The 'knowledge ecology' we need*

Are the core assumptions of the knowledge economy sustainable?

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Abstract

The notion of 'knowledge economy' is underpinned by questionable assumptions and its current unit of analysis (the abstract copy of an idea) leads to intellectual monopoly and to a substantial destruction of the knowledge embedded in the natural world. A governance of knowledge is imperative so that society does not hugely overvalue human innovation over natural-world innovation and in the process corrupt and destroy what is best of both. Critical thresholds or 'safe minimum standards' for both the intellectual asset base as well as the environmental asset base must be established and operationalised by economic science and other sciences.
A comprehensive reframing of the core assumptions and values of the knowledge economy is in order, away from monopoly in knowledge and perhaps more in line with the values of competition and cooperation observable in the 'knowledge ecology' of the natural world. For a governance of knowledge to happen society must use its institutions, governance capacity and creativity to replace its knowledge economy with a 'knowledge ecology'. A salient feature of a knowledge ecology in policy terms is the recognition that our real or imaginary dependencies on intellectual monopoly (wrongly called 'intellectual property') to generate innovation, profits, economic growth and prosperity need to be vigorously and comprehensively removed by politics. Perhaps rather immediately. Peoples and cultures across the globe are sending a rather clear and powerful message in the form of stated preferences and purchasing decisions regarding the present and future of intellectual monopoly. Such a message contains also important information about the future context of sustainability. Without a reciprocal vigorous transformation in politics and in business, it is very difficult to see how the knowledge economy may evolve in parallel with the natural world, with human culture as a whole, or indeed how its current institutions, businesses and employment structures will survive a transition, orderly or not, to sustainability.

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1. Introduction: problematic assumptions and policies

There has been much debate about the relationship between knowledge creation, human development and sustainability. The quality of this debate has been a function of the quality of assumptions being relied upon, which overall has been rather low. Consider the leading premise that knowledge, being the opposite of ignorance, is in essence, a *good* thing, e.g.

> 'Knowledge is like light, weightless and intangible, it can easily travel the world, enlightening the lives of people everywhere' (World Bank, 1999 p.1)

Assumptions carrying such degree of potential confusion between metaphorical and applicable terms have not only lowered the quality of the discussion about such things as the bio-physical impact of knowledge production, they have also been instrumental in setting up the economic agenda of sustainability. In such agenda it is often implied that only a 'dematerialized' knowledge economy will be able to drive the type of economic growth that will be required in the coming decades. Furthermore, the 'intangibility' attribute of knowledge is seen as the key that unlocks the gates to a low-carbon sustainable future. So much so, that today many influential textbooks of environmental economics teach university students to associate such things as 'resource dependency' with economic unsustainability; see for example (Pearce & Barbier, 2000).

The fact that current environmental crisis is rarely seen as partly a consequence of the mass deployment of knowledge since at least the beginning of the industrial revolution points at a curious omission in economic theory. The conferred attribute of 'light' to human knowledge at this point in history has apparently led many opinion leaders to forget that 'we can think of capital essentially as knowledge imposed on the material world' (Boulding, 1966, p. 5.); an imposition that is now widely recognised as unsustainable. All these issues together are a gentle reminder that a full reinterpretation of the terms of reference of the so-called knowledge economy is now as appropriate as it is inescapable.

The expression 'knowledge economy' can be regarded as a popularisation of the latest trends in economic growth thought, viz., so called 'new growth theory', 'post-neoclassical endogenous growth theory' or 'endogenous growth'. From such trends four problems seem to call for attention. The first problem is that 'endogenous economic growth theory' is mostly prescriptive and normative (i.e. how their authors would like things to be valued, typically 'in the twenty-first century') as opposed to descriptive and positive (i.e. why people value things the way they do). Although this sole fact suggests a

fundamental contradiction with the sustainability process, there are some extensive and powerful critiques available of the normative nature of the endogenous growth 'hypothesis' or proposition, purely from an economic science perspective (Solow, 2000)

The second problem is that in order to be prescriptive, endogenous growth hypothesis has had to rely on the assumption that ideas are expensive to produce and cheap to copy and exchange (Gowers, 2006, Grossman & Helpman, 1991, Romer, 1990). This assumption has led to the belief that in a knowledge economy and culture[1], it is legitimate to set the monetary price of cultural inputs at zero while enabling cultural outputs to command monopoly rents and prices in the marketplace via such things as intellectual property rights (IPR), contract law, TPS and TPM[2]. This belief, in turn, has crucially contributed to institutionalise the opinion —or perhaps unconscious impression— that accessing hugely undervalued environmental assets via the income generated by hugely overvalued intellectual assets may not only end up being innocuous to the environment but also absolutely necessary to achieve greater levels of economic, social and environmental sustainability[3].

Undervalued environmental assets —in relation to intellectual assets— are commonly the result of market and non-market valuation procedures via people's 'stated preferences' (frequently called 'contingent valuation techniques'). Meanwhile, overvalued intellectual assets —in relation to natural assets— are commonly the result of state-grated monopoly prices of intellectual assets in an economy. Figure 1 shows nine asset-valuation scenarios of intellectual and environmental assets combined plus the current situation represented in 'C', the knowledge economy's *toxic mix*, as inadvertently promoted today by institutions and business management 'gurus'.

[1] And indeed in a world economic system.

[2] Intellectual property rights and regimes are state-granted commercial monopolies over creations of the intellect. TPS and TPM mean 'Technical Protection Systems' and 'Technical Protection Measures' respectively.

[3] Most critics tend to use the case of international trade to explain this same misconception; often using 'the terms of trade' as unit of analysis, which only takes us halfway through a good understanding of the problem. E.g. Andersson, J.O. & Lindroth, M. (2001) Ecologically unsustainable trade, *Ecological Economics*, 37(1), pp. 113-122.

		INTELLECTUAL ASSETS Predominantly valued via:		
		Non-market pricing (stated preferences)	Market pricing	Monopoly pricing and rents
ENVIRONMENTAL ASSETS Predominantly valued via:	Non-market pricing (stated preferences)	A	B	C knowledge economy's 'toxic mix'
	Market pricing	D	E	F
	Monopoly pricing and rents	G	H	I

Figure 1 – Nine asset-valuation scenarios and 'C', knowledge economy's 'toxic mix'

The everyday reality of cultural exchange, as occurring in vigorous contemporary societies, strongly suggests that the core intuitive assumption that 'ideas are expensive to produce and cheap to copy and exchange' is empirically groundless, unscientific, rather esoteric, socially damaging and utterly unfit to guide economic policy (Boldrin & Levine, 2002). And yet, it has done so in ways that have seemingly set in motion, since at least the 1980's, changes in the way today's cultural and technological innovation ethos is perceived by the knowledge society[4]. So much so, that something resembling a subculture of knowledge has apparently emerged, periodically renewing its terminology in the form of commendatory expressions such as the advent of 'an era of post-scarcity', 'dematerialized wealth creation', 'weightless economic growth' and so on. In a more severe way, this subculture of knowledge has both, led to and coincided with, a third problem: the rather firmly held tenet that economic growth should and indeed could be *decoupled* from environmental impacts (OECD, 2006, OECD, 2008, World Bank, 2004); an assumption directly contradicting long-run historical analysis (coincidentally the one informing the Stern review on the economics of climate change) which attests strong positive correlations between GDP and energy consumption since the eighteenth century[5] (Figure 2) as explained by (Tooze & Warde, 2005 p.6)

[4] Consider for instance UK's Gower's review of Intellectual Property (2006)
[5] For the case of England and Wales throughout the industrial revolution.

