resources not coming through.[33] He wrote this before the international food price crisis started to spike in 2008, arguing that the discovery of new reserves, substitution of capital, resource-saving technological progress, and new methods for recovering resources "have [all] led to generally downward sloping price trends for many natural resources commodities."[34]

Ayres provides compelling historical illustrations of this pattern. Charcoal was scarce in England by the seventeenth century as land was cleared for agriculture, shipbuilding, and grazing.[35] Coal eventually emerged as a substitute for charcoal.[36] Sperm whales were the main source for lamp oil, but their shortages gave way to kerosene (derived from petroleum, a low-

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[28] SIMPSON ET AL., *supra* note 5, at 7.
[29] *Id.* at 9 (quoting John Maurice Clark, *Overhead Costs in Modern Industry*, 31 J. POL. ECON. 47 (1923)).
[30] Robert M. Solow, *A Contribution to the Theory of Economic Growth*, 70 Q. J. ECON. 65, 66 (1956) (treating technological change as a variable correlated to available labor and capital).
[31] Paul M. Romer, *Increasing Returns and Long-Run Growth*, 94 J. POL. ECON. 1002 (1986).
[32] Robert E. Lucas Jr., *On the Mechanics of Economic Development*, 22 J. MONETARY ECON. 3 (1988).
[33] *Jeffery A. Krautkraemer*, RESOURCES FOR THE FUTURE, *Economics of Natural Resource Scarcity: The State of the Debate* 12 (Discussion Paper 05-14, Resources for the Future, 2005).
[34] *Id.*
[35] Ayres, *supra* note 12, at 5.
[36] *Id.*

value product in those days) as a substitute in the mid-nineteenth century.[37] Guano, a natural fertilizer from South America, was almost exhausted by the end of the nineteenth century but was later substituted by phosphate from bones, mineral apatites, and, finally, from synthetic ammonia.[38] Similarly, synthetic rubber became available as natural rubber increasingly became scarce for the western world following Japan's control of key rubber-producing centers at the onset of World War II.[39] Other modern examples of fiber optics for copper include the substitution of fiber optics for copper in telecommunications and insulation and thermal pane windows substituting for the use of natural resources. Krautkraemer also argues that the ability of capital to substitute for natural resources has shifted the mix of goods produced in an economy from more to less resource-intensive commodities.[40] From these examples, Ayres concludes that: "Up to now, scarcities have not proven to be obstacles for economic growth; more often than not they have been stimulants to innovation."[41]

These examples underscore that the critical connection between physical scarcity and marginal returns has been dominated by supply considerations alone. But an economic analysis of scarcity naturally requires a demand angle as well. When both are considered, scarcity is a situation where demand exceeds supply, whether or not the supply side is physically constrained. Scarcity or shortage thus becomes fundamentally an economic circumstance not only determined by physical availability, but also by factors as disparate as logistics and preferences. In fact, from the strictest and simplest theoretical economics perspective, scarcity is not even a problem, because it cannot be a steady state. Well-functioning prices will act as

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[37] *Id.*

[38] *Id.* at 6.

[39] *Id.*

[40] *Krautkraemer*, *supra* note 33, at 36 (citing the Energy Information Agency, Krautkraemer reports that the energy used to produce one dollar of GDP in the United States between 1949 and 2000 almost halved. Yet, the total energy use tripled as population doubled and per capita GDP increased.).

[41] Ayres, *supra* note 12, at 6. However, how useful are those arguments whose conclusions depend on what is compared and the very length of the periods under comparison? I have argued that conclusions from intertemporal comparisons in social sciences are very sensitive to the periods considered. Jose Cuesta, *Theory of Empirics of Democracy and Crime Revisited: How Much Further Can We Go with Existing Data and Methodologies?*, 72 AM. J. ECON. & SOC. 645 (2013). In addition, Krautkraemer warns against the use of economic measures as indicators of resource scarcities: prices, extraction costs, and user costs are in practice limited because they are static, imperfect, and supply side only (in the case of extraction costs) to account for future availability and demand. *Krautkraemer*, *supra* note 33, at 16.

clearing-house mechanisms toward ensuring a permanent equilibrium by presumably rationing demand, increasing supply, or both. From this angle, the problem is not physical scarcity but those obstacles that prevent markets from clearing. As physical constraints start to appear, the market will provide the economic rationale, that is to say the incentives, for innovation and substitution. Consequently, free and adequate functioning of markets, rather than the physical scarcity of resources, become the center of attention for theoretical economists.

Yet there are a number of situations that also make physical scarcity a handicap in the economic sense—at least in the applied economic sense of achieving economic growth. For example, resources like fresh water are required in such massive quantities that substitutes are out of the question and technological innovation may prove useless after some threshold.[42] In effect, even if fresh water can be obtained through desalination of salt water, the process is very energy-intensive, therefore some argue that available energy becomes the key to finding a substitute for scarce resources.[43]

Physical availability may also be subject to uncertainty. For example, the World Bank estimates of subsoil wealth mentioned earlier require a set of strong assumptions, such as simplistic lifetimes of twenty years, specific growth rates for prices and extraction costs, and universal discount rates.[44] In the case of uncertainty, the extent to which the magnitude of reserves is known affects prices. The new G-20 Agriculture Market Information System (AMIS), which is designed to improve information on agricultural markets, shows substantial differences in the estimates of grain stocks in Asian countries depending on whether the data are reported by the Food and Agriculture Organization (FAO) or the United States Department of Agriculture (without any clear and obvious bias). Thus, for example, the differences in grain stock estimates for 2012–2013 vary by 13% in China, 32% in Indonesia, and 53% in Vietnam (similar to differences of over 40% in Brazil and Kazakhstan), according to the AMIS.[45] The fact that food stocks are not known with precision does affect the prices of thinly traded food commodities and may make international prices hypersensitive to non-fundamental factors determining demand and supply of food. In addition, assessments of undiscovered world oil produce scenarios based on prospects

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42 SIMPSON ET AL., *supra* note 5, at 34.

