

From Empty-world Economics to Full-world Economics: Recognizing an Historical Turning Point in Economic Development

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The evolution of the human economy has passed from an era in which manmade capital was the limiting factor in economic development to an era in which remaining natural capital has become the limiting factor. Economic logic tells us that we should maximize the productivity of the scarcest (limiting) factor, as well as try to increase its supply. This means that economic policy should be designed to increase the productivity of natural capital and its total amount, rather than to increase the productivity of manmade capital and its accumulation, as was appropriate in the past when it was the limiting factor. This chapter aims to give some reasons for believing this "new era" thesis and to consider some of the far-reaching policy changes that it would entail, both for development in general and for the multilateral development banks in particular.

Why the Turning Point Has Not Been Noticed

Why has this transformation from a world relatively empty of human beings and manmade capital to a world relatively full of these not been noticed by economists? If such a fundamental change in the pattern of scarcity is real, as I think it is, then how could it be overlooked by economists, whose job is to pay attention to the pattern of scarcity? Some economists—for example, Boulding¹ and Georgescu-Roegen—have indeed signaled the change, but their voices have been largely unheeded.

One reason is the deceptive acceleration of exponential growth. With a constant rate of growth, the world will go from half-full to totally full in one doubling period—the same amount of time that it took to go from 1 percent full to 2 percent. Of course, the doubling time itself has shortened, compounding the deceptive acceleration. If

we take the percent appropriation by human beings of the net product of land-based photosynthesis as an index of how full the world is of humans and their furniture, then we can say that it is 40 percent full because we use, directly and indirectly, about 40 percent of the net primary product of land-based photosynthesis.³ Taking thirty-five years as the doubling time of the human scale (that is, population times per capita resource use) and calculating backward, we go from the present 40 percent to only 10 percent full in just two doubling times, or seventy years, which is about an average lifetime. Also, "full" here is taken as 100 percent human appropriation of the net product of photosynthesis, which on the face of it would seem to be ecologically quite unlikely and socially undesirable (only the most recalcitrant species would remain wild—all others would be managed for human benefit). In other words, effective fullness occurs at less than 100 percent human preemption of net photosynthetic product, and there is much evidence that long-run human carrying capacity is reached at less than the existing 40 percent (see Chapter I). The world has rapidly gone from relatively empty (10 percent full) to relatively full (40 percent full). Although 40 percent is less than half, it makes sense to think of it as indicating relative fullness because it is only one doubling time away from 80 percent, a figure that represents excessive fullness. This change has been faster than the speed with which fundamental economic paradigms shift. According to physicist Max Planck, a new scientific paradigm triumphs not by convincing the majority of its opponents, but because its opponents eventually die. There has not yet been time for the empty-world economists to die, and meanwhile they have been cloning themselves faster than they are dying by maintaining tight control over their guild. The disciplinary structure of knowledge in modern economics is far tighter than that of the turn-of-the-century physics that was Planck's model. Full-world economics is not yet accepted as academically legitimate; indeed it is not even recognized as a challenge.

Another reason for failing to note the watershed change in the pattern of scarcity is that in order to speak of a limiting factor,

the factors must be thought of as complementary. If factors are good substitutes, then a shortage of one does not significantly limit the productivity of the other. A standard assumption of neoclassical economics has been that factors of production are highly substitutable. Although other models of production have considered factors as not at all substitutable (for example, the total complementarity of the Leontief model), the substitutability assumption has dominated. Consequently the very idea of a limiting factor was pushed into the background. If factors are substitutes rather than complements, then there can be no limiting factor and hence no new era based on a change of the limiting role from one factor to another. It is therefore important to be very clear on the issue of complementarity versus substitutability.

The productivity of manmade capital is more and more limited by the decreasing supply of complementary natural capital. Of course in the past, when the scale of the human presence in the biosphere was low, manmade capital played the limiting role. The switch from manmade to natural capital as the limiting factor is thus a function of the increasing scale and impact of the human presence. Natural capital is the stock that yields the flow of natural resources—the forest that yields the flow of cut timber; the petroleum deposits that yield the flow of pumped crude oil; the fish populations in the sea that yield the flow of caught fish. The complementary nature of natural and manmade capital is made obvious by asking, what good is a saw mill without a forest? a refinery without petroleum deposits? a fishing boat without populations of fish? Beyond some point in the accumulation of manmade capital it is clear that the limiting factor on production will be remaining natural capital. For example, the limiting factor determining the fish catch is the reproductive capacity of fish populations, not the number of fishing boats; for gasoline the limiting factor is petroleum deposits, not refinery capacity; and for many types of wood it is remaining forests, not saw mill capacity. Costa Rica and peninsular Malaysia, for example, now must import logs to keep their saw mills employed. One country can accumulate manmade capital

and deplete natural capital to a greater extent only if another country does it to a lesser extent—for example, Costa Rica must import logs from somewhere. The demands of complementarity between manmade and natural capital can be evaded within a nation only if they are respected between nations.