Neither the long-run historical experience, nor the experience of the last thirty years provides any grounds for complacency. There is clearly room for loosening the coupling between economic growth, energy use and CO2 emissions. However, developments in this direction over the last century have been very modest when compared to the overall dynamic of economic growth and the associated increase in the productivity in other factors. The existing framework of private and public governance both at a national and international level has not produced change on the scale that would be necessary to allow continued expansion in the global economy to be reconciled with stabilizing, let alone, reducing CO2 output, certainly not in the medium term. To achieve that goal, will require actions that are quite literally without historical precedent.

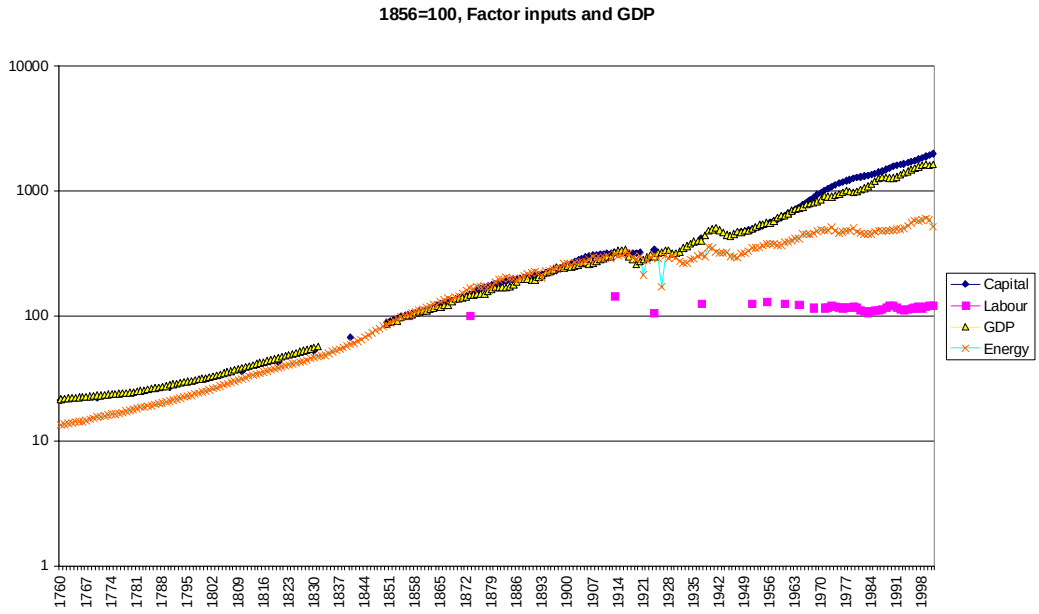

Figure 2 – Energy and GDP (alongside other factor inputs) Source: Warde 2008[6]

The decoupling imperative logic is associated with a fourth essential problem: that the knowledge economy is poised for unprecedented investments in clean technologies, wide-ranging creativity, the power of 'ideas' and the deployment of institutional and legal capabilities to protect and promote techno-efficient 'innovation' by enforcing longer and more stringent intellectual property regimes across sectors and across nations (Jacob, 2004). For this and other reasons the endogenous growth hypothesis and its assumptions have become controversial (Boldrin & Levine, 2008, Boyle, 1997, Cornish, 2004, Jacob, 2004, Kealey, 2008, Solow, 2000, The Royal Society, 2003). Are there alternatives to current understandings of the knowledge economy? In what follows some preliminary challenges to answer such a question will be outlined.

[6] Unpublished conference material

2. The 'sustainable knowledge' challenge

Key message: the commodification of knowledge may lead to a situation where techno-fix oriented research, hence efficient solutions, are privileged (at an opportunity cost) over effective ones that require individual and collective behavioural changes. Beyond normative theories of growth, a sustainable view of knowledge creation and valuation is required if science is to be sustainable and if sustainability is to be understood scientifically.

What type of knowledge is sustainable? What type of knowledge is not? Do these questions have an answer? Because a discussion on this topic could be endless, the criteria by which an SK definition is arrived at becomes crucial. A careful review of the literature on the SK concept consistently suggests the focus should be put on 'processes' rather than 'outcomes' (Murdoch & Clark, 1994). This means that, irrespective of conventional notions of objective science, our notion of SK should focus more on *how* knowledge develops rather than *what* specific content it develops. Presumably, that content would vary widely as attention to local phenomena and context-specific approaches to problem solving have been deemed fundamental to operationalising Sustainable Development.

The roots of the concept of 'sustainable knowledge' (SK) include works on the sociological critique of modernity, the politics and sociology of the environment, the history and sociology of science, the anthropology of science, they would also include, development studies, rural sociology and rural development, co-evolutionary economics, anthropology of economics, the philosophy of knowledge and power, environmental risk management, and green politics. A brief account of the written sources allows us to appreciate how wide and how far we can go exploring the implications of putting notions of 'knowledge' to the test of sustainability objectives.

The notion of SK is useful in describing the existence of an artificial but also real 'value gap' between scientific knowledge and local knowledge. It also helps us understand the gap between stakeholders in terms of the type of knowledge they hold in value the most. One type of knowledge operates 'scientifically' often striving for solutions that, ceteris paribus , seek to be 'efficient'. The other type of knowledge operates 'locally' but often seeking overall empirical effectiveness rather than specific technical efficiency. No empirical observation suggests local cannot be scientifically rigorous nor that scientifically rigorous knowledge cannot be based on the assessment of local phenomena (Murdoch & Clark, 1994). Additionally, no evidence points at the possibility of Sustainable Knowledge being elitist nor accessible to all. Economist Hayek, (Hayek, 1945) has noted that,

> 'The peculiar character of the problem of a rational economic order […] is a problem of the utilization of knowledge not given to anyone in its totality. This character of the fundamental problem has, I am afraid, been rather obscured than illuminated by many of the recent refinements of economic theory, particularly by many of the uses made of mathematics. (Hayek, 1945 p.520)

Evoking a similar issue many decades later though in a very different context the Millennium Ecosystem Assessment (MEA, 2005 p.6) is categorical in one of its final statements,

> 'Science can help ensure that decisions are made with the best available information, but ultimately the future of biodiversity will be determined by society'

A sustainable valuation of knowledge will very likely require us to 'hybridise' the theory, vocabulary and action of different stakeholders. 'Deconstructing' notions of science and rebuilding an idea of it in terms of sustainable development is not an easy task. Defining SK is equally, not a mechanic pin-pointed target but a learning process. (Murdoch & Clark, 1994, p.130)

> 'To speak of 'sustainable knowledge' is to begin to speak of the local and the general, the natural and the social, Western and non-Western cultures in the same breath. It is to begin to think of how bits from all these categories and more, might be combined in mixtures which lead to an enrichment and diversification of the natural/social worlds in which we live. We therefore need a new set of considerations in order to properly value these 'hybrid' worlds, for our present modes of valuation unfortunately rest upon the very distinctions which have brought us to our present impasse.'

In practice, a 'knowledge conflict' often unfolds like this: a community of stakeholders deems their own knowledge and experience relevant to the interpretation and solution of a given problem (often an environmental one). Simultaneously, a second group of stakeholders deems its own 'scientific' interpretation even more relevant to what appears to be the same problem (subsequent analyses often show they were focusing on different aspects of the problem). When the problem in question reaches critical levels, the need for prompt solution often precipitates the type of action whereby one group imposes its knowledge-values upon the other by some form of opportunism or coercion, either physical, legal, or both combined. The solution reached is often short-lived and untenable over the medium or long run. Typically, during such events natural resources and human infrastructure often become polluted or lost, sometimes temporarily, sometimes permanently. Meanwhile, people's perception of institutional authority often becomes diminished. The signs of an 'unsustainable' state of affairs become apparent and yet not all stakeholders may feel that a meaningful lesson can be drawn from the

experience. For that to happen it seems, their knowledge-values would have to go through the kind of unprecedented transformation they are not used to experience. If such transformation does not occur after many years, or after consecutive generations of people, and the problem turns bigger and more complex in nature, then perhaps a pattern of 'unsustainable knowledge' may be positively correlated to a pattern of 'unsustainable development'.