43 In this sense, Weinberg declared energy as the "ultimate resource." Alvin M. Weinberg, *Reflections on the Energy Wars*, 66 AM. SCI. 153 (1978).

44 WORLD BANK, *supra* note 14; *see also* discussion *supra* Part I.

45 *Statistics at a Glance*, AMIS AGRICULTURE MARKET INFORMATION SYSTEM, http://statistics.amis-outlook.org/data/index.html (using the 2012 figures).

of reserves (the Greenland shelf, offshore Suriname, and deposits under the Caspian Sea, for instance) and the expected performance of future exploration. As such, models of global peak production produce intrinsically uncertain predictions[46] and may well themselves contribute to a higher sensitivity of prices to events, shocks, or circumstances that, in the case of oil, may have nothing to do with long-term demand and supply fundamentals.

Uncertainty refers not only to resource stocks and future discoveries but also to future interest rates. In effect, finding a market-clearing solution that implies intertemporal considerations, as is critically the case in relation to exhaustible resources, requires discounting present consumption. Discounting implies comparing present and future consumption and determining the rate at which today's consumption and future consumption are indifferent for the average individual. Economists have typically assumed that this inter-temporal discount rate equalizes real interest rates, so current savings and future consumption are valued equally. For this approximation to work, the "cake" can never completely disappear, which denies the very nature of exhaustibility.[47] The exercise becomes more difficult when this cake refers to a priceless resource, that is, a resource for which markets do not exist, such as biodiversity or climatic stability. Economists also assume that everything with a value can be sold and bought, which denies in practical terms the irreversible nature of goods or services. An exhausted resource or a severely degraded environment cannot be bought in a next period, which means that it will not have any value into the future and, consequently, today's value needs to be adjusted.

Furthermore, Sjak Smulders argues that even if technology can avert diminishing returns by improving production techniques or by creating opportunities for substitution away from scarce resources, it may also create undesired effects on resources.[48] For example, technological fishing developments have led to a more rapid decline in fish stocks.[49] Simpson,

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[46] For example, Ayres reports that Hubbert predicted global peak production would happen just before the year 2000. Ayers, *supra* note 12, at 12; *see also* M. King Hubbert, *Energy Resources*, *in* RESOURCES AND MAN 157 (*Commission on Resources and Man: National Academy of Sciences – National Resource Council 1969*). Campbell and Laherrere predicted global peak production by shortly before 2010. Colin Campbell & Jean Laherrere, *The End of Cheap Oil*, 1998 SCI. AM. 78, 79.

[47] Ayres, *supra* note 12, at 19.

[48] Sjak Smulders, *Endogenous Technological Change*, *Natural Resources and Growth*, *in* SCARCITY AND GROWTH REVISITED: NATURAL RESOURCES AND THE ENVIRONMENT IN THE NEW MILLENNIUM 155 (R. David Simpson et al. eds., 2004).

[49] *Id.* at 160.

Toman, and Ayres argue that nuclear power provides electricity without conventional greenhouse gas (GHG) emissions, but at the cost of hard-to-manage toxic waste.[50] Technological innovation is, like any other economic activity, one that responds to economic incentives and as such may be influenced by perverse subsidies; underprovision of a public good (whose benefits are appropriated by individuals who did not pay for them); and imperfect information. Ayres argues that if one cannot predict their ultimate applications, a society will have a hard time identifying the potential innovations it should invest in.[51]

III. FROM THE ELUSIVE CONCEPTUALIZATION OF SCARCITY TO IDENTIFYING PROPERTIES OF SCARCITY

Economic and physical dimensions of scarcity are not, however, two separate approaches to the concept of scarcity: they intersect and interact mutually. A first, critical, and complex interaction is that physical scarcity itself may or may not have an effect on economic value. In other words, there is not an inevitable economic value in something that is physically scarce or rare. In the case of materials found in the Earth's crust mentioned in the introduction, their value is based not on how uncommon they are but on their physical properties and how difficult it is to work with them. Metals like beryllium or rubidium, some of the most common metals in the earth's crust, have virtually no industrial uses.[52] Unsurprisingly, abundant metals have very different costs per gram.

Let us steer away from natural resources for a moment. A masterpiece painting is valuable because it is unique, produced by an artist whose talent is scarcely distributed across society and time. Certainly that same painting can be reproduced an infinite number of times—into worthless fakes—but even the uniqueness of the original does not guarantee an automatic economic value. Van Gogh's paintings were notoriously worthless in his lifetime. For investors, they have a hefty economic value today because they have a widely acknowledged investment value. Society agrees (or more precisely, keeps agreeing after Van Gogh's death) that Van Gogh's scarce talent will continue to appreciate in the future, so purchasing his unique paintings today will translate into future value. Yet, this agreement may change in the future—as it did in the past—making scarcity of talent a risky investment.

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50 SIMPSON ET AL., *supra* note 5, at 28.
51 Ayres, *supra* note 12, at 22.
52 *Id.* at 3.

