Environmental impact of e-commerce and other sustainability implications of the information economy

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Technologies at the close of the 20th century are a very different breed compared to technologies past, as they move inexorably toward the very core of fundamental knowledge – quantum mechanics driving semiconductors, nanotechnology driving materials and manufacturing, optics driving communications, genomics driving biotechnologies, etc. Significant advances nowadays are those made at the "bottom" – molecular and atomic levels. The results are an explosive growth of knowledge and the ways in which we use the newfound knowledge.

While new and rapidly advancing knowledge will be sure to become a dominant force shaping the future of mankind, experience tells us that advancing technology always bring side-effects. In the euphoria over the unprecedented opportunities brought on by the advent of the information economy, the tendencies are to overlook these side-effects, or simply to dismiss them so they wouldn't spoil the fun. But they are there. Lets look at the environmental impact of e-commerce, for example.

ENVIRONMENTAL IMPACT OF E-COMMERCE

It is hard to imaging the "environmental impact" of e-commerce. After all, it doesn't emit any pollutants or uses much energy and natural resources. It would also be hard to imagine it connected to the now familiar topics of sustainability such as climate change, and biodiversity and habitat losses. But their environmental impacts are there. And the impacts are not only significant, their nature and magnitude are such that the ways to resolve them are by no means evident or familiar to us.

We should be mindful about e-commerce for it is by far the biggest "killer app" of the digital revolution, if for nothing else. In the next four to five years, depending on which market research organization you believe, the size of business-to-business (B2B) e-commerce will grow anywhere from 100 to 1,000 times to 1.3 to 12.5 trillion US dollars, dwarfing the more familiar business-to-consumer (B2C) kind by at least a factor of 10. Looking further out, by 2010, it will likely grow to account for half of all commerce. What's happening here is nothing short of a mass migration of the world's buying and selling from their existing physical and material-based "universe" to a virtual parallel universe, and all of what has been happening with the advances in semiconductors, telecommunications, PCs, the Internet, etc. are like just things that set the stage for this migration.

What is e-commerce anyway? A most common definition is “the buying and selling of products and services over the Internet or other electronic networks”. It promises to make buying and selling a lot more efficient, and considerably cheaper. Figure 1 depicts how it works. The left-hand side of the graph is the traditional way – when a product left the hands of its maker, it goes through a number of layers of intermediaries, like brokers, wholesalers, distributors, retailers or franchises, before it finally reaches the buyers. The markup through this “intermediation process” ranges typically from 200 to 500 percent.

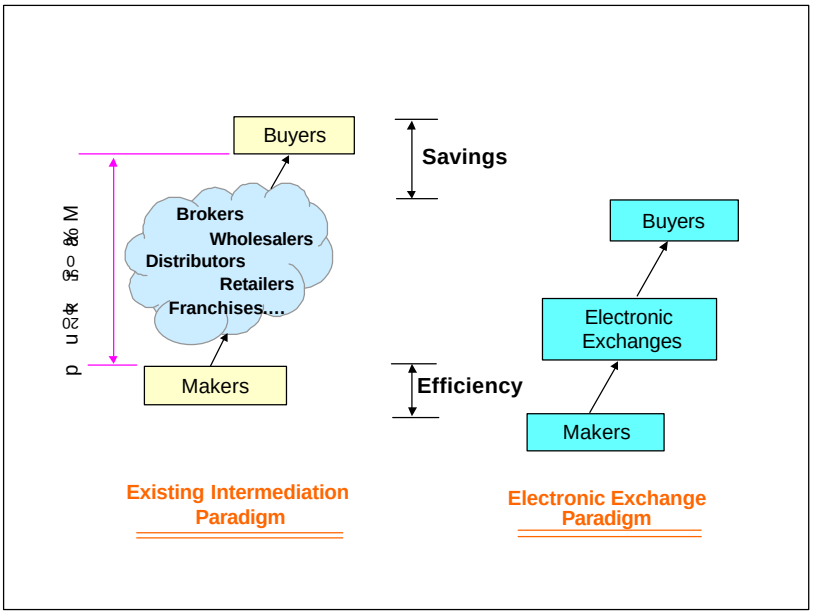

Figure 1: Buying and selling paradigms: old and new

The fundamental changes e-commerce is bringing to this traditional buying and selling paradigm are two-fold. One, much of what we buy and sell will take place over electronic portals and exchanges where information is now available instantaneously and transparently. The result is a much compressed intermediation process and much reduced costs. Two, prices coming out of the makers will also be reduced significantly because the transparency and seamlessness of information flows dictates that prices are now determined dynamically through the process of online bidding and auctions. These two effects will combine to bring product prices down substantially, and this is why e-commerce is such a big, big deal. Furthermore, these cost-down effects are by no means just theories anymore. They are happening right before our eyes. General Electric’s Lighting Business Group, for example, found that using the GE TradeWeb reduced its procurement costs by 30 percent. An experiment carried out at FreeMarket.com, an Internet trading hub, showed that over a one-day period, plastic auto-parts originally

