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Environment and Natural Resources in Economic Growth Analysis: A Review

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Abstract—*The primary aim of this paper is pedagogical. We first present and discuss a "wiring diagram" framework in order to elucidate the general links between economic growth and "natural capital." After developing the general framework, we develop parallel frameworks applicable to several specific sectors of the economy (agriculture, forestry, and manufacturing). This paper provides a brief historical review of the role of natural resources and the environment in economic growth theory.*

Keywords*: Economic growth. natural resources. Sustainable development.*

1. INTRODUCTION

When modern theories of economic growth first began to be developed in the 1950s and 1960s, natural resources and the environment essentially were absent. Economic output flows and rates of output growth were assumed to depend on the applications of services provided by capital and labor. Capital could be augmented by net investment because of domestic savings and external capital flows. There were potential "limits to growth" identified in growth theory in that as capital per person grew, the rate of growth in output per person declined until a steady state was achieved. However, such limits to growth were not related to natural resources and the environment. Technology was added to capital and labor as an input to the growth process. Technical progress was usually assumed to be exogenous and not embodied in specific equipment or skills, though more recent developments in growth theory have relaxed this artificial assumption. Output growth could then be prolonged through (assumed) technical advance. But the role of natural resources and the environment as valuable inputs to the growth process remained outside of growth theory at that time, as did possible constraints from the natural world that could lead to more rapid slowing or even a decline in output per capita over time. Attention to the interfaces between the natural and economic worlds initially came from natural resource and environmental economists interested in problems of limits to growth. In the late 1970's, development economists began seriously rethinking the neoclassical growth model because of the realization that macroeconomic policy recommendations would be incomplete without reference to environmental policy components. Over time, as a result of efforts by specialists of both types, theories of growth with various kinds of natural resource inputs and environmental implications became fairly well developed.

The analytical paradigm was further altered in the late 1980s to reflect concerns about environmentally sustainable economic growth. Sustainable economic growth policies in this perspective depend on the level, quality, and management of renewable and non-renewable natural resources and on the state of the environment.

2. A SCHEMATIC REPRESENTATION OF THE ROLES OF NATURAL RESOURCES AND THE ENVIRONMENT IN ECONOMIC GROWTH

At this level of generality, "environmental services" incorporate a number of productive inputs. Climatic conditions, including temperature and rainfall, are more or less conducive to agricultural and silvi-cultural production. Water bodies (rivers, lakes, estuaries, wetlands) of certain water quantity, turbidity, flow rate, temperature, and chemical composition provide more or less fruitful habitat for valued aquatic organisms (shrimp, fish, plant life) as well as water resources for human consumption and manufacturing. Biodiversity contributes to ecological stability as well as to tourism, long-term agricultural productivity, and possibly pharmaceuticals. Air quality and broader climatic conditions affect ambient temperatures, health conditions, and variability of weather in ways that affect the productivity of inputs in various household and manufacturing activities. "Environmental quality" then can be understood generally as the capacity of the natural system to provide a sustained flow of these various environmental services.

Wastes that are produced (taking into account byproducts management activities) flow back into the natural environment and reduce environmental quality. Reduced environmental quality negatively affects economic productivity by reducing the flows of various environmental services, as described above, and by reducing the productivity of some natural resources. Reduced environmental quality also has a direct negative effect on household well-being, given a level of material consumption.

Therefore, investment in the maintenance of natural capital services is one of the important pathways for achieving sustained growth, though the nature of the tradeoffs among the various forms of investment in practice is an empirical question.

Efficiency problems in the allocation of natural capital resources arise because of externalities that are familiar to natural resource and environmental economists. If a scarce natural resource is nevertheless freely available for the taking (open access), it will be over exploited and incentives to invest in better protection and management will be lacking. If social mechanisms for internalizing the costs of environmental degradation are lacking, then waste production will be excessive and investments in waste byproducts management and environmental remediation will be deficient.

3. SECTORAL-LEVEL ECONOMY-ENVIRONMENT LINKAGES AGRICULTURE

Aside from being a carrier of pollution, water is clearly an important and often scarce input to agriculture. Surface water is ultimately replenish able, but ground water may recharge only slowly or not at all. In either case, expanded water use confronts a rising real opportunity cost of supply. Investments in water conservation capacity represent another channel through which investments in sustainable management of natural resources can support sustainable output.