It is hardly a surprise that in a world historically threatened by the uncertainties of natural events, disease, warfare, and the uncertainty of life in general, an organised scientific community operating in the opposite direction from chaos and towards 'certainty' would be highly regarded by most societies. For a long time the acquisition of scientific knowledge has quite understandably fulfilled this historical need. Today however, localised situations such as the aforementioned, global climate change and other important intended and unintended drivers if sustainability, call for a significant transformation of scientific practice.

What seem now familiar expressions such as 'public engagement', public deliberation', 'stakeholder perceptions', 'governance', 'public understanding of science', 'science communication', are a direct manifestation of the need for SK approaches to environmental problems; this time at the level of institutions, and for a more heterogeneous and legitimate idea of knowledge.

However necessary, the division between natural and social sciences, is a modern artificial division that not only keeps people and people's knowledge separated but also reproduces fragmented social and environmental realities where there should be more actual integration. The concept of SK adds real substance not only to operationalised responses today, it also adds substance to our historical interpretations of how we became unsustainable through our understanding and production of knowledge in the first place.

For the aforementioned reasons, the commodification of science may lead indeed to a situation where techno-fix oriented research, hence efficient solutions, are privileged over effective ones that require individual behavioural changes through a different type of knowledge, sustainable knowledge.

3. The 'knowledge economy' challenge

Key message: choosing the wrong unit of analysis for an 'economics of knowledge' may lead to more intellectual monopoly, more overvaluation of intellectual assets, less ecologically-relevant innovation, hence reinforcing techno-fix views about environmental problems and solutions. The knowledge economy would benefit from emulating the values of competition and cooperation of a knowledge ecology as opposed to trying to extend the values of human intellectual monopoly.

Is the right unit of analysis to understand an 'economy of knowledge' being used today by institutions? How has economic theory gone about valuing and measuring knowledge during the last few decades? Because the word 'knowledge' is often labelled in dissimilar ways: information, data, skills, creativity, innovation, technology, know-how, wisdom, five distinctions become relevant to unpack the key aspects of the knowledge economy problem. Such distinctions are also vital to understand how intellectual assets become overvalued in relation to environmental assets, and how this overvaluation becomes institutionalised.

The **first** distinction is between the economic attributes of 'knowledge as input' and 'knowledge as output'. The consumption side in macroeconomics (i.e. output) has traditionally received less attention in the sustainability debate than the production side of it (i.e. inputs). This has resulted in a focus in how knowledge may contribute to economic growth rather than a focus on how this knowledge-based economic growth may contribute to resource use. Meanwhile, a reverse effect seems to characterise mainstream microeconomic valuation of knowledge, whereby knowledge tends to be valued in terms of its consumption rather than capital good attributes.

A book, for instance, is an output that can be read (i.e. 'consumed') but it can also be used as a capital good input (i.e. raw material) to produce other books. Four centuries ago John Milton (1608–1674) sourced *Paradise Lost*, primarily though not exclusively, from the Bible. Today, dominating 'endogenous growth theory' or hypothesis (Romer, 1990) generally omits the existence of this input-output-input circular dynamics in microeconomic valuation of knowledge and employs the omission to build an unduly reverenced general 'theory' of long-term macroeconomic growth (Boldrin & Levine, 2008, Romer, 1994, Solow, 2000)

A **second** relevant distinction is that between a theory of value and the process of valuation itself. Theories of value should have a different logic than the valuation made by market actors through 'preferences'. Some authors

suggest a theory should tell us something about why people value things the way they do, as opposed to how the authors would value them. In other words a theory of value should be positive/descriptive rather than normative/prescriptive (Hornborg, 1998). The message for economics seems to be that there is always a limit to what can be modelled, this limit has already been recognised for the case of neoclassical economics (not so for the case of 'endogenous growth hypothesis'). In the words of Solow,

> 'every area of economic theory will have to stop somewhere; it will rest on some exogenous elements. Some of those elements will be sociological in character, and some will even be economic. Physics may be able to contemplate a 'theory of everything' without smiling, but that will not be so of economics for as far as the eye can see, and maybe forever' (Solow, 2000 p.180-181)

The relevance of this, as far as knowledge valuation is concerned, is that there will always be elements that render knowledge valuable but which nevertheless cannot be determined or modelled with precision. So it is better not to pretend they can be or should be modelled. If attempts are made to model them (i.e. to 'endogenise' them in the way that Romer and others have tried to), the chances are those elements will be lost or misconstrued as opposed to adequately taken into account.

A **third** distinction relates to the difference between private and public goods. A public good in economics is a good that is non-rivalrous and non-excludable. A good is said to be non-rivalrous when the use or consumption of the good by someone does not reduce availability or preclude others from consuming it. Examples can be a sandy beach, air, a classic song, the use of a public road. A glass of milk and a flight ticket are both rivalrous because they can only be enjoyed by one person once.

A good is said to be excludable when it is possible to prevent people from enjoying its benefits. A good is non-excludable when no one can be effectively excluded from using it (e.g. breathing air, light from a lighthouse). All private goods such as food and cars are excludable. Between private and public goods there are other categories, such as goods that are non-rivalrous and simultaneously excludable, so called 'club goods' include cable television and most online contents.

Open-access goods, frequently associated with the 'tragedy of commons' scenario are those that combine the attributes of being rivalrous and non-excludable[7]. Table 1 represents an ordered array of goods according to their respective categories.

[7] As opposed to 'common goods' whereby the costs of exclusion and monitoring of property rights are high.

Table 1 – A taxonomy of public and private goods

	Excludable	Non-excludable
Non-rivalrous	**Club goods** cable television, online contents	**Public goods** public roads, a sandy beach national defence,
Rivalrous	**Private goods** food, clothing, toys, furniture, cars	**Open-access goods** (Tragedy of commons) fishing, grazing,

A **fourth** relevant distinction applies to competing notions of what is considered a correct unit of analysis in the 'economics of knowledge'. Some authors see 'the abstract copy of an idea' to be such unit (Romer, 1990) while others see 'the copy of an idea' as the correct and economically relevant unit of analysis (Boldrin & Levine, 2008 p.24) The first proposition considers ideas 'in abstraction' and as 'idealized goods that are not tied to any physical good' (Romer, 1990 p.75). The second proposition in contrast, is predicated on the assumption that ideas have a form of material expression, that is, typically 'copies of an idea' exist in physical form, such as a book, a chemical compound, a computer file or a piece of machinery. The environmental implications of choosing one or the other are considerable, especially in light of the following statement (Boldrin & Levine, 2008 p.156)

> 'Property in copies of ideas is good property, enhancing competition. Property in abstract copies of ideas is bad property, leading to monopoly'

From the perspective of the functioning of markets, according to the second view, only a copy of an idea which has a material expression, whether is the first or the hundredth copy, can be considered economically useful and therefore valuable. Contrary to what endogenous growth proponents suggest, copies of ideas are both rivalrous and excludable; they are not a public good. Both first and second propositions lead to different legal forms of protection of private property. To be protected, abstract copies of ideas require *intellectual monopoly rights* (IMR) and protection —wrongly referred to as 'intellectual property rights'—; meanwhile *genuine intellectual property rights* (GIP) conferrable to physical copies of ideas are secured by the ordinary laws against theft.