priced at $ 6.2 million actually traded for only $ 4.6 million [1].

Now, if buying and selling are becoming a lot faster and a lot cheaper because of e-commerce, then what's going to happen to the underlying driving force for our sustainability problems – the demand and consumption of materials and natural resources? The answer is obvious. As prices fall, demand and consumption will rise. This is elementary economics. And with accelerating consumption of natural resources, our sustainability just spirals downward that much faster.

Environmentalists have always looked upon "internalizing the environmental externalities" as the ultimate solution to the sustainability problems we face – the premise being increased costs due to the internalization of environmental externalities would raise prices and therefore reduce the demand and the consumption of materials and natural resources. What's happening with e-commerce will be just the opposite (you may want to call the effect "externalization of internalities"), and judging from its unparalleled momentum as an economic force, the effects will be simply overwhelming.

In fact, not only is it likely that Internet commerce will bring down prices and boost consumption, the very contents of electronic trading are also on the shift toward the more material-intensive. Table 1 shows the trends of volumes traded electronically for different product categories for the year 1999 and those projected for 2004. For the year 1999, material-light computers and peripherals accounted for more than half of all electronic trades. This is reasonable because industries most plugged-in to the information economy would naturally undergo the transition first. The picture, however, will change drastically in the next few years. By 2004, computers and peripheral, trading at 20 times 1999 volume, would nonetheless slip to number 5 on the list, accounting for less than 10 percent of the total, while trading volumes for the very material-intensive products such as food, industrial supplies, chemicals, plastics, paper products will all grow a lot faster and become the main contents of Internet trades [2].

So this will be the situation – while environmentalists eke out whatever little advances in government taxation and economic incentive policies to internalize environmental externalities, e-commerce – the ultimate magnet for mankind's brightest innovations and the largest wealth generating machine mankind ever invented, is actually pulling things in the opposite direction. It is shaping up to be a mismatch of epic proportions.

B2B VOLUMES

	1999		2004	
SECTORS	10^9	RANKING	10^9	RANKING
FOOD PRODUCTION & PROCESSING	0.79	3	320	1
INDUSTRIAL SUPPLIES	0.72	4	220	2
PAPER, PLASTCS & TEXTILES	0.12	7	160	3
CHEMICALS	0.62	5	141	4
COMPUTERS & PERIPHERALS	5.52	1	95	5
MINING & METALS	0.89	2	71	7
PACKAGED SOFTWARE	0.25	6	13	13
TOTAL B2B	9.27		1,313	

Table 1: Internet trading trends (1999 and 2004)

WHAT CONSTITUTES SUSTAINABILITY?

I have participated in quite a few discussions on the topic of "technology and sustainability" at both technological and environmental gatherings, and have always gotten a lot of interests for these views on the environmental impact of e-commerce. Most of the responses have been: "Yeah. It is obvious to me now. How come I never thought about it this way before?"

The reason we didn't think about it this way before is because, in spite of the fact sustainable development was supposed to integrate environmental and developmental considerations, conventional environmentalism has largely stayed within the environmental confines and rarely ventured out to the developmental aspects of things. When we think about sustainable development, we seemed automatically to focus right away on "consequences" such as climate change, losses of biodiversity, rain forests and top soils, etc., without ever really addressing their "causes". The causes are to be found over at the developmental end of things. Lets look at Figure 2.

