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Natural capital: hard economics, soft metaphor?

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This paper views the concept of natural capital from an economist's perspective. It begins by drawing on historical debates in economics on the nature of capital. These serve to identify central issues to do with the relationship between theory, empirics and method in the way in which the concept of capital is deployed in economic discourse. It is suggested that these have resonance for current discussions of the concept of natural capital. Against this background, the paper then discusses the way in which natural capital figures in the analysis of sustainability, and pinpoints various incoherencies. Finally, it draws on recent analyses of technical innovation as a possible solution to the problem of sustainability. It is suggested that there may be a conflict between narrow path-dependent solutions to the alleged problem, and more open learning-based approaches. The latter are exemplified by building on and reinterpreting the environmental economist's concept of a quasi-option.

Capital debates

This paper builds on the economist's conceptualisation of natural capital. The central argument is that there are serious problems with this conceptualisation and that these tell us much about the deployment of metaphor in the discourse of economists. A subsidiary argument concerns the ways in which learning may intrude into this discourse.

To begin with, this paper will focus on the word 'capital' rather than the word 'natural', and in particular on the notion that societies can be sensibly described as holders of portfolios of various sorts of capital assets. This portfolio notion is, of course, basic to the standard economic discussions of sustainability, but often these discussions are fairly casual in capital-theoretic terms. Thus there are a number of relatively unexplored issues.

We believe that a sense of history is important, of possibilities opened up and foreclosed. From time to time, there have been vigorous debates *within* the economics

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profession—broadly defined to extend beyond just the mainstream of so-called neo-classical economists—concerning the nature of capital and of its functioning within the economic system. These debates encapsulate a rather different, and possibly broader, argument—since it is about capital in general—from that about the meaning of *natural* capital in neo-classical as compared with ecological economics. Among the most significant of the debates were those in the 1930s—involving Frank Knight, Friedrich von Hayek and others (classically reviewed by Kaldor, 1960)—and those in the 1960s, this time involving groups of economists—including many of the brightest and the best—grouped around the Massachusetts Institute of Technology and Cambridge, UK, as defenders and critics of the neo-classical position, respectively. (This later controversy being dubbed, therefore, the 'Cambridge controversies'; an admirable account is Harcourt's [1972].)

These debates involved quite technical analytical issues interrelated with fundamental questions about the meaning and functioning of basic concepts in economic discourse. The central issue is this. Capital clearly comprises a vast and heterogeneous array of objects. What sense does it make to construct models in which this is reduced to some sort of ur-capital, a simple underlying primordial entity? In the 1930s debate this underlying entity was, on the one hand, presented as 'time', the notion that capital, in effect, represented a deferral of immediate gratification in order to accumulate more productive assets, and, on the other, as some sort of 'substance' which could be embodied in various forms. There are clearly complex metaphors being deployed here.

Though there is much that is worth revisiting in this earlier debate, we will focus on the later Cambridge controversies. The interesting issue, from our perspective, is the way in which arguments about analytical precision, the meaningfulness of measurement, and of the role of what were then called 'parables' as an aid to understanding the economy, were deployed. A constant complaint from the Cambridge UK side was that once they believed they had pinned down a question, the other side changed the question, and indeed, eventually—in effect—walked away from the debate and turned to other things. And, worse, with the return, on a large scale, to the study, both theoretical and empirical, of economic growth, by economists in the last few years, the old assumptions have simply reappeared. (As, for example, in some very influential studies of the impacts of innovation and investment in modern information and communications technology on productivity growth.) These debates would be worth revisiting for this last reason, alone—and, indeed, there have recently been some attempts to do so—but more because one suspects that, with the vastly expanded definitions of capital stocks now being deployed in economic discourse (as discussed in the next section of this paper), the sorts of problems debated in the 1960s will reappear a fortiori. They certainly appear in the so-called weak sustainability model which we turn to later.

The Cambridge controversy involved several strands, but central to the debate was the Cambridge UK observation that in a model with numerous capital goods there would not necessarily be a simple relationship between the aggregate value of the capital stock and the rate of return to that stock. (Basically because the prices of the

capital goods being aggregated are not independent of the rate of return to them.) Such a relationship was central to the standard growth models in economics (and remains so—as noted above—in the recent resurgence of interest in economic growth). It also, relatedly, had major implications for understanding the distribution of income between labour and capital.