It is obvious that common economic wisdom about the economics of knowledge as is known and publicized today by powerful stakeholders, supports the first argument which leads to intellectual monopoly. However, it

is also necessary to bring in elements of scientific relevance to the debate. In this regard, the following statement is an example deserving systematic attention, (Boldrin & Levine, 2008 p.157)

> 'It is copies of ideas that have economic value. Copies of ideas should have the usual protection afforded to all kinds of property: they should not be taken away without permission, and the owner should have the legal right to sell them. However, intellectual property in the form of patents and copyrights is not about property rights in this sense. It is about the right to control other people's copies of ideas and by doing so establish a legal monopoly over all copies of an idea. Because it makes this fact transparent, we prefer the term intellectual monopoly to the usual term intellectual property'.

The confusion about the right unit of analysis for an economics of knowledge, insignificant as it might seem, has exacerbated the debate between those who think there are material limits to the economic process and those who do not (Sachs et al., 1998). Influencing this debate are the World Bank and the OECD, who point at the need for 'decoupling' economic growth from environmental impacts. Also influential yet severely criticised (Al-Ubaydli & Kealey, 2000, Boldrin & Levine, 2008, Solow, 2007) has been 'endogenous growth hypothesis'(Romer, 1990) which proposes an end to scarcity thought the long-run steady-state economic growth of an 'economy of ideas' (Romer, 2008). If the unit of analysis of wealth creation is considered as having no biophysical links with reality it is no surprise that their proponents will advocate a notion of 'unbound' economic growth. In contrast, if the unit of analysis is considered as having minimum links to the material world —as empirical reality happens to show— then a very different story is told, one where wealth has some physical impact.

To work, Romer's vision of endless growth through physically detached 'ideas' depends on a long chain of theoretical assumptions that serious economists including Nobel laureate Robert Solow (2000) have deemed too arbitrary to be considered serious economic science. Romer (2008) seems to envision a type of 'techno-ecological utopia' whereby natural ecosystems are eventually replaced, partially or totally, by the creativity of human proprietary 'designs' and innovations, all of which are driven by a technological change that arises from intentional investment decisions made by profit-maximizing agents and through intellectual monopoly power. Such techno-ecological utopia is made possible by choosing the abstract copy of an idea as unit of analysis of the knowledge economy. Romer seems to envision a type 'I' scenario in Figure 1.

At various points of his critique, Solow (2000) has referred to Romer's theoretical attempts to 'endogenise' growth in a long term steady-state model

as 'requiring Santa Claus assumptions' (p.105), 'a far from innocent knife-edge assumption […] one is asked to believe that one of the key parameters of this model just happens to be determined so that there can be steady endogenous growth' (p.163). At some point Solow describes Romer's growth rate premise as 'asking for a lot, […] actually asking for something much more special, more arbitrary than one might at first suspect' (p.100)

The economic and investment implications implied in Romer's principle that 'new ideas are expensive to create while cheap to copy' has been very influential in economics and indeed powerful in politics; to a point where it has become a subculture of knowledge or indeed an ideology. Most OECD countries have now adopted an economic model, in the case of the UK based in 'post-neoclassical endogenous growth theory' that promises economic growth based primarily on wealth generation thorough knowledge with benefits for the environment in the form of a 'dematerialized' type of development.

This in turn has seemed to reinforce the idea that 'decoupling' economic growth from environmental impacts is possible. It has also lead to the strengthening of intellectual property regimes and the subsequent reaction from the scientific community. The Royal Society has expressed concern on current Intellectual Property Regimes affecting scientific research, in the following way (The Royal Society, 2003 p.v.)

> 'Advances of technology and commercial forces have led to new IP legislation and case law that unreasonably and unnecessarily restrict freedom to access and to use information. This restriction of the commons in the main IP areas of patents, copyright and database right has changed the balance of rights and hampers scientific endeavour. In the interests of society, that balance must be rectified'

Less influential but still within the 'decoupling' debate, are those views advocating the 'de-linking' of welfare from consumption as a more realistic and essential objective for sustainability than attempting to 'de-link' economic output from resource use. However, some of the most interesting developments having the potential for even a more substantial contribution seem to have come from the 'economic and social fairness' rather than the global environmental sustainability debate.

Before we continue, let us stop for a moment and illustrate the workings of different units of analysis. Consider the six hypothetical 'statements of rights' provided in Table 2, whereby the attributes of both intellectual monopoly rights and genuine intellectual property rights are compared.

Table 2 – A comparison of six hypothetical 'statements of rights'. Genuine intellectual property rights versus intellectual monopoly rights.

UNIT OF ANALYSIS	ECO-FRIENDLY BATTERY	SOUND FILE	MODIFIED CARROT SEEDS
Abstract copy of an idea	The idea-patent of this battery technology and all the physical expressions embedding this idea	The idea-copyright of the song and all the physical expressions embedding this idea of the song	The idea-trademark-patent of this carrot seeds and all the physical expressions embedding it
Intellectual Monopoly Rights (IMR)	**1** "The proprietor of this patent has issued a time limited class 'A' licence to manufacture this battery technology. Unauthorised use or sharing of license information is strictly prohibited. Any such action establishes liability for a civil action and may give rise to criminal prosecution."	**2** "The proprietor of this file has licensed you a protected copy of this sound file. Unauthorised copying, editing, file sharing, use in public locations such as prisons, clubs, hospitals, airlines, oil rigs, schools is strictly prohibited. Any such action establishes liability for a civil action and may give rise to criminal prosecution."	**3** "The proprietor has licensed carrot seeds class 'A' for home growing and home consumption. Unauthorised sowing, crossing with other varieties, sale or growing in public locations such as gardens, allotments and schools is strictly prohibited. Any such action establishes liability for a civil action and may give rise to criminal prosecution."
Physical copy of an idea	An actual battery made with that eco-friendly technology	A recorded unit of the song in any physical format, including digital files	The carrot seeds themselves
Genuine Intellectual property rights (GIP)	**4** "The purchaser and now owner of this battery may freely: • Reverse engineer and improve its technology • Manufacture any amount of batteries and sell them • Resale or share technology with others • Advertise the green attributes of it • Other"	**5** "The work contained in this sound file should not be plagiarised. Its author should be acknowledged. However, by virtue of purchase the now proprietor of the file may freely • Play this file in public places • Share with others • Re-arrange the song, improve or borrow the ideas contained in it • Change the lyrics to suit a mood • Broadcast a version of it • Create mashups • Make copies of it and sell them • Encourage others to do the same and advertise the authorship of the file"	**6** "The purchaser and now owner of these seeds may freely, • Grow carrots anywhere • Turn them into juice • Grate them for salad • Turn them into sticks • Decorate a snowman • Make carrot cake • Make carrot soup • Draw the carrots • Take pictures of them • Cross the carrots with other varieties of carrots • Produce carrot-based telly characters, films and animations • Give them away • Other"

'The copy of an idea' as the economically relevant unit of analysis of an 'economics of knowledge' proposed by Boldrin and Levin (2008) is useful in that it opens up the cross-disciplinary possibility of establishing critical thresholds or 'safe minimum standards' in order to avoid both, intellectual asset overvaluation, and environmental asset undervaluation (as in the case of the 'toxic mix' of Figure 1). The category of safe minimum standard is closely related to other concepts such as 'critical natural capital' (Ekins, 2003), 'glue value' (Turner, 1992) and life support functions and processes.

Such safe minimum standards applicable to intellectual and environmental assets would need to be set up before both type of assets can be considered a form of capital and ultimately a source of sustainable economic growth. Policies aimed at removing intellectual monopoly seem a reasonably comprehensive first step to setting up the conditions for safe minimum standards in both intellectual and environmental assets. In some important respect, 'the physical copy of an idea' as the economically relevant unit of analysis of an 'economics of knowledge' is a fair and conciliatory proposition: it welcomes the (non-monopolistic) economic gains of ideas but without loosing the essential physical link that knowledge-led economic growth should be attributed with in relation to the biophysical aspects of sustainability. It may even come close to informing about the actual content of the 'co-evolutionary' type of sustainability indicator that some authors seem to have been looking for since at least a decade (Turner 1997).