If scarcity is by itself not a sufficient condition for economic value, the obvious question then is what features of natural resources make them economically valuable? A first candidate to start looking into is the property of finite supply, that is, *exhaustibility*. Water exists in nature as a finite resource. Even though it is renewable through rainfall or conservation, its sources—underground aquifers and glaciers—are exhaustible. Not all sources of fresh water are tapped already (for example, Antarctic and Arctic natural stocks of water or undiscovered underground sources), and recycling practices and technologies may increase the world's supply of fresh water in a given period of time by effectively slowing down its depletion rate. Land provides a similar example. By the physical limitations of space on our planet, land is neither infinite nor renewable, even though some areas not apt for agriculture can be adapted for this use or, alternatively, arable land can be used for alternative activities without limiting the production of food if yields were to improve.

Food, fisheries, forests, and sunlight constitute different cases. They are renewable. They, of course, can disappear as a result of the actions or omissions of humans, nature, or both, such as floods, droughts, wars, or pandemics. However, those resources are subject to net increases in a continuous, uninterrupted fashion. For example, in the case of food, with each successive crop more food becomes available globally.

Some authors differentiate between resources that are renewable at a relatively slow rate and others that accrue at a rapid rate. For example, forests would be in the former group while sunlight, fisheries, or food would belong to the latter. However, what slow and rapid mean in this context is not precisely spelled out: Do they refer to absolute measures of time (say, less than a year or a day?) or more generally to an economic concept, that is, slow or fast in relation to a theoretical optimal level of use of resources?[53]

So, does renewability (and its speed) affect the economic value of a resource? It depends. The current economic values of sunlight and water are very different, even though both resources are critical in environmental and biological terms to preserving life on Earth. The difference lies in that water is easily marketed while sunlight is not. Sunlight requires a currently costly technology that transforms this resource into solar energy and distributes it from point *A* to point *B*. Here, the economic value of the resource is determined by the supply technology and not by its renewability or its final use. A more extreme example would be water compared to perfume. A liter

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[53] *See, e.g.*, Hotelling, *supra* note 8; Joseph Stiglitz, *Growth with Exhaustible Resources: Efficient and Optimal Growth Paths*, 41 REV. ECON. STUD. 123, 131 (1974).

of French perfume has a much heftier tag than a liter of water not because perfume has a more critical end use than water or because perfume is a more finite commodity than water (water is of course a critical component of perfume), but because production costs to supply the respective quantities of each resource demanded by the market make perfume more costly than water. Interestingly, a liter of cola, which requires more water to produce than perfume,[54] is cheaper than perfume. The technology that produces and distributes soda in mass quantities allows for such a cheap product. As indicated above, clearly each liter of soda does not include in its price its contribution to the reduction of water in the future, typically without doing much or anything to recycle it. This is true even in places with obvious water restrictions like Saudi Arabia, where the cost of a bottle of water is U.S. $0.27, below the cost of a popular soda—U.S. $0.40 for the same size bottle.[55] Conflict literature has discussed certain properties of resources that make them more prone to association with conflict, to the extent that such properties make them more likely to generate the revenues and/or grievances necessary to fuel conflict. Four features are typically said to have an impact on conflict: LOOTABILITY, that is, how easy it is to extract resources;[56] PROXIMITY TO ECONOMIC, POLITICAL, OR MILITARY POWER CENTERS;[57] CONCENTRATION, that is, whether resources are found "point-sourced" in specific geographic areas or diffused across vast territories;[58] and SELLABILITY, that is, how easily they can be sold in regulated or unregulated international markets.[59] Resources' ultimate capacity to finance conflict varies; for example, diamonds sold in international markets with little transparency may help both governments and rebels alike, whereas oil, sold in more regulated markets, tends to only help governments. Lootable (that is, alluvial) diamonds have a strong positive relationship with civil war, while non-lootable (underground) diamonds may have a strong negative relationship with war onset. Underground diamonds need large investments

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[54] An article in the *Economist* reports that almost three liters of water are needed to produce one liter of a well-known cola; the three liters include not only the water content of the product, but also the cleaning of assembly lines and flushing out of glass bottles. *Coca-Cola in Hot Water*, ECONOMIST, Oct. 6, 2005, *available at* http://www.economist.com/node/4492835.

[55] Prices refer to 0.33 L bottles, as reported by Numbeo. *Cost of Living in Saudi Arabia: Prices in Saudi Arabia*, NUMBEO, http://www.numbeo.com/cost-of-living/country_result.jsp?country=Saudi+Arabia&displayCurrency=USD (last updated Sept. 2013).

[56] Tony Addison et al., *Conflict in Africa: The Cost of Peaceful Behaviour*, 11 J. AFR. ECON. 365 (2005); Lujala et al., *supra* note 6.

[57] Le Billon, *supra* note 6, at 569.

[58] *Id.* at 570; *see also* World Bank, *supra* note 3.