Three sorts of responses by neo-classical economists evolved to this. One was to say that the aggregate models were simplifications: that what everyone really had in mind were fully disaggregated models with lots of capital goods, and it is quite easy to spell out the conditions on which the aggregated models would approximate to these. (In fact it is not.) Secondly, that the real purpose of the aggregate models was to provide a framework for empirical estimation—and we can, in practice, measure aggregate capital stocks without concern for analytical niceties. Thirdly, that the aggregate model was a 'parable' that successfully captures the essence of the way the economic system works. (This last clearly has echoes of the debate of the 1930s.) All these statements are questionable individually, and even more in conjunction. The first we return to shortly. On the second and third we can ask, respectively, whether there can be measurement before meaning, and how we can grasp essence if the model in our minds lacks coherence.

A deeper issue was whether or not the neo-classical model implied some sort of *causal* relationship between the capital stock and the return to that stock of capital, in which case the impossibility of defining that stock independently of the return to it (since that return determines the prices of the capital goods which are then necessary to aggregate them) seemed suspiciously circular. This certainly troubled some of the more perceptive early pioneers of neo-classical capital theory (notably the Swedish economist Knut Wicksell), who grasped for some measure which was ostensibly independent of prices, such as 'time'. (Wicksell's work was a point of reference in the debates of both the 1930s and the 1960s.) Is there some relationship here with the way in which some ecological economists approach the notion of natural capital: measurement embodied in the stuff itself?

We think it is obvious that we have much to learn from revisiting these discussions, both on specifics and—for the purposes of this paper—on broader conceptual and methodological issues. We turn to this in the penultimate section.

The multi-capital model

The debates which we have just outlined were all concerned with physical capital in the fairly narrow sense of, in the widely used chauvinistic expression, 'man-made', more-or-less durable inputs in production. However, economists have been steadily expanding the categories of capital which their models encompass. So let us move on to the so-called 'four capitals model', which distinguishes physical, human, natural and social capital.

Though there are various definitions, permutations, and extensions around this model, this has become basic to nearly all serious discussion of sustainability. It is widely deployed in macroeconomic, growth-theoretic approaches to sustainability,

but also in more micro-contexts, such as the resource-profiles, sustainable livelihoods and asset vulnerability approaches common in development studies. There are distinctions among these approaches, but they all share the common notion of communities or households as being appropriately viewed as holders of portfolios of assets. In fact, the model is often transmogrified into a five-capital model, with financial resources being added to the list. This only makes sense if the financial resources are not simply obligations within the social unit being studied. If they are, then we are double counting: my asset is your liability. This is, in fact, quite a general problem to which we return, that can apply especially to social capital. (We also note that the macro–micro spatial dimension is important and neglected: we return to that also.)

Essentially, the multi-capital model is an inventory. We can ask two related questions: how is the inventory defined and what is its purpose?

On the question of definition, there are three issues, which are often confused. First, are the components of the inventory quantifiable, or do some components have intrinsically non-quantifiable aspects? Secondly, are the components comparable in some sense, or is the set partitioned up in ineluctable ways, which points to an important social dimension. Do people really compare all these things? Should they? Thirdly, can the components be aggregated: this requires not just that the components are quantifiable and comparable, but that they are commensurable. Neoclassical economists, routinely assume the last, with prices as the aggregators. It is important to understand the force of this assertion, which is often misunderstood by critics. Prices are regarded by neo-classical economists as not just arbitrary weights, but as universal indices of efficiency, rooted in the ultimate preferences held and constraints faced by economic agents. Conversely, they contend that other aggregators, such as the spatial weights used in ecological footprinting, are indeed arbitrary or non-universal.