As we have seen, some people imply, perhaps irresponsibly, that intellectual property over abstract ideas leading to intellectual monopoly is the way forward to a sustainable future (Romer, 1990) while others assume, perhaps correctly, that conventional property rights over physical copies of ideas are more likely to lead to fairer sustainable innovation via greater social surplus and greater welfare (Boldrin & Levine, 2008). One model asserts the link of ideas (as both inputs and outputs) to matter; the other denies this link while also diminishing the attributes of knowledge as a capital good.

If the notion of decoupling is to have any meaningful direction it must have a specific criteria from which to understand the input and output effects of intangible knowledge over tangible natural resources. It is clear that knowledge has a huge potential to optimise resource use, but no evidence suggests this potential can be boundless as implied by Romer but rather the contrary[8]. The notion of sustainable knowledge previously discussed suggests the attention should be focused on processes rather than outcomes (*how* as opposed to only *what* knowledge). From the point of view of processes,

[8] E.g. as many people often like to point out 'at the end of the day people don't eat ideas but food'.

critical thresholds or safe minimum standards regulating asset valuation seem more consistent with an ecologically relevant innovation process whereby the 'physical copy of an idea' is taken as the relevant unit of analysis and where social surpluses are not monopolised and environmental assets are not underpriced or destroyed.

At this point a **fifth** useful distinction is necessary. There are two identifiable styles of knowledge valuation, viz., the 'knowledge economy' valuation model and the 'knowledge ecology' valuation model. Both constitute competing, perhaps fundamentally opposed, characterisations of the knowledge innovation process as well. The innovation process in turn is important because it points at an acute need in economics but also in ecology and conservation and in the sustainable development process to look at things in terms of dynamic flows rather than stationary stocks. To make the aforementioned features more visible we need to compare the 'knowledge economy' and the 'knowledge ecology' valuations models side by side to appreciate the general assumptions that each model makes to arrive at a monetary valuation of assets. See Figure 3.

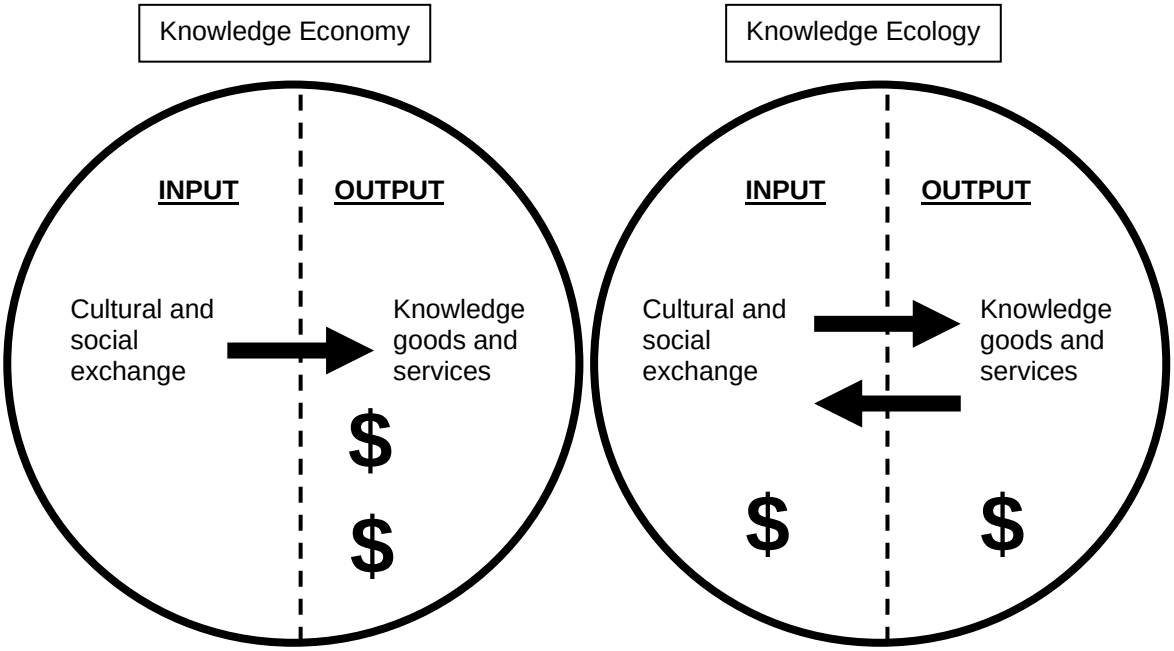

Figure 3 – Two valuation models, arrows representing transactions of copies of ideas.

The fundamental difference between these two models is that the 'knowledge economy' model considers the transactions of copies of ideas as fundamentally effortless or involving 'trivial costs' (Romer, 1990) while the 'knowledge ecology' model considers them to be often the product of deliberate and costly human effort (Boldrin & Levine, 2008, Solow, 2007).

All arrows in Figure 3 represent transactions of copies of ideas. Although we are using the knowledge ecology model (on the right) to represent what happens to intellectual assets in the absence of intellectual monopoly, note that such model explains also the innovation process as it occurs in the natural world for the case of environmental assets (i.e. ecosystem functions, processes and services). In a knowledge economy as represented by Romer, the incumbent monopolist tends to appropriate most or all social surplus whereas in the knowledge ecology model things are closer to being the way ecological processes work and there is an innovation process where inputs and outputs are not treated so differently in terms of economic valuation.

As a minimum condition for a balance to exist between the gains of the innovator and the social surplus that generates the culture where innovation takes place, intellectual monopoly needs to be removed. It has been suggested that the free exchange of ideas has been the keystone of innovation and that such has been the nature of innovation since the beginning of time. This includes the use of language and the construction of vocabulary, scientific discovery and technological development. The reality of cultural exchange from the point of view of economics is that knowledge has attributes of both consumption and capital goods and that copies of ideas as we have defined them are not public goods because they are rivalrous and excludable; this means they exhibit the attributes of private property without necessarily being formally so (e.g. a specialised book in a public library being read only by those few who have invested time educating themselves in the subject). Kealey (2008) for example, has explained in detail how science is a closed world by virtue of the existence of what he has called 'invisible colleges'. The acquisition of patents and copyrights so as to command monopoly prices is akin to asking society to pay twice for something it has already paid for once. The social harm being described is the source of unsustainability of intellectual monopoly regimes. Although in theory ideas are expensive to produce and cheap to copy, in practice knowledge is expensive to produce and expensive to access. In short, choosing the wrong unit of analysis for an 'economics of knowledge' may lead to less sustainability relevant science and innovation[9], more intellectual monopoly, less opportunities for meaningful behavioural changes, and ultimately to the reinforcement of views about environmental problems and solutions where techno-fix efficiency is frequently overvalued. Are there ecological consequences of such overvaluation? How can they be understood systematically?

[9] According to our notion that sustainable knowledge needs to focus its attention on *how* knowledge is developed rather than *what* knowledge is developed.

4. The 'knowledge ecology' challenge: fairness to the natural world

Key message: while we the human species do not have a de facto or de jure monopoly over knowledge we also produce a lot of knowledge that destroys the type of knowledge which is embedded in the evolution and everyday processes of the natural world. A shared unit of analysis between the knowledge economy and the knowledge ecology is 'the physical copy of an idea' analogous to 'a gene' in evolutionary biology. Both categories are crucially engaged to some form of physical embeddedness.