It follows from this discussion that various investments in the maintenance of natural capital services in the form of soil productivity and water availability (quantity and quality) are among the important pathways for achieving sustained growth in the agricultural sector. We can also apply the general reasoning developed in the previous section to see how policy and institutional failures can reduce the overall economic efficiency of the agricultural sector. On the environmental services side, failure to price water, land services (because of insecure property rights), and environmental loadings according to their true opportunity costs will excessively deplete or degrade natural and environmental resources and in so doing limit opportunities for sustainable economic progress in the agricultural sector. On the agricultural markets side, distortions in the prices of agricultural outputs or material inputs like agro-chemicals will have both direct consequences in reducing economic efficiency and indirect consequences on efficiency and sustainability through effects on the natural system. 4. Sectoral-Level Economy-Environment Linkages: Rotation Forestry and Non-Timber Forest Products and Services Let us turn next to a stylized representation of the economy-environment interface as it arises in connection with forest resources. Figure 3 illustrates some key interconnections. We have designed Figure 3 to apply principally to a situation in which there is rotational timber harvesting of more or less natural regrowth, with some management inputs. The solid lines in Figure 3 represent the flow of physical inputs or other productive services at various points in the process. The dashed lines represent the flow of payments to pay for factors of production and undertake various kinds of investments.

One key economy-environment is the services of the land base and growing conditions for supporting forestry. Unlike in our discussion of agriculture, however, we emphasize that forested areas produce a number of socially valued goods, some of which are traded in markets and others which are substantially or largely nonmarket goods. There are both complementarities and tradeoffs in the production of different menus of outputs from the forest that are a key part of the economy-environment linkage.

On the other hand, putting greater amounts of land under rotational harvest management and applying human inputs to those lands more intensively may well reduce those outputs associated more with natural forest conditions. In terms of the diagram, expanded timber output slides the vertical dashed line in the outputs box to the right, reducing outputs in the right hand column. Some of the outputs that are reduced when timber harvest increases from a particular forested area could be biodiversity (from disruption of natural habitats), watershed protection (from reduction of forest cover that allows more erosion), and some non-timber forest products (perhaps medicinal plants) that benefit from more natural growing conditions. Figure 3 emphasizes a pathway for investment in maintaining "natural capital" that is especially important for forested areas, though it is also important for other sectors of the economy as well. Investments in knowledge and technology can reduce the tension between different forest outputs by expanding the size and even the menu of outputs that can be achieved.

Various investments in the maintenance of natural capital services – including improved knowledge and technology – are an important pathway for achieving sustained growth in the overall social value derived from forest areas. In this case especially, the mix of valued outputs can vary and policy decisions must weigh what kinds of output growth to promote as well as how to promote output growth. Again, policy and institutional failures that distort the price of any input or output, including non-market outputs, will reduce overall economic efficiency, constraining growth and causing the mix of outputs to diverge from what society intended. For example, distortions in timber markets, including logging subsidies and open access to forest lands, will stimulate excessive and too rapid harvest which is economically wasteful directly and harms non-market outputs. The problems on the environmental side include potential undervaluation of key ecosystem services whose provision might compete at the margin with timber extraction. More extreme versions of the challenges discussed in the previous paragraph can arise when market and policy distortions create incentives for deforestation and land conversion that make sense for the individual actors involved but do not serve a larger social interest.

4. SECTORAL-LEVEL ECONOMY-ENVIRONMENT LINKAGES: MANUFACTURING

Both steps (natural resource extraction and final output production) involve creating byproduct wastes. Those wastes that do pass back to the environment have an adverse effect on air and water quality and also may harm the productivity of the natural resource stock (in particular, biological stocks like a fishery).This illustrates a second key economy-environment link. However, the services of what we refer to generally as "environmental technology" can be used to reduce the waste intensity of intermediate or final output and to manage remaining wastes to reduce their environmental harms.