Of course, multiplying specific examples of complementarity between natural and manmade capital will never suffice to prove the general case. But the examples given above at least serve to add concreteness to the more general arguments for the complementarity hypothesis given in the next section.

Because of the complementary relation between manmade and natural capital, the very accumulation of manmade capital puts pressure on natural capital stocks to supply an increasing flow of natural resources. When that flow reaches a size that can no longer be maintained, there is a big temptation to supply the annual flow unsustainably by liquidation of natural capital stocks, thus postponing the collapse in the value of the complementary manmade capital. Indeed, in the era of empty-world economics, natural resources and natural capital were considered free goods (except for extraction or harvest costs). Consequently the value of manmade capital was under no threat from scarcity of a complementary factor. In the era of full-world economics, this threat is real and is met by liquidating stocks of natural capital to temporarily keep up the flow of natural resources that support the value of manmade capital. Hence the problem of sustainability.

More on Complementarity Versus Substitutability

The main issue is the relation between natural capital, which yields a flow of natural resources and services that enter the process of production, and the manmade capital that serves as an agent in the process for transforming the resource inflow into a product outflow. Is the flow of natural resources (and the stock of natural capital that yields that flow) substitutable by manmade capital? Clearly, one resource can substitute for another—we can transform

aluminum instead of copper into electric wire, for example. We can also substitute labor for capital, or capital for labor, to a significant degree, even though the characteristic of complementarity is also important. For example, we can have fewer carpenters and more power saws, or fewer power saws and more carpenters, and still build the same house. But more pilots cannot substitute for fewer airplanes, once the airplanes are fully employed. In other words, one resource can substitute for another, albeit imperfectly, because both play the same qualitative role in production-both are raw materials undergoing transformation into a product. Likewise capital and labor are substitutable to a significant degree because both play the role of agent of transformation of resource inputs into product outputs. However, when we come to substitution across the roles of transforming agent and material undergoing transformation (efficient cause and material cause), the possibilities of substitution become very limited, and the characteristic of complementarity is dominant. For example, we cannot make the same house with half the lumber no matter how many extra power saws or carpenters we try to substitute. Of course! we might substitute brick for lumber, but then we face the analogous limitation-we cannot substitute masons and trowels for bricks

The Complementarity of Natural and Manmade Capital

The upshot of these considerations is that natural capital (natural resources) and manmade capital are complements rather than substitutes. The neoclassical assumption of near perfect substitutability between natural resources and manmade capital is a serious distortion of reality, the excuse of "analytical convenience" notwithstanding. To see how serious, imagine that in fact manmade capital were indeed a perfect substitute for natural resources. Then it would also be the case that natural resources would be a perfect substitute for manmade capital.

Yet if that were so, we would have had no reason whatsoever to accumulate manmade capital, since we were already endowed by nature with a perfect substitute! Historically,

of course, we did accumulate manmade capital long before natural capital was depleted, precisely because we needed manmade capital to make effective use of the natural capital (complementarity!). It is quite amazing that the substitutability dogma should be held with such tenacity in the face of such an easy *reductio ad absurdum*. Add to that the fact that capital itself requires natural resources for its production-that is, the substitute itself requires the very input being substituted for-and it is quite clear that manmade capital and natural resources are fundamentally complements, not substitutes. Substitutability of capital for resources is limited to reducing waste of materials in process-for example, collecting sawdust and using a press (capital) to make particle board. And no amount of substitution of capital for resources can ever reduce the mass of material resource inputs below the mass of the outputs, given the law of conservation of matter-energy.