[59] Lujala et al., *supra* note 6, at 542.

for extraction, and investments of that magnitude are more likely in politically stable contexts. If natural resources are diffuse and distant from power, then warlordism is likely to emerge; if natural resources are diffuse and proximate, rebellion and rioting are more likely; if resources are concentrated and proximate to power, coups are more likely.[60]

Natural resources may not only generate grievances and mobilize resources internally but also across nations. It is true that civil wars associated with natural resources have been driven by all sorts of commodities from oil, diamonds, gems, and precious and nonprecious metals to copper, timber, narcotics, and even various agricultural resources.[61] However, while all resources are equally likely to trigger civil war, some resources are more prone than others to be used, as described by Fang, Jaffee, and Temzelides, as a "tool of statecraft and diplomatic leverage."[62] In other words, some natural resources can play a substantive international *geopolitical role*. Klare argues that about four-fifths of the world's known petroleum reserves lie in politically unstable or contested areas, and many other sources of vital resources such as gas, water, and timber are also located in "chronically unstable areas."[63] Not surprisingly, many states see controlling certain natural resources as a matter of national security. It is generally argued that if the Russian Federation—a major world exporter of oil and natural gas—formed a gas cartel with Middle Eastern countries (mainly Qatar) or became part of the OPEC cartel on oil (alongside Saudi Arabia), this would significantly change the way energy markets operate and, ultimately, would have a large influence on international relations.[64]

Water and land are other such geopolitical commodities. As Brown reminds us, any water extracted from the Upper Nile River Basin to irrigate Ethiopia, Sudan, and South Sudan will not reach the Arab Republic of Egypt,

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[60] Le Billon, *supra* note 6, at 570.

[61] Ross, *supra* note 6.

[62] SUNGYANG FANG ET AL., JAMES A. BAKER III, INSTITUTE FOR PUBLIC POLICY OF RICE UNIVERSITY, NEW ALIGNMENTS? THE GEOPOLITICS OF GAS AND OIL CARTELS AND THE CHANGING MIDDLE EAST 5, 5 (2012), *available at* http://bakerinstitute.org/files/499/.

[63] Michael T. Klare, *The New Geography of Conflict*, 80 FOREIGN AFF. 49 (2001).

[64] Factors such as the ongoing oil-for-security relationship between Saudi Arabia and Qatar and the United States, the increasing attention to domestic demands after the Arab Spring, the rising influence of Iran as a regional military and political powerhouse (in part financed by oil revenues), the threats of price wars, and the substitution possibilities (in this case, oil and natural gas being close substitutes for energy purposes) all affect the supply decisions of the producers of these resources. *See* FANG ET AL., *supra* note 62.

thus increasing the number of countries competing for water in the region.[65] Likewise, as food prices increase and become more volatile, exporters are more reluctant to make long-term commitments. This has led large importers of grains, such as Saudi Arabia, China, and the Republic of Korea, to buy or lease land in other countries to grow food for themselves. Ironically, these land purchases or "land grabs" involve countries in Africa where vast numbers of citizens are sustained by international food donations.[66]

Natural resources are not only commodities but also "services" known as environmental resources, which include biodiversity, climatic stability, clean air and water, and wildlife protection. They are also known as resource amenities or ecosystem services, and clearly differ from natural resources commonly treated as economic goods.[67] The main difference, however, is not their service nature but their TRADABILITY. In effect, resource amenities are typically "open access resources" and public goods that lack a marketplace and a price mechanism to clear.[68] Technology is less likely to provide substitutes for resource commodities than resource amenities.[69] Moreover, the poor in particular have no substitutes for filthy water, polluted air, or degraded ecosystems, which means that amenities are not luxury services but rather fundamental necessities.[70]

So, from an economic point of view, physical scarcity—scarce supply—itself is not a problem and, for many, is a situation that typically sparks innovation and substitution. Economic scarcity, that is, demand exceeding supply, is a condition for which economists, policymakers, and lawmakers have devised a space (marketplaces), a simple mechanism (prices), and a complex surrounding legal system (property rights) that ensure matching supply and demand. Because the real world is not that of Economics 101 textbooks, uncertainty, imperfect knowledge, myopia, and absence of markets, among other factors, take natural resources outside the scope of simple market solutions. Yet, the very nature of natural resources may have an important (but not the only) say in their economic value. Physical scarcity by itself may matter more than simple neoclassical economics presume, but so does the resource's storable capacity; its ability to generate

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65 LESTER R BROWN, EARTH POLICY INSTITUTE, A PRESENTATION FOR FULL PLANET EMPTY PLATES: THE NEW GEOPOLITICS OF FOOD SCARCITY 40, *available at* http://www.earth-policy.org/images/uploads/book_items/FPEP_SlidesEarthPolicyInstitute.pdf.

66 BROWN, *supra* note 16, at 104.

67 *Krautkraemer*, *supra* note 33, at 5.

68 *See id.* at 11.

69 John V. Krutilla, *Conservation Reconsidered*, 57 AM. ECON. REV. 777, 783 (1967).

70 SIMPSON ET AL., *supra* note 5, at 34.

revenues and grievance to fuel conflicts; its associated production technologies; and its geopolitical value.

In short, scarcity clearly matters when it has economic implications, though these are not always present and may change over time. These economic implications, in turn, may or may not relate to scarcity alone, but also to other characteristics such as diffusion, concentration, lootability, and renewability. Concerns should not be restricted only to cases with economic value, but neither should we worry about all types of scarcity equally. If we care about the wellbeing of future generations, we should be concerned—a lot—about water scarcity, much more so than about the availability of non-abundant metals with hardly any industrial or commercial application.