Once again, various investments in the maintenance of natural capital services can be an important pathway for achieving sustained growth in industrial output. The investments in this case include the reduction and management of unwanted byproducts in the environment that reduce productivity as well as causing direct harm to people, along with investments in the development and improved management of natural resources. And as already explained, failure to account for these environmental feedbacks in the pricing of goods and services or distortions in input and output markets with potential environmental side effects all reduce overall economic efficiency and thereby unnecessarily constrain growth.

5. THE ROLE OF ENVIRONMENT AND NATURAL RESOURCES IN ECONOMIC GROWTH THEORY

A complete history of the role of environmental and natural resources in economic growth analysis would go back at least to the 19th century writings of Malthus, Mill, and Jevons. Our less ambitious task here is to provide a brief summary of key developments in the literature over roughly the past 30 years. We divide the material to be discussed into four parts, which are considered in roughly chronological order. These parts are: growth and natural resource depletion; growth and pollution/natural resource degradation; endogenous growth, innovation and the environment; and trade, development, and the environment. In discussing these various parts of the literature we provide selective citations of key studies. Surveys by Beltratti (1997), Smulders (1999), and Margolis (2002) provide a more complete review of the literature.

6. GROWTH AND NATURAL RESOURCE DEPLETION

This topic, which has figured prominently in various debates over "limits to growth," attracted much attention in the wake of the oil market shocks of the early 1970s and remained prominent in the literature for at least a decade thereafter. Perhaps the most important articles in this strand of literature were by Dasgupta and Heal (1974), Solow (1974), Stiglitz (1974), and Hartwick (1977). In these studies , economic output depends on an "essential" depletable natural resource as well as investment in conventional capital. The key insights derived from these studies can be summarized as follows:

- Given the assumptions of the models, scarcity of the natural resource implies an inherent limit to growth, unless some kind of resource-augmenting technical progress can work to alleviate the scarcity constraint so as to allow growth to occur unimpeded. Merely investing in more capital is not enough.
- Investment in more capital may be a way to maintain output over time. But if capital cannot be readily enough substituted for the natural resource, growing natural resource scarcity will eventually lead to inexorably worsening economic conditions.
- If substitution to maintain output is technically feasible, society may still not be able to sustain output unless the societal rate of savings is raised. The "scarcity rents" associated with the depletable natural resource can be reinvested to augment the capital stock, but this rate of savings likely will be inconsistent with individuals' preferences for higher near-term consumption.

The models used to generate these results are quite stylized and incomplete, excluding in particular both renewable substitutes for depletable natural resources and endogenous investment in new technologies and skills. Therefore the results obtained from the models cannot be taken too seriously. However, the models remain useful for highlighting the importance of essential natural capital and the implications of limited substitution possibilities between natural and other capital. For example, the ability to endlessly substitute capital for energy inputs is physically impossible given the laws of physics; yet many of the models purporting to show a "way out" of natural resource scarcity require such substitution. The scarcity models also can shed light on the consequences of depletion of nonrenewable and difficult-to-replace ecological resources, like biodiversity and (at some stage) the carbon-holding capacity of the atmosphere.

7. GROWTH AND POLLUTION/NATURAL RESOURCE DEGRADATION

This literature began to develop in the early 1970s and grew rapidly through the mid- 1980s, with contributions continuing to the present. One strand of this literature describes how pollution byproducts of economic activity can accumulate in the natural environment and cause social losses, either directly affecting households (worsened health, loss of amenities) or indirectly affecting them through reduced production possibilities. Another strand focuses on the role of renewable natural resources in economic output and the adverse effects of renewable natural resource depletion. From a formal analytical perspective the two strands are strongly related. Both involve different kinds of stock effects on output and well-being; both involve similar natural stock dynamics (pollution accumulation and decay, renewable natural resource

extraction and regeneration); and both allow for the possibility of various kinds of threshold effects (species extinction, discontinuous damages from pollution accumulation).

A typical theoretical finding in this part of the literature, as discussed in Appendix A, is the optimality of some long-term steady state in which pollution growth balances natural decay, or natural resource extraction balances regeneration. However, it is also possible for the optimal outcome to be a corner solution in which the renewable natural resource is exhausted or pollution is allowed to accumulate without bound. Such outcomes are more to be expected when the discount rate is high or possibilities for economic progress through more environmentally "benign" means are limited (that is, societies with limited quantities of other capital).