Substitutability of capital for resources in aggregate-production functions reflects largely a change in the total product mix from resource intensive to different capital-intensive products. It is an artifact of product aggregation, not factor substitution-that is, along a given product isoquant. It is important to emphasize that it is this latter meaning of substitution-producing a given physical product with fewer natural resources and more capital-that is under attack here. No one denies that it is possible to produce a different product or a different product mix with fewer resources. Indeed, new products may be designed to provide the same or better service while using fewer resources, and sometimes less labor and less capital as well. This is technical improvement, not substitution of capital for resources. Light bulbs that give more lumens per watt represent technical progress, qualitative improvement in the state of the arts, not the substitution of a quantity of capital for a quantity of natural resource in the production of a given quantity of a product.

It may be that economists are speaking loosely and metaphorically when they claim that capital is a near perfect substitute for natural resources. Perhaps they are counting as "capital" all improvements in

knowledge, technology, managerial skill, etc.-in short, anything that would increase the efficiency with which resources are used. If this is the usage, then "capital" and resources would by definition be substitutes in the same sense that more efficient use of a resource is a substitute for using more of the resource. But to define capital as efficiency would make a mockery of the neoclassical theory of production, where efficiency is a ratio of output to input, and capital is a quantity of input.

The productivity of manmade capital is more and more limited by the decreasing supply of complementary natural capital. In the past, when the scale of the human presence in the biosphere was low, manmade capital played the limiting role. The switch from manmade to natural capital as the limiting factor is thus a function of the increasing scale of the human presence.

More on Natural Capital

Thinking of the natural environment as "natural capital" is in some ways unsatisfactory, but useful within limits. We may define capital broadly as a stock of something that yields a flow of useful goods or services. Traditionally capital was defined as produced means of production, which we are here calling manmade capital as distinct from natural capital, which, though not made by man, is nevertheless functionally a stock that yields a flow of useful goods and services. We can distinguish renewable from nonrenewable, and marketed from nonmarketed, natural capital, giving four cross-categories. Pricing natural capital, especially nonmarketable natural capital, is so far an intractable problem, but one that need not be faced here. All that need be recognized for the argument at hand is that natural capital consists of physical stocks that are complementary to manmade capital. We have learned to use the concept of human capital (acquired skills and knowledge), which departs even more fundamentally from the standard definition of capital. Human capital cannot be bought and sold, although it can be rented. Although it can be accumulated, it cannot be inherited without effort by bequest as can ordinary manmade capital, but must be relearned anew by each generation. Natural

capital, however, is more like traditional manmade capital in that it can be bequeathed. Overall, the concept of natural capital is less a departure from the traditional definition of capital than is the commonly used notion of human capital.

There is a troublesome subcategory of marketed natural capital that is intermediate between natural and manmade, which we might refer to as "cultivated natural capital," consisting of such things as plantation forests, herds of livestock, agricultural crops, fish bred in ponds, etc. Cultivated natural capital supplies the raw material input complementary to manmade capital, but it does not provide the wide range of natural ecological services characteristic of natural capital proper. For example, eucalyptus plantations supply timber to saw mills and may even reduce erosion, but do not provide wildlife habitat nor preserve biodiversity. Investment in the cultivated natural capital of plantation forests, however, is useful not only for the lumber, but as a way of easing the pressure of lumber interests on the remaining true natural capital of real forests.

Marketed natural capital can, subject to the important social corrections for common property and myopic discounting, be left to the market. Nonmarketed natural capital, both renewable and nonrenewable, will be the most troublesome category. Remaining natural forests should in many cases be treated as nonmarketed natural capital, and only replanted areas treated as marketed natural capital. In neoclassical terms, the external benefits of remaining natural forests might be considered "infinite," thus removing them from market competition with other [inferior] uses. Most neoclassical economists, however, have a strong aversion to any imputation of an "infinite" or prohibitive price to anything.

Policy Implications of the Turning Point

In this new full-world era, investment must shift from manmade capital accumulation toward natural capital preservation and restoration. Also technology should be aimed at increasing the productivity of natural capital more than manmade capital.

If these two things do not happen, we will be behaving uneconomically-in the most orthodox sense of the word. That is, the emphasis should shift from technologies that increase the productivity of labor and manmade capital to those that increase the productivity of natural capital. This would occur by market forces if the price of natural capital were to rise as it became more scarce. What keeps the price from rising? In most cases natural capital is unowned and consequently nonmarketed. Therefore it has no explicit price and is exploited as if its price were zero. Even where prices exist on natural capital the market tends to be myopic and excessively discounts the costs of future scarcity, especially when under the influence of economists who teach that accumulating capital is a near perfect substitute for depleting natural resources!