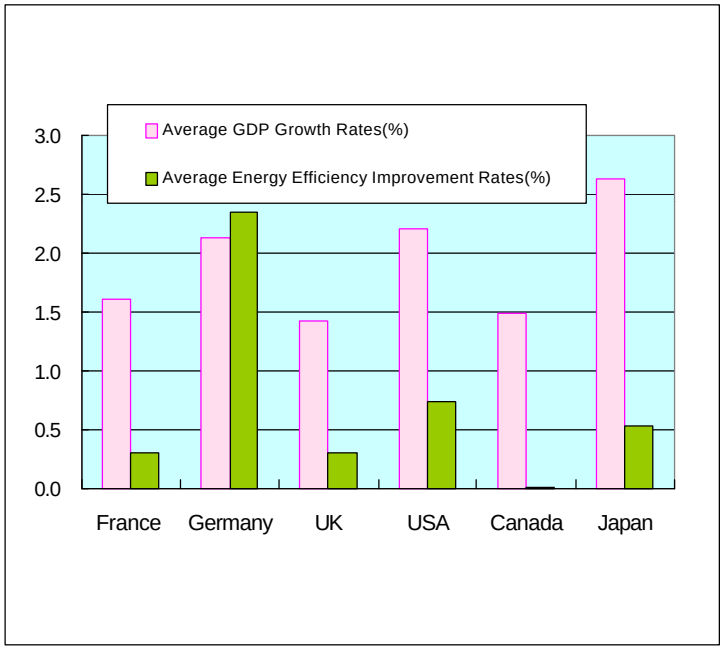

Figure 2: Average economic growth rates and energy efficiency improvement rates for six OECD economies between the year 1990 and 1997

The bars in this graph are average annual economic growth rates and energy efficiency improvement rates for six OECD countries between the year 1990 and 1997 [3]. The point here is that if the growth bars and the efficiency bars are the same heights, then growth would take place with no extra energy consumption. If we keep this up for many years, our wealth and, supposedly, our wellbeing will grow substantially while energy use would remain the same as year one. That is sustainability, or as close as we will come to it. Well, the bars in Figure 2 are, of course, not the same heights (Germany's was an abnormal case brought on by reunification). In fact, the efficiency bars are almost always far short of the growth bars.

If you want to get a feel of the fundamental dynamics of sustainable development, you really don't need to go any further than this graph. The persistent gaps between our economic growth rates and material intensity improvement rates are the root causes of our sustainability problems (energy is but one category in the many "materials" or natural resources). At the present rates (3 percent growth, less than 0.5 percent efficiency improvement), our energy consumption will grow more than 10 times in the next 100

years. And that's just the next 100 years. In 200 years, we will need to consume 100 times the energy we use now. We clearly cannot go on like this. That's why we call sustainable development "sustainable" development.

What constitutes sustainability anyway? If you begin with the consequences, it gets complicated very quickly and you are very quickly mired in the details. However, if you begin with the causes, it becomes very simple – sustainability is reached when we have:

dematerialization rate = growth rate

Here the word "dematerialization" stands for the reduction of the consumption of "materials" (energy, water, land, forests, minerals, etc.) in each unit of economic output.

This should be plain to understand. As long as we dematerialize at a rate slower than our economic growth rate, or in other words if we run a "dematerialization deficit", our sustainability problems can only accumulate and get worse. The only way to stop it is to erase the deficit. The equation pretty much sums up Herman Daly's "steady state economics" too [4].

Besides being a criterion, the equation serves another purpose sustainable development sorely needs – it quantifies the "size" of the challenges we need to overcome to reach sustainability. Not knowing the size of our tasks is like an architect not knowing the size of the building he was supposed to design and build. How can he even begin planning for it? The equation says for sustainability to happen, we will have to accomplish two things. First, we must accelerate dematerialization (in the case of energy, at least several-fold) so that it catches up with growth. Furthermore, once we are up there, we need to keep going at that kind of speed year after year … until forever. That's the size of our sustainability challenges.

The equation also makes monitoring our sustainability easy. At the end of each year, check you dematerialization and growth data. That's all it takes. If the gap narrows, we are making progress. If not, we are not. It works at the company level. It works at the country level. It works at the world level too.

ENVIRONMENT/DEVELOPMENT INTERFACES

Linking dematerialization and growth is fundamental if we are to plot a way to eventually implement sustainability. Although dematerialization is not a new concept [5 - 9], we are nevertheless liable to draw very wrong conclusion if we don't understand that dematerialization performances should always be measured against growth effects in sustainability considerations. I will give a few examples:

Is Technology Good or Bad for Sustainability?

People in sustainable development tend to talk one moment about the ravages brought by technology, and the next about how we will all be saved by new technologies. Is technology good or bad for our sustainability anyway?