A steady state can be supported by a theoretically optimal set of shadow prices, and in principle policy can focus on market, policy and institutional reforms that move actual prices toward the theoretical ideal. Note that the options for policy intervention are richer in this setting than with simple depletion models, incorporating natural resource management and defensive expenditures to enhance natural resource regeneration or environmental improvement as well as efforts simply to conserve natural capital. But natural resources and environmental quality are still a limit to growth in these models. Especially when the effects of natural resource or environmental degradation are experienced through reduced economic productivity, such policies can be considered a subset of development policies. In practice, the focus until recently in this part of the literature has been more on natural resource and environmental policies than on broader development policies (for example, how improving opportunities for human capital formation may help economic growth and natural resource protection).

8. ENDOGENOUS GROWTH, INNOVATION, AND THE ENVIRONMENT

This part of the literature began to emerge in the mid-1990s (though endogenous growth models without an environmental component began to be developed in the 1980s). The general idea in all endogenous growth models, including those with an environmental component, is that the marginal product of human-supplied capital broadly defined does not decline toward zero even as the volume of capital grows. "Human-supplied capital" incorporates not just equipment, but also knowledge and skills. The ability to augment human as well as machine capital is one of the pathways emphasized in the theoretical assumption that marginal product of investment can remain above some positive threshold level. Other pathways include the effects of learning by doing and economies of scale from investment in various kinds of infrastructure. Key findings from this part of the literature include the following:

- With the assumed ability to sustain the marginal product of human-supplied capital over time, sustained (not just transitional) income growth is possible without complete environmental degradation or natural resource depletion being inevitable. The models thus seem to suggest a way around limits to growth: in addition to sound natural resource and environmental practice, invest adequately in built and human capital.
- While income growth is possible in these models, it is not inevitable. A society with strong preferences for environmental amenities could shift increasing quantities of investment toward natural capital protection as income rises. A society with a high rate of discount could still choose extensive natural resource depletion.
- Environmental and natural resource policies that ameliorate supply-side depletion effects can have sustained long-term productivity enhancement effects. This seems to point toward an appealing win-win opportunity. But natural resource and environmental protection also has short term costs, including crowding out of other investment – some of which could have been in innovation to enhance human capital. Thus, crowding out can have long-term as well as short-term costs.

While the endogenous growth literature seems to offer a way around limits to growth, it is important to be cognizant of the assumptions underlying these models. They depend in particular on the ability of capital growth broadly defined to generate sustained income growth, even while flows of natural and environmental resource services remain bounded. This seems more plausible than the simple capital-resource substitution story in the natural resource depletion models of the 1970s, but it is still not entirely self-evident. For example, can increased flows of knowledge and skills from innovation provide for rising output, for example by providing ever-easier and cheaper access to solar energy and dilute-concentration minerals? Moreover, even if capital investment broadly defined can sustain growth, the ability to do so likely depends on sustaining (preventing unlimited deterioration) of some natural capital. Investment in maintenance of services from natural capital as well as other forms of investment is required.

9. TRADE, DEVELOPMENT, AND THE ENVIRONMENT

Stylized, relatively aggregated growth models based on at least an implicit assumption of well-functioning markets will not capture several important aspects of growth and the environment relevant to developing countries. Natural resources and the environment figure prominently, either directly or indirectly, in the exports as well as overall output of many developing countries (mineral extraction, use of soil and water for agricultural exports, local environmental effects of commodity output for trade). It is thus important to ask if developing countries necessarily benefit over the longer term from natural resource-intensive export orientations.

Recent theoretical examinations of this issue indicate that (a) such an orientation can worsen natural resource and environmental conditions; and (b) it is even possible for overall well-being to decline in such an approach to trade and development. However, (a) is not inherently inconsistent with efficient and sustainable development over time. Some degree of tradeoff between natural and environmental resources and income generation is both unavoidable and desirable. It is an inefficiently large degree of natural and environmental resource degradation that is of concern. Moreover, the theoretical conditions under which increased and natural resource-intensive trade could reduce overall well-being appear to be somewhat limited and do not provide a blanket argument against trade liberalization and natural resource dependent exports as a strategy for longer-term growth.