Natural capital productivity is increased by: (1) increasing the flow (net growth) of natural resources per unit of natural stock (limited by biological growth rates); (2) increasing product output per unit of resource input (limited by mass balance); and especially by (3) increasing the end-use efficiency with which the resulting product yields services to the final user (limited by technology). We have already argued that complementarity severely limits what we should expect from (2), and complex ecological interrelations and the law of conservation of matter-energy will limit the increase from (1). Therefore the focus should be mainly on (3).

The above factors limit productivity from the supply side. From the demand side, tastes may provide a limit to the economic productivity of natural capital that is more stringent than the limit of biological productivity. For example, game ranching and fruit gathering in a natural tropical forest may, in terms of biomass, be more productive than cattle ranching. But undeveloped tastes for game meat and tropical fruit may make this use less profitable than the biologically less productive use of cattle ranching. In this case a change in tastes can increase the biological productivity with which the land is used.

Since manmade capital is owned by the capitalist, we can expect that it will be maintained with an interest to increasing its

productivity. Labor power, which is a stock that yields the useful services of labor, can be treated in the same way as manmade capital. Labor power is manmade and owned by the laborer, who has an interest in maintaining it and enhancing its productivity. But nonmarketed natural capital (the water cycle, the ozone layer, the atmosphere, etc.) is not subject to ownership, and no self-interested social class can be relied upon to protect it from overexploitation.

If the thesis argued above were accepted by development economists and the multilateral development banks, what policy implications would follow? The role of the multilateral development banks in the new era would be increasingly to make investments that replenish the stock and increase the productivity of natural capital. In the past, development investments have largely aimed at increasing the stock and productivity of manmade capital. Instead of investing mainly in saw mills, fishing boats, and refineries, development banks should now invest more in reforestation, restocking of fish populations, and renewable substitutes for dwindling petroleum reserves. The latter should include investment in energy efficiency, since it is impossible to restock petroleum deposits. Since natural capacity to absorb wastes is also a vital resource, investments that preserve that capacity (for example, pollution reduction) also increase in priority. For marketed natural capital this will not represent a revolutionary change. For nonmarketed natural capital it will be more difficult, but even here economic development agencies have experience in investing in complementary public goods such as education, legal systems, public infrastructure, and population control. Investments in limiting the rate of growth of the human population are of greatest importance in managing a world that has become relatively full. Like manmade capital, manmade labor power is also complementary with natural resources, and its growth can increase demand for natural resources beyond the capacity of natural capital to sustainably supply.

Perhaps the clearest policy implication of the full-world thesis is that the level of per capita resource use of the rich countries

cannot be generalized to the poor, given the current world population. Present total resource use levels are already unsustainable, and multiplying them by a factor of five to ten as envisaged in the Brundtland Report, albeit with considerable qualification, is ecologically impossible. As a policy of growth becomes less possible, the importance of redistribution and population control as measures to combat poverty increase correspondingly. In a full world both human numbers and per capita resource use must be constrained. Poor countries cannot cut per capita resource use; indeed they must increase it to reach a sufficiency, so their focus must be mainly on population control. Rich countries can cut both, and for those that have already reached demographic equilibrium, the focus would be more on limiting per capita consumption to make resources available for transfer to help bring the poor up to sufficiency. Investments in population control and redistribution therefore increase in priority for development agencies.

Investing in natural capital (nonmarketed) is essentially an infrastructure investment on a grand scale and in the most fundamental sense of infrastructure—that is, the biophysical infrastructure of the entire human niche, not just the within-niche public investments that support the productivity of the private investments. Rather we are now talking about investments in biophysical infrastructure ("infrainfrastructure") to maintain the productivity of all previous economic investments in manmade capital, be they public or private, by investing in rebuilding the remaining natural capital stocks, which have come to be limitative. Indeed, in the new era the World Bank's official name, the International Bank for Reconstruction and Development, should emphasize the word reconstruction and redefine it to mean reconstruction of natural capital devastated by rapacious "development," as opposed to the historical meaning of reconstruction of manmade capital in Europe devastated by World War II. Since our ability to recreate natural capital is very limited, such investments will have to be indirect—that is, conserve the remaining natural capital and encourage its natural growth by reducing our level of current exploitation. This includes investing in

projects that relieve the pressure on these natural capital stocks by expanding cultivated natural capital (plantation forests to relieve pressure on natural forests, for example) and by increasing end-use efficiency of products.