The 'copy of an idea' concept (Boldrin & Levine, 2006) is analogous to 'a gene' in evolutionary biology in that both units of analysis always manifest in practice some form of material expression or physical 'embeddedness'. Genes do not occur in abstract form or in the absence of physical embodiment. An analogous 'copy of an idea' for the case of intellectual assets suggests therefore the possibility of interdisciplinary applicability and potentially a shared unit of analysis between the knowledge economy and the knowledge ecology. Table 3 is a preliminary characterisation of both knowledge systems. As previously described, critics of mainstream valuations of knowledge such as Boldrin and Levine (2008) have pointed at what they have considered crucial misleading assumptions and errors which strongly resemble those equally criticised for the case of ecosystems services valuation (Turner et al., 1998). The most important aspects of ecosystem services (i.e. ecosystem structure, processes and functions) are also the most difficult to value with monetary and non-monetary techniques. Some critics within the economic profession cast doubts on whether the expectations of protecting life support systems will be fulfilled through economics, or at least with existing techniques of valuation.

There are powerful reasons to believe such critique could be extended in similar ways to the production and consumption cycle of both human and natural 'knowledge resources' manifested in the form of 'knowledge inputs' and 'knowledge outputs' both, intellectual and environmental. Because inputs of knowledge in economics suffer from systematic input 'de-valuation' or 'zero-valuation', most disciplinary sustainability indicators, such as 'genuine savings' (Hamilton et al., 1997, Pearce & Atkinson, 1993), are bound to produce false answers that are nevertheless internally consistent, therefore misleading. Inputs must be valued before they enter those equations that seek to measure sustainability (and also before they enter university textbooks). Similarly and beyond artificial attributes, an updated category of knowledge that includes the 'intrinsic' or 'embedded' knowledge that can be found in nature is required if such a category is to indicate genuine sustainability value and values.

Table 3 – The knowledge economy and the knowledge ecology: preliminary characterisations

	THE KNOWLEDGE ECONOMY (as known today)	**THE KNOWLEDGE ECOLOGY (we need)**
Promoted unit of analysis	The abstract copy of an idea (normative, detached from matter, only outputs have economic value)	The physical copy of an idea (Positive, linked to matter, inputs and outputs have economic value)
Promoted type of property rights	The right to control other people's copies of ideas via intellectual monopoly, creating other forms of monopoly of property in the process.	The right to private property (copies of ideas as property) but not the right to control and regulate how other people should use their intellectual property
Promoted property rights protection	So-called 'Intellectual Property rights'	The ordinary laws against theft.
Property rights might better be called	Intellectual monopoly rights and regimes (IMR)	Genuine intellectual property rights (GIP)
Traceability of physical impact of knowledge	Covert and made diffused and confusing by its unit of analysis	Made transparent and fairly identifiable by its unit of analysis
Intellectual assets mostly valued via	State granted monopoly pricing	Market and non-market mechanisms (people's stated preferences)
Environmental assets mostly valued via	Market and non-market mechanisms (except patented organisms which are able to command monopoly prices)	Market and non-market mechanisms (people's stated preferences)
Effects on trade	Leading to monopoly (Intellectual and physical)	Contributing to competition and cooperation in trade
Environmental costs of opportunity due to income-yielding attributes	The income-yielding monopoly attributes of intellectual assets overpower and destroy those of environmental assets	Income-yielding attributes of intellectual and environmental assets are aligned to competition and cooperation values, in practice and theory
Core assumption regarding the 'decoupling imperative'	Because profitable ideas can be disengaged from matter in theory, material impacts may be decoupled from economic growth in practice. (makes decoupling appear possible)	Knowledge-based economic wealth must be decoupled from intellectual monopoly if it is to foster sustainable employment and prosperity (makes unrealistic decoupling unnecessary)
Goal of economic theory often perceived as	To make intellectual monopolists as rich as possible so that they can invest in techno-fix efficiency and innovation upon which sustainability is believed to be conditioned	To provide the minimum conditions of fairness and functionality for sustainable development to happen in a knowledge-based economy and society
Sustainable innovation often perceived as	Sophisticated techno-fixes, sophisticated personal finances or sophisticated laws often replacing sophisticated user mentality, personal development, character and human dignity	Sophisticated techno efficient innovation is tempered with effective behavioural innovation and the nourishment of human character and dignity

Ecologists have recognised such a category of knowledge as 'knowledge embedded in the natural world' (Ehrlich et al., 1999), philosophers have identified it as 'knowledge as a naturally occurring phenomenon' (Kornblith, 2002); cognitive ethologists as 'animal cognition' and 'awareness' (Griffin, 1981). Interestingly, economists working in the management of pathogens in agriculture have factored into their equations 'innovation processes' that are carried out by our 'biological competitors' (Goeschl & Swanson, 2002). Institutions have not been indifferent to naturally occurring knowledge either; note that since 1972 the United Nations Scientific and Cultural Organisation (UNESCO) through its World Heritage Convention links together the concepts of *natural* and *cultural* heritage in order to produce its famous 'list' of world heritage sites. This seems to imply the institutional recognition of naturally occurring knowledge as constitutive of human heritage and culture.

If, on the one hand sustainability is understood as a co-evolutionary process that is driven by intentional and unintentional actions and events (e.g. climate change policy + climate change) and the idea of knowledge is assumed to involve skills and information gained over time —skills being the ability to do something; there is then no scientific reason in principle to assume that a sustainability-relevant category of knowledge is inextricably conditioned to human agency, consciousness or awareness. The 'human agency requirement' for our category of knowledge is broken by the sustainability imperative of co-evolution between humans and the rest of nature's evolution (Norgaard, 1984).

Meanwhile the 'human consciousness' requirement is at least weakened if not broken by what some authors have called the 'communitarian dimension of epistemology' or 'knowledge by agreement' (Kusch, 2002), whereby knowledge is primarily an unconscious attribute of groups rather than one belonging to a specific conscious individual. Natural evolution as well as the sustainability process, understood as a combination of 'the intentional plus the unintentional' maybe considered for the aforementioned reasons as a process that necessarily involves large amounts of knowledge embedded in the natural world without necessarily having to fulfil the anthropocentric requirement of 'self-consciousness of knowledge' or the presence of a human agent.

While we the human species do not have a *de facto* or *de jure* monopoly over knowledge, our current economic and ecological situation suggests we have been producing a lot of overpriced human knowledge that destroys the knowledge which is embedded in the evolution and everyday processes of the natural-world. This is done by allowing the income-yielding monopoly attributes of intellectual assets always overpower the costs of opportunity of

environmental assets whose income yielding attributes are conferred through stated preferences as opposed to monopoly. In such circumstances no investment in the environment is a reasonable one, the only exception being perhaps bleak and extremely dangerous scenario 'I' of Figure 1, which will not be explained here.

Paradoxically, the economic value of the natural world's knowledge is not only about the difficulties of valuing ecosystem functions and services but also about the difficulties of understanding the *overvaluation* of human knowledge output. To get a rough sense of what the problem is consider the following example: 'U.S. [Intellectual Monopoly][10] at the beginning of the twenty-first century is worth between $5 trillion and $5.5 trillion USD, equivalent to about 45 percent of U.S. GDP and greater than the GDP of any other nation in the world (Shapiro & Hassett, 2005 p.3) U.S. Ecological Footprint[11] in planet-equivalents is 5.3; that is, the number of Earths it would take to support humanity's ecological footprint if everyone had the average American lifestyle (Global-Footprint-Network, 2006). If these numbers are correct for the US economy and if the hermeneutic value of Ecological Footprint Analysis is to be believed, we can also calculate the 'Intellectual Footprint' of the US, measured by the Intellectual Monopoly content embedded in trillions of goods and services which represent, roughly, 2.38 planet overshot equivalents (5.3 x 45%)[12].