IV. FROM CONCEPTS TO PRAXIS: FOOD SCARCITY OR SCARCITY OF GOOD POLICIES FOR FOOD?

There is another issue of particular importance that is specific to food and water and separates them from other natural resources.[71] There are biological demands for dignified and healthy life that determine a minimum and inevitable demand. This makes physical and economic scarcity more intertwined than in other resources where fashion, perception, or taste determines demand. In fact, food scarcity and hunger as contributors to conflict are hardly new. As indicated above, the realization of their association goes back as far as Malthus' early theses on food, population, and catastrophes and continues with food riots in 1848 Europe; recurrent famines in conflict-ridden areas in the twentieth century; and numerous food riots mushrooming worldwide in 2008—sixty food riots in thirty countries—and thereafter.[72]

According to recent figures from the Food and Agriculture Organization, the percentage of hungry people in the world—unable to consume 1,800 kcal per person per day—has declined only slightly during the last thirty years, from 16% in 1990 to 13% in 2008.[73] This modest improvement has been insufficient to offset the absolute number of people facing starvation, which rose from 848 million in 1990 to 850 million in 2008, and is estimated to

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[71] *See generally* Jose Cuesta, *Theory and Empirics of Democracy and Crime Revisited: How Much Further Can We Go With Existing Data and Methodologies?*, 72 AM. J. ECON. & SOC. 645 (2013).

[72] MARCO LAGI ET AL., THE FOOD CRISES AND POLITICAL INSTABILITY IN NORTH AFRICA AND THE MIDDLE EAST (2011), *available at* http://necsi.edu/research/social/food_crises.pdf.

[73] FOOD & AGRIC. ORG., 2012a, *2012 World Hunger and Poverty Facts and Statistics Fact Sheet* (2012).

increase further due to successive crises in the cost of food, the international financial crisis, and the recent famine in the Horn of Africa.[74] Asia is home to an overwhelming majority (67%) of the global undernourished population, with China and India accounting for most of the regional malnutrition.[75] Africa is still home to over a quarter of all undernourished children even though food supply has largely kept pace with population growth in most African countries since the 1990s.

In other parts of the world the situation is very different. East Asia and Latin America are the regions that will meet the Millennium Development Goal of halving hunger by 2015. Despite the dismal absolute numbers, enormous progress has taken place in China since 1990, as well as in Indonesia and the Philippines. In China alone, the starving population declined from 210 million in 1990 to 129 million in 2008.[76] At the same time, major progress has been made in average caloric intake in China, which increased from 2,580 kcal a day per person in 1990 to 2,990 in 2008.[77]

At the start of the new century, global agricultural production was guaranteeing 17% more calories per person than thirty years earlier, despite a 70% increase in population. FAO calculations indicate that this increase is sufficient to ensure a daily intake of 2,720 kcal per person.[78] All things considered, the FAO concludes that the world currently produces enough food to feed everyone and even satisfy the diversified demand of a

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[74] Sailesh Tiwari & Hassan Zaman, *The Impact of Economic Shocks on Global Undernourishment* (2010), *available at* http://elibrary.worldbank.org/content/workingpaper/10.1596/1813-9450-5215; Henk-Jan Brinkman et al., *High Food Prices and the Global Financial Crisis Have Reduced Access to Nutritious Food and Worsened Nutritional Status and Health*, 140 J. NUTRITION 1535 (2010), *available at* http://jn.nutrition.org/content/140/1/153S.full.pdf+html (estimating that 63 million more people have been added to the total since 2007–2008).

[75] Shenggen Fan et al., *What Policy Changes Will Reverse Persistent Malnutrition in Asia?*, 25 EUR. J. DEV. RES. 28 (2013). In East Asia, the percentage of malnourished children has declined only slightly, from 52% to 43% between 1990 and 2009, despite the area's economic growth and reduction in poverty. Even more disturbing (and inexplicable) are the figures on child malnutrition according to socioeconomic level. Although it is well known that shortages of nutritious food, poor diet and hygiene, lack of access to sanitary facilities, and the resulting high incidence of diarrheal diseases contribute to very high rates of malnutrition in poor children (about 60% in 2009), it is much more difficult to explain why as many as 40% and 26% of South Asian children in the fourth and fifth wealthiest household quintiles of the distribution, respectively, are also malnourished. U.N. Department of Economic and Social Affairs of the United Nations Secretariat, Millennium Development Goals Report 2011, 13–14, *available at* http://www.refworld.org/docid/4e42118b2.html.

[76] FOOD & AGRIC. ORG., FOOD SECURITY INDICATORS: CHINA (2012).

[77] *Id.*

[78] FOOD & AGRIC. ORG., S *Metedata*, 5 FAO Stat. Y.B. (2012).

demographically changing world.[79] The problem today is that many people either do not have land to cultivate, enough income to buy food, or access to safety nets to mitigate the impacts of temporary shortages.

Looking to the future, the food challenge expected for 2050 is similar in magnitude to the one faced in the 1960s: the world's food demand is expected to increase by 70% as its population increases to 9 billion.[80] The obvious question is whether the pace of future agro-technological progress will be sufficient to meet the increasing demand for food from the growing population. Alexandratos's and Bruinsma's projections maintaining current agricultural yield growth suggest that the world would be producing more grain than required by the estimated demand through 2050.[81] Yields would expectedly increase by 44 kg per hectare per year up to 2050, in line with the historical trends observed since 1960—even if this absolute increase in yields implies declining agricultural productivity in relative terms.[82] More optimistic scenarios from Nelson et al. in terms of overall productivity growth and yields growth specific to maize, wheat, and cassava (exceeding 2% increases per annum) in developing countries further confirm a favorable outcome to the challenge.[83] Nelson et al. report a range of caloric

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[79] *Id.*

[80] To be sure, even though the population increased by 70%, the production of calories during the same period increased by 100%. Tilman et al. predict an increase of 100%–110% in global caloric demand by 2050—larger than the widely reported 70%, which they attribute to a closer relationship between income and dietary choices compared with the FAO's reliance on expert opinions on national and regional trends. David Tilman, *Global Food Demand and the Sustainable Intensification of Agriculture,* PROCEEDINGS NAT'L ACAD. SCI. 20260 (2011).