There are two levels of difficulty, both of which have possible learning implications. First, observed market prices may not approximate these 'true' indices. They may be 'distorted' by monopoly, for example. More importantly, they may be the product of markets in disequilibrium, that is, where supply and demand do not match, and agents may be in a, possibly perpetual, process of learning the true prices, particularly in dynamic contexts. It is also possible that observable prices may not exist at all: they may have to be imputed, through procedures such as contingent valuation which asks questions about, for example, the valuation that people place on endangered species. Such procedures raise serious issues both technical and conceptual. These issues are probably not separable in the way practitioners seem to suppose: what does it mean, for example to censor 'protest' (that is, where people cite apparently extravagant values) bids in contingent valuation surveys? More generally, there must be learning here: we have suggested elsewhere (Winnett, 2004), that respondents may anchor their valuation responses in unfamiliar situations by drawing on their more mundane experiences of observed day-to-day market prices.

The second level of difficulty is that there may not be true indices of efficiency to be found at all. The neo-classical model of economic agency may be simply misconstrued and the economy may not generate prices in the way presupposed by that

model. This returns us to the questions raised just above about quantification and comparability in asset portfolios with rather more generality. We have plenty of evidence, for example, that people do not or cannot make the sorts of all-encompassing comparisons that neo-classical economists suppose. Such compartmentalising of decisions may come about through processes external to the agent in the wider socio-economy or internally, so to speak, in the agent's mental functioning. Such partitions may be, in some sense, central to system-functioning, in terms of stability, for example. They may prevent or mitigate the consequences of 'bad' decisions in one place spilling over into other places. Nor is everything about which people make decisions quantifiable, though that is probably a less fundamental issue. This suggests quite different ways of thinking about 'where prices come from'.

Sustainability and resilience

What are the multi-capital models used for? Obviously, we are particularly interested in their deployment in the conceptualisation of long-run sustainability, but there are other uses, particularly at more micro-levels. In particular, we can ask about the system's resilience to shocks (recognising that these shocks may ultimately be generated by more macro, longer-run processes, such as climate change) or, more simply, to the ability to cope with more or less predictable fluctuation. There is a general though questionable presumption that more diversity in portfolios means more resilience. That, of course, means that the response of the components of portfolios to particular shocks are not positively correlated. So the type of shock needs to be carefully looked at, whether it is, say, a natural disaster or a macro-policy shock. These may obviously affect the components of a portfolio in different ways.

There is also a more subtle issue: in the extended capital model particular resources may be counted as more than one sort of capital. A tribal forest area may be both natural and social capital, in the sense of it functioning as a focus of community cohesion; or livestock may function as social capital though conferring status. Thus portfolio diversity may be illusory. This illusion is a result of the multiple functioning of certain sorts of resource and the ways in which we have chosen to work with a certain classification of capital which is ultimately, perhaps, arbitrary. Is this where metaphor enters rather specifically and powerfully: in driving these classifications? Notice that this argument also holds for the weak sustainability model, which we discuss shortly: what does 'substitution' mean in this context if we are doubtful about the entities being substituted one for another?

To return, briefly, to the resilience question, we also note that there is a real problem of measurement here: much social capital is effectively a reciprocal claim. Thus if many agents are affected similarly by shocks, the capital is valueless (like financial deposits in a bank-run). How do we value social capital under these conditions? And there are questions here to do with the spatial and or institutional domain over which aggregation is implemented.

Let us now turn explicitly to the standard sustainability arguments. We can define sustainability in a rough and ready way as maintaining some flow of per capita

benefits to a typical member of society (whoever that is) above some specified minimum over an indefinite horizon. Subject to some initial conditions and assuming zero technical progress and zero population growth, *weak* sustainability 'works' if the 'elasticities of substitution' among the various capital inputs are sufficiently high and if an appropriate investment plan is followed by society. In simple terms, can sufficient investment in 'man-made' capital make good the degradation of natural capital in terms of maintaining a flow of benefits to society? It is important to phrase the issue at this level of generality; some commentators seem to mistakenly think that there should be some sort of one-for-one technical replacement, such as renewable energy sources for fossil fuels. Notice also that we have tacitly extended the definition of 'man-made' capital to include anything that is humanly creatable, not just physical capital like plant and equipment but also human capital like education and skills, and social capital, like institutions.