The overvaluation of intellectual assets is the result, amongst other things, of employing a unit of analysis that leads directly to intellectual monopoly. The evidence suggests that intellectual monopoly increases access to undervalued natural knowledge assets in an unfair and unsustainable manner. Mainstream economics tends to concentrate attention to outputs but not to inputs. In other words the relationship between such things a purchasing power and consumption is for the most part considered irrelevant. This points at an imbalance between the valuation of two types of knowledge and a governance of knowledge problem and challenge that needs to be addressed.

[10] Or so called 'Intellectual Property'

[11] www.footprintnetwork.org

[12] "Global overshoot occurs when humanity's demand on nature exceeds the biosphere's supply, or regenerative capacity". "Every individual and country's Ecological Footprint has a corresponding Planet Equivalent, or the number of Earths it would take to support humanity's Footprint if everyone lived like that individual or average citizen of a given country. It is the ratio of an individual's (or country's per capita) Footprint to the per capita biological capacity available on Earth (1.8 gha in 2003). In 2003, the world average Ecological Footprint of 2.23 gha equals 1.26 Planet Equivalents". Source: www.footprintnetwork.org

5. The 'governance of knowledge' challenge

Key message: the notion of 'knowledge economy' is underpinned by questionable assumptions and a destructive unit of analysis. Such notion has also become unhelpful (at least at the level of scientific enquiry) to understand competing meanings of the sustainable development process. A governance of knowledge able to accommodate different types of knowledge around a shared unit of analysis is imperative. This means society must use its institutions, organisational capacity and creativity to replace its knowledge economy with a knowledge ecology. Establishing critical thresholds or 'safe minimum standards' for both the intellectual asset base as well as the environmental asset base is at the heart of the knowledge ecology we need.

A 'governance of knowledge' is required to deal with coexisting types of knowledge and knowledge-valuation models and systems. More specifically, we need a knowledge ecology rather than a knowledge economy. The ability and underlying conditions to govern competing valuations and usages of knowledge is far from being a problem easily resolved with the current unit of analysis underpinning the knowledge economy. A new unit of analysis ought to be compatible between the intellectual asset base and the environmental asset base. That unit of analysis, we have been suggesting, is the 'physical copy of an idea'; a unit that is compatible with the analogous idea of 'a gene' existing in the natural world and which also exists only tied to some form of physical expression. The physical copy of an idea as a shared unit of analysis is conducive to competition and cooperation amongst innovators (both human and natural) as opposed to human intellectual monopoly.

If we are serious about tackling the current unsustainability of development, we need to apply different criteria to wealth creation as we understand it in a knowledge based economy. A wealth of empirical evidence around the world exhibited in the form of people's stated preferences regarding intellectual assets, suggests the knowledge economy's excessive dependency on intellectual monopoly is unsustainable culturally, environmentally and economically. The same evidence suggests the innovation process may have become corrupted. The physical copy of an idea as a unit of analysis of an 'economics of knowledge' is required if fairness, behavioural changes in individuals and sustainable innovation are to be achieved. A different reframing of the knowledge economy as we know it is required, perhaps more in line with the values of competition and cooperation observable in the natural world. This means our knowledge economy must move in the direction of a knowledge ecology so as to adopt its valuation processes. One

thing the evidence seems categorical about is the incompatibility between the sustainability of knowledge —human and natural— with monopoly in knowledge, or to be more precise with 'double monopoly in knowledge'. Monopolies occur naturally, when a species occupies a single niche for example, or when a wine merchant has a monopoly in a high street by being the only one. State-grated monopolies are an artificial invention like no other and they often duplicate the power of naturally occurring monopolies. As a result of this duplication of power, Intellectual Monopoly is indeed on its way to appropriate monopolise and transform the knowledge embedded in the natural world through the unprecedented convergence of nanotechnology, biotechnology, cognitive and information sciences.(The Royal Society, 2004).

The idea that property in physical copies of ideas is good property, enhancing competition while property in abstract copies of ideas is bad property because it leads to intellectual monopoly (Boldrin and Levin 2008) and environmental asset undervaluation and destruction suggests 'the physical copy of an idea should be taken as the correct unit of analysis of an 'economics of knowledge'. It also suggests the possibility of establishing critical limits for assets or safe minimum standards for both the environmental resource base and for the intellectual resource base so that society does not overvalue human innovation over natural-world innovation and in the process perhaps destroy what is best of both. To avoid the overvaluation of human innovation and intellectual assets over natural-world innovation and environmental assets, it has been argued, a new governance of knowledge is required whereby politics and the law allow society at large to use its institutions, organisational capacity and creativity to replace its knowledge economy with a knowledge ecology. Only then a governance of knowledge may become possible in the foreseeable future.

6. Conclusion

To question economic growth —or trade for that matter— in the name of sustainability, as many still do, is unhelpful for three reasons. First, sustainability will be either the result of a co-evolutionary process between humans and the natural world or it simply will not be anything (Norgaard 1994). Second, irrespective of grassroots developments, macroeconomic growth presents itself as a co-evolutionary imperative for humanity to approach international obligations such as Kyoto and the Millennium Development Goals (World Bank 2003); goals from which there is no intelligent or desirable escape. Third, the quantitative target of economic growth is conditional upon qualitative targets being met, especially in the less developed regions, in order to 'leapfrog' the same industrialisation path that

has led to current global environmental crisis (WCED 1987). This means a window has been left open for fundamental changes in the way the use of growth is envisioned, not technically but politically. The political path however is paved with practical inconsistencies, such as how to turn the 'decoupling imperative' into meaningful long-term interventions.

Historical analyses suggest the 'decoupling imperative' makes sense politically but not technically (Tooze & Warde 2005). The illusion that decoupling is achievable is the result of convergent needs and promises; and if a spade is to be called a spade, between the acute need of political leaders to announce that economic growth is coming with the opportunistic emergence of an esoteric proposal about how human exchange and wealth creation should happen 'endogenously' in a culture (Solow 2000). Because such a proposal is not people-based but special interests-based, the political capital gained through 'decoupling' mandates and strategies may be bound to encounter its limits sooner than expected. In fact, this political capital seems vastly offset already by the high opportunity costs of not acting promptly in the face of overwhelming empirical evidence about how the knowledge economy really works. Such evidence is already available for most nations in the form of 'stated preferences' and individual 'willingness to pay' for intellectual assets as opposed to the legally imposed 'need to accept' intellectual monopoly prices in such things as pharmaceuticals, educational materials, financial instruments, agricultural inputs, automobiles, computer software and even entertainment.

Such a wealth of evidence seems to point in one consistent direction for a governance process for the knowledge economy that seems very different from the one guided by policy today. What apparently needs to happen is not a major decoupling between physical environmental impact and weightless, disengaged profitable 'ideas' but a major decoupling between macroeconomic growth and the perceived dependency of business on Intellectual Monopoly to generate profits. It would also help the sustainability process to decouple intelligent realistic alternatives from irresponsible economic ideology.

Today more than ever, 'it is not the goal of economic efficiency to make intellectual monopolists as rich as possible, in fact it is rather the opposite' (Boldrin & Levin 2008 p. 128). Put in a different way, to decouple economic growth from environmental impacts is akin to decoupling economic outputs from inputs and then declare that because the world has now a resource problem, this mental exercise should now have legitimate applicability in reality. Consider a rough example. In 2009 professional consultants have estimated the brand value of Cola-Cola Company to represent more than 50%

of its total market value[13]. Is this a reason to reliably believe the company has now managed to 'decouple' 50% of its value from causing environmental impact? Should the future of a national economy or region be envisioned with the same managerial style? Could the cost of being wrong be estimated by anyone? Though this might seem to some people like a good way to do politics, a governance of sustainability seems to require very different propositions.