[81] Nikos Alexandratos & Jelle Bruinsma, *World Agriculture Towards 2030/50: The 2012 Revision* 15 (Agri. Dev. Econ. Division, Food & Agri. Org., ESA Working Paper No. 12-03, 2012), *available at* http://www.fao.org/fileadmin/templates/esa/Global_persepctives/world_ag_2030_50_2012_rev.pdf.

[82] *Id.* at 5–15. World average cereal yields growing almost perfectly linearly with annual increments of 44 kg per hectare between 1960 and 2007 imply declining yield growth rates: from 3.1% in the early 1960s, to 2.4% in the early 1980s, and 1.3% in the mid-2000s. Using FAO data, Beddow, Pardey, and Alston have shown that average annual crop yield rates for corn, wheat, rice, and soy declined between 1961 and 1989 and again between 1990 and 2007. However, these global rates conceal marked regional differences. Increases in productivity in China went from 2.29% to 4.45% per worker and from 2.81% to 4.50% per hectare from 1961 to 1989 and from 1990 to 2005 (compared with world levels of 1.12% and 2%, respectively). However, this spectacular growth in productivity is not a phenomenon that extends to the rest of Asia. When China is excluded, the productivity growth in Asia actually slowed during the period in question, as it did in the rest of the world, with the exception of Latin America. Jason Beddow et al., *The Shifting Global Patterns of Agricultural Productivity*, 24 CHOICES no. 4, at 1 (2009).

[83] GERALD C. NELSON ET AL., FOOD SECURITY, FARMING AND CLIMATE CHANGE TO 2050: SCENARIOS, RESULTS, POLICY OPTIONS 52 (2010).

availability for the developing world between 2,400 kcal and 3,000 kcal per person, depending on assumptions of yield productivity, population and income growth, and climate change.[84]

These projections should not be taken as downplaying the actual challenge of feeding the world's increasing population, but instead as intended to bring food access to the center of the debate alongside food production.[85] Nor should the role of policies be underestimated. In fact, much has been written about the causes and consequences of the recent food crises.[86] I have has summed up the causes of what I call a "perfect storm," where a series of factors, circumstances, and policy choices converged to trigger a sudden surge in prices.[87] In an example of poor policy-making, during 2007 and 2008 the governments of China, India, and Vietnam imposed bans or restrictions on the export of rice to neighboring importers within the region, such as Indonesia, Bangladesh, and the Philippines. Another recent example of this type of policy is the credit program for growers in Thailand (the world's top exporter of rice) known as the Rice Mortgage Scheme. In this program, the Thai government guarantees domestic farmers prices well above market levels, which has resulted in substantial loss of competitiveness in Thai rice exports compared to other exporters in the region, to the point of threatening Thailand's status as the world's leading exporter of rice.

One important aspect of the volatility that surrounds international food prices is their heightened sensitivity to a variety of factors, including uncertainty about the actual food stocks available, as mentioned in Part II.

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[84] *Id.* at 50. These improvements may bring about reductions in under-five malnourishment rates between ten and forty-five percentage points for the period of 2005–2050.

[85] Moreover, current yield growth rates still need to be sustained for decades at an annual cost that the FAO estimates to be in the vicinity of U.S. $83 billion in additional investment in agriculture across developing countries. That amount represents a financing gap of 50% of the current private and public investments in agriculture in the developing world, which currently average U.S. $142 billion per year. Food & Agric. Org. *How to Feed the World in 2050*, 16–17 (2009), *available at* http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf.

[86] *See, e.g.*, JOACHIM VON BRAUN ET AL., INT'L FOOD POLICY RES. INST., HIGH FOOD PRICES: THE WHAT, WHO AND HOW OF PROPOSED POLICY ACTIONS (2008); Donald Mitchell, *A Note on Rising Food Prices* (The World Bank, Policy Research Working Paper No. 4682, 2008), *available at* http://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/2008/07/28/000020439_20080728103002/Rendered/PDF/WP4682.pdf; JULIA COMPTON ET AL., OVERSEAS DEV. INST., IMPACT OF GLOBAL FOOD CRISIS ON THE POOR: WHAT IS THE EVIDENCE? (2011), *available at* http://www.odi.org.uk/sites/odi.org.uk/files/odi-assets/publications-opinion-files/6371.pdf.

[87] José Cuesta, *'Knowledge' or Knowledgeable Banks? International Financial Institutions' Generation of Knowledge in Times of Crisis*, 28 DEV. POL'Y REV. 43 (2010).

With respect to safety nets—a critical instrument to mitigate the effects of high and volatile food prices and natural disasters—a recent World Bank report indicates that between 2008 and 2011, eighty of the 137 countries analyzed had weak or nonexistent social welfare systems, and only nine of these countries had made a decided effort to improve their systems.[88] Further progress toward transparent information and sound safety nets became a missed opportunity in terms of good policy choices in the face of the 2007–2008 food price crisis.