Most of the attention has been on the elasticity issue. Essentially, in the two-input case (say where we have just physical capital and natural capital), this elasticity has to be at least one. It is difficult to find any serious discussion of multi-input cases, but we guess it is a lot more complex from parallel discussions elsewhere. This returns us to the aggregation issue and to what classifications of these capital inputs are being deployed. (It would be good to include, at least, human capital, since this expands the range of possibilities for weak sustainability to work, one would guess from studies of models which have human and physical capital in them.) Economists are generally optimistic on this and have tried to show that this elasticity condition has generally been met, but—the usual caveats about measurement without meaning aside—that is from the historical record and tells us nothing about the future.

There are two reasons for doubting this weak sustainability argument. First, production functions may not be like this: they may have complementarities in them, especially as some inputs (here the focus is on depleting natural capital stocks) approach lower bounds. At some point, we simply cannot do without, say, a finite amount of oil. Secondly, the benefit stream may have within it minima for some particular components (and here the focus is on the stock, as compared with the flow, services of natural capital). We cannot manage in our everyday lives without, say, some finite level of air quality. The former has been more discussed. It is these arguments which motivate the *strong* sustainability model, which essentially imposes additional side conditions on the weak sustainability model. These are in the form of lower bounds on some or all of some natural capital stocks.

There are varying degrees of aggregation implicit in the various strong sustainability arguments, which presumably flow from views about substitutability in subcomponents of the natural capital stock, whether in production or consumption. The way to model this is to use additively separable functions—that is, where we may be able to substitute among some lower-level types of natural capital but not at higher levels—one birdsong for another but not birds for fish. However, it is usually not formalised in this way—rather, we typically simply list some 'critical' types of natural capital. This looks like another instance where we have forgotten the rather stringent

economic model with which we have started and gone to some not properly thought through empirics.

There is, however, a much bigger problem. In effect, strong sustainability implies that as we approach natural capital stock lower bounds, their relative prices approach infinity. They become infinitely valuable. Thus we cannot form the overall capital aggregates on which the whole economic approach to sustainability rests on, since these aggregates will be unbounded. Thus there is no conceivable level of investment that society could undertake in 'man-made' capital which would ensure sustainability. In short, the notion that in some sense, weak sustainability is a minimal condition which has to be strengthened by adding in some additional natural capital constraints is simply incoherent. This point is obvious, and, in effect, many ecological economists have arrived at the same conclusion. We find it difficult, however, to find a clear statement in the literature about the implications of this well-known valuation argument for the relationship between weak and strong sustainability.

There is another incoherence. Let us suppose that weak sustainability works. The associated investment plan for society (the prototype of which is Hartwick's [1977]) assumes that natural capital is depleted 'efficiently', according to the famous Hotelling rule or an extension of it. This rule says that over time we should deplete, say, oil reserves in such a way that the price of oil rises at the rate of interest at which society discounts the future; this implies that the rate of extraction gradually falls over time. Quite apart from all the issues, ethical and otherwise, surrounding discounting, is there not a basic inconsistency between this approach to future generations—which is based on discounted utilitarianism—and the underlying ethic of sustainability—which generally rests on some version of a Rawlsian or similar approach that requires us to treat all generations even-handedly? This issue seems to be circled round in some of the technical discussions of intergenerational choice but has not been very well focused in the sustainability literature.

We return briefly to the spatial dimension. Apart from the question of how to value reciprocal claims, mentioned above, there are two basic issues. One is to do with the level at which sustainability applies, given that at anything less than the global level, we are dealing with open systems, and yet most discussions of sustainability seem to presume closed systems. (But not all: for example, Hartwick has analysed the modifications to his basic model necessary in internationally open economies—however, this is a specific, model-dependent valuation issue.) Secondly, it raises questions about where our classifications of capital come from: is spatial area per se a capital asset? Can we be sure that the categories of the standard multi-capital models are exclusive and exhaustive? If they are not, presumably the framework collapses. (A similar issue arises in relation to knowledge, as discussed in the final section.)