Whatever the alleged contributions of intellectual monopoly rights to redefine environmental problems to fit techno-efficient commercial solutions[14], more crucially, in what seems a rather risky historical experiment with the use of the law as it affects the use of nature and the abuse of culture, intellectual monopoly inadvertently enables societies to dramatically increase the uneven exchange between highly overvalued intellectual assets and highly undervalued environmental assets. Such a problem has been ubiquitous in the north for some time now and is rapidly emerging in the south as the century develops[15]. Although the results for the global sustainability process are covertly devastating, the policy dimensions of the problem are not at all irreversible. From a free market and free trade perspectives a governance policy alternative has indeed emerged.

If human-generated wealth and innovation is to co-evolve with the wealth and innovation generated by the natural world, and if the inputs and outputs of the knowledge economy are to be consistent with a socially inclusive sustainability process, a minimum trade-off must be allowed to happen. Rather than a knowledge economy we need a 'knowledge ecology' whereby it is recognised that our real or imaginary dependencies on intellectual monopoly to generate innovation, profits, economic growth and prosperity need to be vigorously and comprehensively removed by politics. Peoples and cultures across the globe are sending a rather clear and powerful message in the form of stated preferences and purchasing decisions regarding the present and future of intellectual monopoly. Such message contains also important information about the future context of sustainability. Without a reciprocal vigorous transformation in politics and in business, it is very difficult to see how the knowledge economy may evolve in parallel with the natural world, with human culture as a whole, or indeed how its current institutions, businesses and employment structures will survive a transition, orderly or not, to sustainability.

[13] Jasmine Montgomery, UK Managing Director of Future Brand, BBC Radio Four 'The bottom line' 28/Feb/2009
[14] A feature governments and the scientific community in particular may have to be very concerned about indeed.
[15] Not without the opposition of a majority of people who do not see the benefits of it.

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REFERENCES

Al-Ubaydli, O. & Kealey, T. (2000) Endogenous Growth Theory: A Critique, *Economic Affairs*, 20(3), pp. 10-13.

Andersson, J.O. & Lindroth, M. (2001) Ecologically unsustainable trade, *Ecological Economics*, 37(1), pp. 113-122.

Boldrin, M. & Levine, D. (2002) The Case against Intellectual Property, *The American Economic Review*, 92(2), pp. 209-212.

Boldrin, M. & Levine, D. (2008) *Against Intellectual Monopoly* Cambridge University Press).

Boldrin, M. & Levine, D.K. (2006) Globalization, intellectual property, and economic prosperity, *Spanish Economic Review*, 8(1), pp. 23-34.

Boulding, K.E. (1966) The Economics of Knowledge and the Knowledge of Economics, *The American Economic Review*, 56(1/2), pp. 1-13.

Boyle, J. (1997) A Politics of Intellectual Property: Environmentalism for the Net?, *Duke Law Journal*, 47(1), pp. 87-116.

Cornish, W.R. (2004) *Intellectual property: omnipresent, distracting, irrelevant?* Oxford University Press).

Ehrlich, P.R., Wolff, G., Daily, G.C., Hughes, J.B., Daily, S., Dalton, M. & Goulder, L. (1999) Knowledge and the environment, *Ecological Economics*, 30(2), pp. 267-284.

Ekins, P. (2003) Identifying critical natural capital: Conclusions about critical natural capital, *Ecological Economics*, 44(2-3), pp. 277-292.

Global-Footprint-Network (2006) Global Footprint and Biocapacity (2006 Edition) Online Data File http://www.footprintnetwork.org/).

Goeschl, T. & Swanson, T. (2002) On the economic limits to technological potential: will industry resolve the resistance problem?, in: T.M. Swanson (Ed) *The Economics of Managing Biotechnologies* Kluwer Academic Publishers).

Gowers, A. (2006) Gowers Review of Intellectual Property. HM Treasury UK).

Griffin, D.R. (1981) *The question of animal awareness* Rockefeller Univ. Pr.).

Grossman, G.M. & Helpman, E. (1991) Innovation and Growth in the Global Economy [M]Cambridge, MA: MIT Press).

Hamilton, K., Atkinson, G., Pearce, D.W. & Centre for Social and Economic Research on the Global, E. (1997) Genuine Savings as an Indicator of SustainabilityCentre for Social and Economic Research on the Global Environment).

Hayek, F.A. (1945) The Use of Knowledge in Society, *The American Economic Review*, 35(4), pp. 519-530.

Jacob, R. (2004) Intellectual Property in the New Millennium *Inaugural lecture by Sir Robin Jacob on the occasion of the launch of SCRIPT* Centre for Intellectual Property and Technology Law. The University of Edinburgh).

Kealey, T. (2008) *Sex, Science and Profits: how people evolved to make money* Vintage Books).

Kornblith, H. (2002) *Knowledge and Its Place in Nature* Oxford University Press, USA).

Kusch, M. (2002) *Knowledge by agreement: The programme of communitarian epistemology* Oxford University Press).

MEA (2005) *Millennium Ecosystem Assessment: Ecosystems and Human Well-Being: Global Assessment Reports. Island Press, Washington, DC*

Murdoch, J. & Clark, J. (1994) Sustainable knowledge, *Geoforum*, 25(2), pp. 115-132.

Norgaard, R.B. (1984) Coevolutionary Development Potential, *Land Economics*, 60(2), pp. 160-173.

OECD (2006) *Decoupling the Environmental Impacts of Transport from Economic Growth* OECD Publishing).

OECD (2008) *Environmental Outlook to 2030* OECD Publishing).

Pearce, D.W. & Atkinson, G.D. (1993) Capital theory and the measurement of sustainable development: an indicator of "weak" sustainability, *Ecological Economics*, 8(2), pp. 103-108.

Pearce, D.W. & Barbier, E. (2000) *Blueprint for a Sustainable Economy* Earthscan Publications).

Romer, P.M. (1990) Endogenous Technological Change, *Journal of Political Economy*, 98(S5), pp. 71.

Romer, P.M. (1994) The Origins of Endogenous Growth, *JOURNAL OF ECONOMIC PERSPECTIVES*, 8, pp. 3-3.

Romer, P.M. (2008) Economic Growth in: a. Library of economics and liberty (online (Ed) *http://www.econlib.org/cgi-bin/printcee.pl*

Shapiro, R.J. & Hassett, K.A. (2005) The Economic Value of Intellectual Property - Online Report USA for Innovation).

Solow, R.M. (2000) *Growth Theory: An Exposition* Oxford University Press).

Solow, R.M. (2007) The last 50 years in growth theory and the next 10, *Oxford Review of Economic Policy*, 23(1), pp. 3-3.

The-Royal-Society (2003) Keeping science open: the effects of Intellectual property policy on the conduct of science

The-Royal-Society (2004) Nanoscience and nanotechnologies: opportunities and uncertainties in: A. Dowling, R. Clift, N. Grobert, D. Hutton, R. Oliver, O. O'neill, J. Pethica, N. Pidgeon, J. Porritt & J. Ryan (Eds) *The Royal Society & The Royal Academy of Engineering Report*

Tooze, A. & Warde, P. (2005) A long run historical perspective on the prospects for uncoupling economic growth and CO 2 emissions, *Submission to the Stern Review, December*.

Turner, R.K. (1992) Speculations on Weak and Strong Sustainability. (Working paper). Centre for Social and Economic Research on the Global Environment (CSERGE). University of East Anglia).

Turner, R.K. (1997) Georgescu-Roegen versus Solow/Stiglitz: a pluralistic and interdisciplinary perspective
Ecological Economics, 22(3), pp. 299-302.

Turner, R.K., Adger, W.N. & Brouwer, R. (1998) Ecosystem services value, research needs, and policy relevance: a commentary, *Ecological Economics*, 25(1), pp. 61-65.

World-Bank (1999) Wold Development Report on Knowledge for Development

World-Bank (2004) *Responsible Growth for the New Millennium: Integrating Society Ecology, and the Economy*