We pin a lot of hope on new technologies because they almost always dematerializes. A part of our evolution has always been to become more efficient, to use less and less energy and materials to produce more and more goods and services. Historically, each new generation of technologies has also been, by and large, more efficient and less material intensive. Now, if technological progress basically dematerializes, how come the results it brought on the environment were so bad? This is the typical growth vs. dematerialization situation. Technology by itself is not bad. The trouble is that new technologies are always created mainly for growth reasons and, therefore, has always done a lot more for the growth side of the equation than the dematerialization side. And that's how it became such a killer as far as sustainability is concerned. Knowing this, we probably shouldn't regard information age technologies any differently, at least until rigorous investigations on their direct and indirect effects would indeed prove them different.

Is the Annual One- Percent Energy Efficiency Improvement Rate a Positive Sign?

It is almost standard practice now for a certain school of thinkers in sustainable development to cite the fact that our energy intensity has been improving by about an average of one-percent a year since the 1800's as the sign we are moving continuously on a positive course. This cannot be more wrong. Not only is this not a sign of improvement, the fact that energy efficiency gains have consistently been far outpaced by the growth rates of our economic activities, and therefore the increases in the demands and

consumption of energy, is the very cause we are in such a lot of climate change troubles now.

Why is One- Percent Dematerialization Hard, While 5-Percent Easy?

While OECD economies are struggling to get their dematerialization rates up to one-percent (Figure 2), China has gotten to 5 percent easily (Figure 3) [3]. Why? Dematerialization, if we understand its inner workings, are actually dependent upon

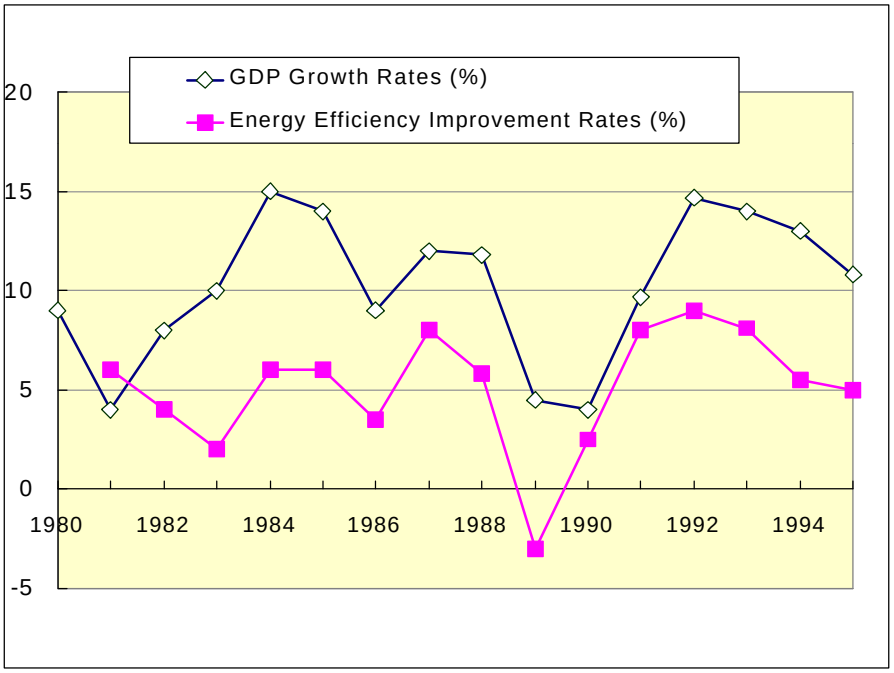

Figure 3: Variations in economic growth rates and energy efficiency improvement rates for China (1980 - 1995)

growth performances. When growth is robust, capacities are better utilized and efficiency improves. The key is in the "deficits" between the rates of dematerialization and growth. When China's dematerialization rates hit 5 percent, its growth rates were actually hitting 10 percent. Is China contributing more to global sustainability now that its dematerialization performance is way up? Of course not. It runs a much larger dematerialization deficit, and that's what counts as far as sustainability is concerned, not dematerialization itself. So watch the deficit, dematerialization by itself often send just the opposite signals.

WHY IS THE INFORMATION ECONOMY SO IMPORTANT TO SUSTAINABLE DEVELOPMENT?

When people in sustainable development think about “actions”, their thoughts are usually centered around things like efficiency, cleaner production, recycling, industrial ecology, etc. For the sake of simplicity, I will group them all together and call it “conventional dematerialization”. These measures are the most effective and least costly weapons at our disposal now for our fights to reach sustainability, and should be the first things we focus our attentions and resources on. They have, however, a fundamental problem. By themselves, they are not enough for us to win the war for sustainability. Lets look at some numbers.