The tradeoffs governing (a) and (b) depend strongly on the nature of domestic institutions for environmental and natural resource management. The weaker these institutions, the more likely that adverse spillover effects from use of natural and environmental resources will dissipate the apparent income gains. The management institutions themselves are endogenous – more wealth and a rising relative value of natural resource stocks will encourage improved public and private management efforts (as well as more rent seeking). Nevertheless, side effects could be significant, underscoring the need for trade liberalization and export promotion policies to be accompanied with improved natural resource and environmental management policies to help ensure overall benefits are realized.

Finally, models that look at the economy as a whole through the lens of the "representative agent" give somewhat short shrift to some important distributional issues. If natural resource rents from exploiting natural capital for export go mainly to benefit an already educated and affluent elite, the benefits for development may also be limited. This is especially the case if, as is the case in many countries, a significant impediment to development is a shortage of human capital and distortions in financial markets that make it difficult for poorer households to upgrade skills. Under these conditions, increased taxation of natural or environmental resource use to fund human capital formation may ultimately support development, even if it renders natural resource-intensive exports less competitive internationally. In this situation, the basic theorem of Hartwick (1977) concerning reinvestment of natural resource rents needs extending to address how the funds are used.

10. CONCLUSIONS AND EMPIRICAL CHALLENGES

This paper has attempted to clarify at an intuitive and conceptual level how economic growth and the environment are interconnected. The framework developed here has emphasized that natural resources and environmental quality can and should be thought of as targets for investment by society in promoting an improved quality of life in developing countries, investments that compete against other valued allocations of social savings. Economic growth affects the natural environment, but the natural environment also affects growth. This implies that concern for the natural environment needs to be at the core of development policy, not just a stand-alone environmental policy.

By describing investments in natural capital as competing with other uses of savings, we intend to underscore the inherent tradeoffs societies face in allocating savings. Investments in natural capital should not automatically be favored over other uses of resources, as advocated by some activists. Some degradation (depreciation) of natural capital can be appropriate. By the same token, however, we are arguing against the idea that the environment is somehow a luxury good or for some other reason inherently of secondary importance to those interested in economic growth and the well-being of people.

We have noted that natural capital is inefficiently allocated in practice not just because of market and institutional failures affecting natural resources and the environment, but also because of broader market and institutional failures that simultaneously hamper development and excessively degrade natural capital. In both cases the appropriate policy response must take into account the source and size of the misallocation problem, and the practical constraints of institutional capacity prevailing in the country. Sometimes the best remedy for environmental problems can be found in policies that focus on alleviating institutional barriers to economic growth. However, it does not follow automatically that growth policies alone should be pursued to ameliorate environmental problems.

While the conceptual framework we have developed in this paper is well grounded in the economic theory of growth and the environment, the empirical literature on these interconnections is less well developed. Further investigation through work in the field should put a high priority on reducing these empirical gaps.

Less is known empirically about the effects of environmental quality on economic growth. Some individual studies have described how air and water pollution can reduce agricultural yields and damage materials, as well as forcing industry to invest in costly water clean-up before it uses raw water for industrial purposes. Both water and air pollution seemingly can, through human health effects, reduce labor productivity. And natural resource degradation, of the types mentioned in the previous paragraph, limit long-term productivity in the affected sectors. But the empirical literature at the sectoral level for developing countries remains limited, and the macroeconomic consequences of these impacts in terms of growth are even less well understood. Perhaps the least is known empirically about the effects on growth of investing in natural resource and environmental infrastructure, though this has been an important strand in growth theory recently. A useful broad perspective on the connections between different

types of infrastructure and economic progress was provided in the World Bank's 1994 World Development Report, which found that whatever the nature of the causality, per capita infrastructure stocks generally correlate highly with per capita GDP levels. However, the reasons for this apparent relationship are not entirely clear, and the specific importance of natural resource and environmental infrastructure is even less well understood. To move ahead in understanding the connections between economic growth and natural capital, deeper probing of both physical and social infrastructure issues ranks as an especially high priority.

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