Less cited, however, are the contributions that even lagging regions can make—and, in fact, are already making—toward being better prepared for future food crises. Despite the shortcomings mentioned above, several of the countries in Asia decided voluntarily to participate in the Agricultural Market Information System (AMIS). Recently, countries such as Pakistan and India have stepped up to fill the worldwide gap created by Thailand's increased prices for rice exports. The Asian and African regions lead the way in developing innovative agricultural production practices, which have come to be referred to as "smart climate agriculture."[89] The goal of this type of agriculture is to simultaneously offer increased agricultural productivity (thus reducing poverty and food insecurity); improved crop resistance to extreme weather conditions (adaptation); greater sequestration of carbon emissions; and curtailment of deforestation (mitigation).[90] World Bank examples of smart climate agriculture include programs for the restoration of mangrove forests in Vietnam's Mekong Delta, which act as a line of defense against typhoons[91] and floods, and reforestation of the Loess Plateau in China.[92] Rwanda is developing water-harvest and hillside irrigation.[93] Other projects in Africa include natural regeneration of forestry in Niger[94] and conservation farming in Zambia.[95] Silvopastoral techniques are being developed in Costa Rica.[96] A widely cited example is the development of financing mechanisms that compensate farmers during the transition to lower carbon emissions in the province of Qinghai in the north of China. Also in China, the use of biogas for cooking in the province of Guangxi is estimated

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[88] ARUP BANERJI, WORLD BANK, UPDATE ON WORLD BANK WORK ON SOCIAL SAFETY NETS AND COUNTRY ASSESSMENT OF THE READINESS OF SAFETY NET SYSTEMS (2011).

[89] *See generally* WORLD BANK, CLIMATE SMART AGRICULTURE: A CALL TO ACTION (2011).

[90] *Id*. at i.

[91] *Id*. at 14.

[92] *Id.* at 18.

[93] *Id*. at 8.

[94] *Id*. at 9.

[95] *Id*. at 13.

[96] *Id*. at 22.

to have saved women up to sixty days a year—time they formerly spent collecting wood and tending to cooking fires.[97] The Asian region, especially China, is also piloting other innovative agro-technological practices—for example, vertical farming—that could result in considerable increases in agricultural productivity.[98]

Whether or not the developing world will be able to scale up these interventions and sustain them over time essentially will determine the future challenges of feeding a growing population. In turn, these scaled-up interventions will be sustainable over time to the extent that—as in the case of vertical cultivation—they relax constraints on land availability or benefit from technologies and practices that are more economical in the use of water, food, or renewable energy.[99]

An additional issue is that vast demographic changes[100] will most likely accompany the growth in global production. The expected increase in the demand and diversity of food will most likely bring about changes in diet composition, with a relative reduction in the demand for grains in favor of meat, fish, oils, and fruit. Conservative estimates indicate that the demand for meat, dairy products, and vegetable oils could increase more rapidly than seen so far in recent decades, with fish and shellfish demand slowing down and the demand of grains growing below population growth. So, the argument goes, the future pressure on food supply composition might not come from population growth alone but also from the change in the

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[97] *Id*. at 19–20.

[98] Mary Jander, *Asia: Vertical Farming Testbed,* UBM'S FUTURE CITIES (Aug. 15, 2013, 5:00 AM), http://www.ubmfuturecities.com/author.asp?section_id=234&doc_id=525597.

[99] More controversial is the use of genetic engineering technologies. These technologies include innovative grain varieties that are resistant to diseases, natural disasters, and saline soils, among other hardships. But there is some uncertainty around their repercussions on health, and poor social acceptance of genetic engineering is a real impediment to more decisive development in the near term. Nevertheless, society's eventual familiarization with the phenomenon—by 2050, genetic engineering technologies will have been in operation for decades—and further technological advances (such as genetic erasing) pose interesting issues in predicting a greater role for genetic technology in future global food production.

[100] Average world real income per capita is expected to more than double in this period, to about U.S. $25,000. U.S. GRAINS COUNCIL, FOOD 2040: THE FUTURE OF FOOD AND AGRICULTURE IN EAST ASIA 77 (2011). Large increases in the numbers of middle-income and high-income earners across the developing world are also expected. The world's population will age significantly, and the role of women could change substantially, with women marrying at a later age or deciding not to marry at all, which is already happening in middle-income countries. *Id*. at 60–65. Urbanization and epidemiological transitions, thus far only witnessed in rich countries, will have important consequences in diet composition as well as aggregate food demand. *Id*. at 110–11.

preferences of the emerging population as socioeconomic equalization—that is, substantial growth of the middle class—takes place.[101]

Even though the expansion of the middle class may look like an irreversible process, evidence on global poverty reduction shows that greater economic growth does not necessarily lead to equalization. The World Bank estimates that the great majority of the 649 million poor people in the world who ceased to be poor (according to the criterion of an income of U.S. $1.25 per day per person) between 1981 and 2008 still continue to be poor by the standards of middle-income and upper-income countries.[102] In fact, the number of moderately poor—that is, persons with incomes above U.S. $1.25 a day but less than U.S. $2 a day—increased from 648 million in 1981 to 1.18 billion in 2008. Ultimately, evidence shows that the reduction of extreme poverty, as critical as it may be, does not necessarily imply an automatic increase in the middle class, much less one of the magnitude needed for substantive changes to take place in global demand for food.[103] It remains to be seen whether the case will be the same for demand for other scarce resources.