The Electric Power Research Institute (EPRI) of the United States has estimated that we have a reserve of technologies that would improve energy efficiency by 24 to 44 percent [10]. If we go at our present rate of efficiency improvement, which is less than 0.5 percent a year (Figure 2), 44 percent would last us for more than 70 years. That’s kind of like “forever”, and at this kind of speed and time scale there also is no reason to worry whether technological advances would always stay ahead of our efficiency needs or not.

Now, lets look at what happens when we start to improve our efficiency at a rate equal to our growth rate as required by the criterion to stay sustainable, which is about 3 percent now. At this rate, we will blitz through those 44 percent in 12 short years. Furthermore, in another 12 years we are going to need a brand-new 44 percent. In 100 years, we are going to need something like 2,000 percent. And that’s just the next 100 years. Would technology advances be able to keep up? No.

In fact, if information technologies are going at “Internet speed”, most conventional dematerialization technologies would give you the impression they are going at “glacial” speed. We are almost 30 years from our first energy crisis now and renewable energy has made such little headways, that even with heavy, heavy incentives and government subsidies, they are still a minor and symbolic part of our overall primary energy supply, and will most likely remain so for a long time to come. Outside of nuclear fusion which may become commercially viable in perhaps 50 to 100 years, there are no viable alternatives to fossil fuels remotely in sight.

If all of our conventional dematerialization resources add up to less than what we need to

reach sustainability, then where are we to find that certain something that would put us over the top? The right-hand side of the equation, of course. Growth must change fundamentally. It needs to decouple itself from materials or at least become very, very material-light. That's why the information economy is so very crucially important if we are ever to achieve sustainability.

SUSTAINABILITY PROMISES OF THE INFORMATION AGE

Unquestionably, the information age has the potential to alter our material profiles in a big way. Our own study of the Hsinchu Science Park, the so-called Silicon Valley of Taiwan, showed that its energy intensity was approximately one eighth of all-industry average [11], and their water use intensity was even smaller – on the order of one-fiftieth [12]. It is to be noted, furthermore, that companies inside the Hsinchu Science Park mainly engage in information hardware manufacturing. Material intensities on the "soft" side of information industries would have to be even lower. Additionally, these information industries are growing at a much faster pace than traditional material-intensive industries. They have expanded at over 20 percent a year all through the 90's to take up greater than 50 percent of Taiwan's manufacturing output now.

This is why the information economy is so important to sustainable development. To truly dematerialize our growth, growth must itself become material-less or at least very, very material-light. That's the main sustainability promises of the information economy. Even e-commerce, once it plateaus off and the "externalization of internalities" problems recedes in 10 to 20 years' time, may turn from a negative to a positive force (that is, of course, if the accelerating changes brought by the information age wouldn't spring other unpleasant surprises).

TECHNOLOGY AND SUSTAINABILITY: THE TWO-EDGED SWORD

Now if the information industries are so material-light and growing so robustly, then how come we don't see the evidences of dematerialization showing up where they count, at bottomline places like Figure 2? Sustainability has never had it easy, has it? Wherever we find dematerialization, we seem always to find a bigger growth effect. In the information age, this is no exception.

In fact, if there is one thing the rapidly advancing information age technologies will be

sure to bring, it is not faster dematerialization, but greater productivity and therefore faster growth – the thing dematerialization must overtake if we are to have any chance at achieving sustainability. I shall quote *Wired* (July 1997) [13], the so-called "magazine of the networked world":

"*Historians will look back on our era as an extraordinary moment. They will chronicle the 40 years from 1980 to 2020 as the key years of a remarkable transformation. In the developed countries of the West, new technologies will lead to big productivity increases that will cause high economic growth. And then the relentless process of globalization, the opening up of national economies and the integration of markets, will drive the growth through much of the rest of the world."*

This may be nirvana for business executives, but nightmares for those who are looking for ways to implement sustainable development. Epochal technological advances are pushing the developed countries of the world onto new "S curves", giving them the impetus for faster growth heretofore unimaginable with these "mature" economies. America is now growing at greater than 5 percent a year, Germany and France greater than 3. Furthermore, with the Internet and the explosive communications technologies driving the globalization of not only knowledge but ideas, economic democracy and free-market entrepreneurship will flourish in the third world, unleashing many new Taiwans and Koreas into the newly industrialized ranks. Two countries on the move are China and India, the first and second most populous states on earth each with quality technical capabilities, low cost labor supply and large domestic market to create and sustain comparative advantages and robust economic performances for years to come. If you think growth is bringing too much pressure to our ecosystems now, think again. All signs are pointing to faster growth, and therefore greater dematerialization challenges, as we enter the new millenium.