The difficulty with infrastructure investments is that their productivity shows up in the enhanced return on other investments and is therefore difficult both to calculate and to collect for loan repayment. Also, in the present context, these ecological infrastructure investments are defensive and restorative in nature—that is, they will protect existing rates of return from falling more rapidly than otherwise, rather than raising their rate of return to a higher level. This circumstance will dampen the political enthusiasm for such investments but will not alter the economic logic favoring them. Past high rates of return on manmade capital were possible only with unsustainable rates of use of natural resources and consequent (uncounted) liquidation of natural capital. We are now learning to deduct natural capital liquidation from our measure of national income.⁶ The new era of sustainable development will not permit natural capital liquidation to count as income and will consequently require that we become accustomed to lower rates of return on manmade capital—rates on the order of magnitude of the biological growth rates of natural capital, since that will be the limiting factor. Once investments in natural capital have resulted in equilibrium stocks that are maintained but not expanded (yielding a constant total resource flow), then all further increase in economic welfare would have to come from increases in pure efficiency resulting from improvements in technology and clarification of priorities. Certainly investments are being made in increasing biological growth rates, and the advent of genetic engineering will add greatly to this thrust. However, experience to date (for example, the green revolution) indicates that higher biological yield rates usually require the sacrifice of some other useful quality (disease resistance, flavor, strength of stalk). In any case, the law of conservation of matter-energy cannot be evaded by genetics: more food from a plant or animal implies either more inputs or less matter-energy going to the nonfood structures and

functions of the organism. To avoid ecological backlashes will require leadership and clarity of purpose on the part of development agencies. To carry the arguments for infrastructure investments into the area of biophysical/ environmental infrastructure or natural capital replenishment will require new thinking by development economists. Since much natural capital is not only public but globally public in nature, the United Nations seems indicated to take a leadership role.

Consider two specific cases of biospheric infrastructure investments and the difficulties they present. (1) A largely deforested country will need reforestation to keep the complementary manmade capital of saw mills (carpentry, cabinetry skills, etc.) from losing their value. Of course, for a time, the deforested country could resort to importing logs. To protect the manmade capital of dams from the silting of the lakes behind them, the water catchment areas feeding the lakes must be reforested or the original forests protected to prevent erosion and siltation. Agricultural investments depending on irrigation can become worthless without forested water catchment areas that recharge aquifers. (2) At a global level, enormous stocks of manmade capital and natural capital are threatened by depletion of the ozone layer, although the exact consequences are too uncertain to be predicted. The greenhouse effect is a threat to the value of all coastally located and climatically dependent capital, be it manmade (port cities, wharves, beach resorts) or natural (estuarine breeding grounds for fish and shrimp!). And if the natural capital of fish populations diminishes due to loss of breeding grounds, then the value of the manmade capital of fishing boats and canneries will also be diminished in value, as will the specialized human capital devoted to fishing, canning, etc. We have begun to adjust national accounts for the liquidation of natural capital, but have not yet recognized that the value of complementary manmade capital must also be written down as the natural capital that it was designed to exploit disappears. Eventually the market will automatically lower the valuation of fishing boats as fish disappear, so perhaps no accounting adjustments are called for. But ex ante

policy adjustments aimed at avoiding the ex post writing down of complementary manmade capital, whether by market or accountant, is certainly called for.

Initial Policy Response to the Turning Point

Although there is as yet no indication of the degree to which development economists would agree with the fundamental thesis here argued, three United National agencies (World Bank, United Nations Environment Program, and United National Development Program) have nevertheless embarked on a project, however exploratory and modest, of biospheric infrastructure investment known as the Global Environment Facility. The Facility would provide concessional funding for programs investing in the preservation or enhancement of four classes of biospheric infrastructure of nonmarketed natural capital. These are: protection of the ozone layer, reduction of greenhouse gas emissions, protection of international water resources, and protection of biodiversity. If the thesis argued here is correct, then investments of this type should eventually become very important in the lending portfolios of development banks. Likewise the thesis would provide theoretical justification and guidance for present efforts to found the Global Environment Facility and its likely extensions. It would seem that the "new era" thesis merits serious discussion, both inside and outside the multilateral development banks, especially since it appears that our practical policy response to the reality of the new era has already outrun our theoretical understanding of it.

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