A provisional summing-up

Let us try to very briefly and perhaps rather forcefully summarise thus far, drawing in explicitly the role of metaphor. It seems to be the case that, on the one hand, economists have drawn-in concepts such as natural and social capital, either directly or

though relabelling from elsewhere, and then attempted to subject them to the rigours of their capital and growth models. (The comment on categories, immediately above, is germane here.) This has led to all sorts of incoherencies, some of which have just been outlined. On the other hand, the apparent rigour of their models exposes them to serious lines of logical dispute, such as those identified in the Cambridge controversies. Such critiques are then shuffled out of by appealing to measurement without meaning, or, more basically, by arguing that meaning is in the metaphor (or, as it was called in the Cambridge controversies, the 'parable'), which seems an extraordinarily non-rigorous position for a supposedly rigorous science such as economics to have drifted into. It is this two-way traffic that needs exploration. The power of the economic model as metaphor significantly derives from its supposed rigour, and yet it is drawing on at least partially unexamined metaphors to patch over lacunae, conceptual and logical. Indeed, perhaps this reflective deficiency is a general characteristic of the (successful?) deployment of metaphors.

What is special about natural capital?

In an earlier section we focused our attention on natural capital as simply one of several types of capital asset. We identified various problems which arise with the conceptualisation of capita-in-general. It is clear that these may apply with particular strength to natural capital and to its incorporation into wider portfolios of capital assets, particularly those problems which arise from problems of quantification, comparability and commensurability. These arguments can be readily inferred from what we have said above. But very similar things could be said of social capital.

In the previous section, we turned to problems with the most widely used sustainability models. These invoke a particular characteristic of natural capital. In contrast with physical and human capital, it is not 'man-made'; it is not reproducible by human action. This, after all, is what creates the sustainability 'problem' and also the possibility of 'solving' it by substituting the one for the other. However, consider social capital. This is manifestly a product of human action but it is like natural capital in that at least some of its components may be subject to *irreversible* destruction. Indeed, exactly this argument has often been made anecdotally in comparing loss of linguistic diversity with natural species extinction. To push the argument even further, some of what seems like irreversible destruction of some natural capital may turn out to be reversible after all, with possibilities of species re-creation and so on. It is probable that what is really irreversible is destruction of some sorts of ecosystemic characteristics. The parallel here is very close to social capital. This is a very speculative argument. With natural capital we have generally been using a metaphor which relies on a distinction between what is humanly creatable and what is not. (The slightly religious tone of this is not misplaced.) But, as the parallel with social capital suggests, if we think rather of emergent properties of systems we may move closer to the core meaning of whatever the concept of sustainability is trying to capture.

Innovation and learning: options

This leads directly into the final stage of our argument. In various places above (notably in discussions of disequilibrium and preference), we have suggested how attention to learning processes is implicated in some quite fundamental problems with neoclassical accounts of sustainability. However, we have opened up a deeper issue here: let us approach this obliquely by reverting back to our discussion of the economic model of sustainability-as-substitution. Apart from considerations of input substitution the other line of argument from those economists who are sanguine on issues of sustainability is to focus on questions of technical progress and its potential to relieve resource and environmental constraints. What is more, such technical progress is essential to sustainability if there is population growth. But with technical progress, rules of the Hartwick type become irrelevant: anything can happen depending on the extent and nature of technical progress.

Earlier regarded in much of the standard analysis of economic growth as exogenous, technical progress (sometimes tellingly referred to as 'manna from heaven') has increasingly become endogenised within growth models. Most notably, so-called neo-Schumpeterian models (such as those of Aghion & Howitt, 1998, drawing on Joseph Schumpeter's seminal work of the mid-twentieth century on innovation) suggest that sustainable development is feasible if the rate of technical progress is sufficient to maintain the return to capital above the rate at which society discounts the future. This is possible if innovation-generating sectors are less natural capital-intensive than other sectors, so that, as inputs are transferred in to them, overall natural capital dependency declines and productivity rises. This is a formalised version of the casual argument that modern technology, especially in information and communications technology, has opened up new prospects for sustainable development, sometimes described as a shift from an energy-based to an information-based or knowledge-based economy. Indeed, there may be an even stronger argument, which is that technical progress shows an induced bias in this direction as natural capital becomes scarcer. All this is very new and little analysed, let alone examined empirically.