V. CONCLUDING REMARKS

Economics deals with the effective use of resources, and yet it does not have a clear definition of what scarcity means as other disciplines, such as geology, have. A generic definition of scarcity is demand exceeding supply. It is generic because it can be applied to natural resources as well as other types of commodities and services. Under this proposition, the economics of resource scarcity is very much in line with any other factor of production, namely getting the right price by constructing the appropriate instruments, incentives, and institutions for prices and markets to work toward the efficient allocation of resources. From a mere economic point of view,

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[101] *See generally id.*

[102] SHAOHUA CHEN & MARTIN RAVALLION, DEV. RES. GROUP, WORLD BANK, AN UPDATE TO THE WORLD BANK'S ESTIMATES OF CONSUMPTION POVERTY IN THE DEVELOPING WORLD 2 (2012).

[103] The Latin America region has experienced a most impressive reduction in poverty: countries like Argentina, Costa Rica, Mexico, and Uruguay have middle classes of around 50% of their respective populations—measured as those earning income between U.S. $10 and U.S. $100 a day—which is far above the proportions in other countries of the region. MAURICIO CÁRDENAS ET AL., BROOKINGS INSTITUTION, LATIN AMERICA'S GLOBAL MIDDLE CLASS 23 (2011). Even more demanding figures on the expected share of middle class in the total population are reported for Asia by 2050: 70% in India, 75% in China, and 80% in Indonesia (using an income of U.S. $2–U.S. $4 per day per person to define middle class). ASIAN DEV. BANK, ASIA 2050: REALIZING THE ASIAN CENTURY 23–24 (2011).

physical shortage or exhaustible supplies typically prompt demand rationing, substitution, or technological change. Numerous historical examples validate this analysis and have given way to an unyielding trust in knowledge as the solution to old Malthusian fears.

This convenient explanation, however, overlooks a number of issues specific to natural resources in limited supply. There are many reasons why markets may not function well or technology may not solve the Malthusian conundrum in a *systematic* fashion. Demand for some of these resources, such as water, is of such magnitude that it cannot simply be substituted for. Natural resources (and our knowledge about them) are subject to a scope of long-term uncertainty not easily comparable with other resources. This delinks markets and individual behavior from fundamentals and subjects them to geopolitical pressures, panic shocks, and hypersensitivity to imperfect knowledge—in addition to other usual problems of global public goods for which the standard economic fundamentals do not work.

In specific cases, the public good associated with natural resources also has unintended consequences. For example, how can we encourage innovation (to improve sustainability, welfare, or both) in the substitution of essential exhaustible resources without creating increased demand for toxic or energy-intensive materials? For instance, prohibiting the use of heavy structures may increase demand for light plastics.[104] In order to be effective, simple solutions, such as banning solders or painters from using lead or photographic film from using silver, need technological interventions or timely economic incentives. One cannot presume ex ante that all business, political, and social interests will be aligned at just the right time so that changes can occur.[105] Especially troublesome are cases for which the allocation of property rights associated with the resource is difficult. Subsoil minerals belong to a country—even though the mere presence of these resources may create breakaway tensions. But some resources, such as rivers, may exceed national boundaries; others, such as land or diamonds, may be easily appropriable (legally or illegally) by other nations; and still others, such as fisheries, may migrate across national boundaries.

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[104] Ayres, *supra* note 12, at 22. Simpson, Toman, and Ayres also illustrate this point by suggesting that even "a tax on carbon dioxide emissions that led "farmers to plant renewable energy crops [might] in the process expand land under cultivation [and] reduce biodiversity." SIMPSON ET AL., *supra* note 5, at 37.

[105] These problems are also observed in solutions such as optimal taxation or quotas, which often in practice go beyond a theoretical argumentation and typically bring on a cumbersome power struggle among vested groups.

Furthermore, it has been widely proven that certain characteristics of resources are more likely to be associated with conflict, which has important consequences for their extraction and supply and, ultimately, for the well-being of populations. Some of these features are lootability, proximity to power, concentration, legality, geopolitical strategic power, and tradability, all of which add to the significance of renewability as a critical feature of natural resources.

Yet, there are two other distributional considerations associated with some natural resources that constitute special features. Minimum levels of fresh water, clean air, and food are absolutely required for humans to live and prosper, and they do not have substitutes. In addition, consumption today has inter-temporal consequences tomorrow, which economists typically solve with a convenient discount rate. This technical solution does not fully deal with the fact that intertemporal consumption decisions are fundamentally an asymmetric equity problem. In effect, tomorrow's decisions are constrained by today's decisions but not vice versa. Future generations cannot simply bring back a completely depleted resource.

All of these considerations make scarcity of natural resources a complex issue beyond the simple economics of scarcity. This complexity does not mean that natural resource scarcity always constitutes a problem: for example, this is the case when the scarce resources are not demanded or when they have no economic value at all—both facts which can change over time, however. But unremitting optimists also need to acknowledge that economic solutions (taxes, restrictions, substitution, and technological change) will not be able to solve every natural resource availability problem.

This has implications not only for economic policy but also for both national and international law, the latter specifically when resource scarcity or abundance transcends national boundaries. International laws regarding the environment, seas, outer-space, trade, and property are all testament to this shared concern. If economic policy is about the development of economic institutions, incentives, and instruments, then the practice of law needs, at the least, to ensure that well-functioning institutions are enforced and obstacles to proper functioning removed. And these enforcement and corrective activities need to be carried out even though economics fail to provide a clear definition and framework of natural resource scarcity. The recommendation of this review is to focus on particular features of natural resources specifically threatening the proper functioning of existing economic and noneconomic structures, rather than pursuing an elusive technical definition.