This raises a number of issues. First, should we include 'knowledge' explicitly as a capital input, instead of assuming it is embodied in other inputs, physical, social and human? Much knowledge may not be like this. In some sense, it may exist independently of a specific material carrier. One well-known version of this argument is that once society has learnt how to do something, such as create an atomic bomb, we know that we can do it even if all bombs, the people who know how to make them and (possibly) even the blueprints cease to exist. And there are lots of more mundane examples. There is much work in progress on these issues, particularly in the work of national income accountants on the measurement of what they call 'intangibles'. (With reference to our preceding discussion, the valuation issues are horrendous.) What does this do to the way we categorise our capital inputs and thus to the ways in which we analyse sustainability if we adhere to some version of the multi-capital model?

Secondly, and relatedly, knowledge is clearly founded on learning processes. But what does this mean? There is an issue here of particular importance for sustainability. Successful innovation may be heavily path-dependent, in the sense that later innovations build on earlier ones and are often impossible without them. The downside of this is that there may be lock-in effects: some possible paths may be excluded. These are powerfully reinforced if there are system-wide effects which make it economically infeasible to backtrack down the path of innovation and start all over again. Consider for example the relationship between innovation in transport technology and patterns of urban development. This focusing may be problematic for two reasons. Considered narrowly, whole fields of innovation may be closed off since they cannot build on the learning built into a whole path of innovation. Considered more broadly, we may lose sight of, shall we say, alternative styles of living. (The transport example is germane here.) So, might there be tensions between the technical feasibility of pursuing sustainable paths of one sort or another, or more broadly of thinking about the meaning of what constitutes sustainable life experiences? For example, sustainability may be seen as dependent on successful innovation in improving the fuel efficiency of vehicles, whereas we have closed off the prospects of alternative, less vehicle-dependent lifestyles.

Let us restate this. The view of sustainability which we have mostly examined in this paper revolves around the notion of natural capital as one among several assets. The 'solution' to problems of sustainability is then seen to lie in society's ability to create these other sorts of asset in sufficient quantities to replace natural capital: this is the weak/strong sustainability issue. Alternative, but not mutually exclusive, is the ability to improve the productivity of society's assets: this is the innovation and technical progress argument, within which learning may be heavily implicated. The difficulty with this latter type of argument is that the learning—if it is to be effective in a rather narrow, productivity-enhancing sense, may itself tend to be rather path-dependent and narrowing.

A radically different view of sustainability is that it may be concerned with maintaining not capital assets in the usually understood sense, but in maintaining the *options*—as embedded in those assets—which society has to pursue alternative paths. Notice that not all paths can be kept open: that is just meaningless. The real issue is how and when we chose to foreclose on some options. What society acquires by keeping options open is not just the negative avoidance of bad outcomes but also the positive good of maintaining options for future learning as more information accrues.

Can we make this a little more precise? Environmental economists have long used the concept of a value which attaches to so-called *quasi-options* (Arrow & Fisher, 1974). A quasi-option arises when we are considering making an irreversible decision, say, the destruction of a unique ecosystem by dam construction. If we defer the decision, more information may emerge which will enable us to better value the outcome. We may learn more about the value of ecosystems or about alternatives for power generation. This is different from a straightforward option value which occurs when we are not sure if the ecosystem will be there or not and we are, in effect, prepared to pay an insurance premium to protect ourselves against the risk. Thus embedded in

quasi-options, as compared with simple options, is exactly what we are after: positive possibilities of learning. Quasi-option values are hard to estimate and usually regarded as something of a luxury add-on in environmental valuation studies. However, one way of thinking about the foregoing, large-scale, path-dependency issue is that they may be very significant, even dominating in macro-contexts.

We can be more radical still. If what really matters about 'natural capital'—and, as suggested above, much the same applies to social capital—is some sort of systemic property, then we are in to the domain of quite radical uncertainty (and not just calculable risks) about the possible losses and—as importantly—the potential gains from irreversible decisions. These systemic properties may be of two sorts. They may emerge from the complexity of the system, where that complexity is resistant to calculability, or they may be evolutionary possibilities which are resistant to forecasting. These suggest, even more strongly than the arguments developed throughout this paper, the limitations of the metaphor of society as holder of capital assets and the case for deployment of new metaphors built around society as holder of options which encompass much more open-ended learning possibilities. It remains an economic metaphor, but of a new sort.

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