This brings up another interesting question – is efficiency a good thing for sustainability? The answer is "sometimes". If the efficiency in question is "material" efficiency, then it is good. If it is "production" efficiency, then look out.

ALWAYS ASK FOR NUMBERS

Many solutions have been proposed to rein in the environmental side-effects of development. Some are real and serious solutions. Some are false and unfounded hopes.

And some are even cynical lip services. There is, however, always a way to tell the real ones from the false and cynical ones – don't accept just words, ask for numbers. Any proposed solution that cannot back itself up with numbers is most likely suspect. Once we have numbers, we can see whether they measure up and also check and monitor whether they actually work. This kind of discipline works at all levels, from a company level all the way to the world level. The following are two examples, one on the company level, one on the world level.

Corporate Environmental Actions: How Much Would Be Enough?

We are all very happy now companies are doing corporate environmentalism and publishing company environmental reports (CER). Some governments are now contemplating voluntary compliance. Some of the leading environmental activists are now even joining the corporations they once protested against as their environmental officers and consultants. But should we be so very happy with just any kind of environmental performance improvement? Is the company attacking its most serious environmental side-effects? How much improvement would be adequate, and how much would be just largely PR?

If a company says in it CER that it has improved its energy or water intensity 5 percent last year, was it good? Yes and no. If the company's sales grew 10 percent, then 5 percent efficiency improvement was not good enough. Now, if that company dematerialized certain natural resources 20 percent, which was twice its 10 percent revenue growth, was it good? Still yes and no. Very large gains in material intensity reductions are most often the results of certain old technologies being phased out. The aggressive targets usually end when the phasing-out is done (and the focal point of the next report would be shifted to something else). There is a very simple rule – the company needs to focus on its most crucial sustainability problems, and set dematerialization targets at equivalent or greater than the company's growth rate on a continuous, year in and year out basis. If the company's environmental performance targets fall short of that, it is not doing enough to stop the accumulating environmental impact brought on by its own existence, let alone contributing to the welfare of the world as a whole.

Sustainability or environmental performance indices are very popular nowadays. The trouble is we have so many of them (the World Bank lists more than 600 of them!). We have to understand that some indices are more important than others, and

indiscriminately publishing a large number of them often camouflage rather than elucidate environmental performance.

How Much Should the Rich Countries Do for the Poor Countries?

Sustainability ills at developed and developing countries are diametrically different – the former from too much growth while the latter not enough growth. For sustainability to be achieved on a global basis, the developed countries must do extra so that the developing countries can grow out of their unsustainable ways as fast as they can. This is the so-called "North/South Issue" – one of the truly central issues of sustainable development.

The issue has, however, been mired in international environmental politics for 10 years now, yielding much conferencing but little results. The stalemate boils down to "how much" extra the developed countries should do for the developing ones, and the "how much" soon turned into "how much money", and soon everybody just balked.

Now if a universally satisfactory answer in monetary terms to the "how much" question is unlikely to be found under the old negotiation regime, why not try a different approach that's easier to understand, quantitative in nature and involves no money changing hands? We can have such an answer by going to the fundamental "dematerialization = growth" criterion.

If we divide the world up at per capita income of $ 10,000 into two blocks, the North and the South (Table 2), simple calculation based on the "dematerialization = growth" criterion will show that a 1 extra percentage point of dematerialization by the North would give the South 2 extra percentage points of growth while still satisfying the overall sustainability requirement for the world as a whole. That is essentially unrestrained growth for the South. So, there you have it. What the North needs to do is one extra percentage point of dematerialization beyond meeting their own minimum obligations. That in a nutshell is the "size" of the North/South Issue. No money needs to change hands here.

	North	South
Average Per Capita GDP (US$)	23,000	1,000
No. of Countries	48	169
Total GDP (US$ billion)	19,326	4,983
Population (million)	846	4,823

Data Source: Britannica Book of the Year, 1996

Table 2 Breaking the World down into the North and the South

DIGITAL DIVIDE AND THE SOCIAL ASPECT OF SUSTAINABILITY

Besides the environment, technology as a two-edged sword cuts deep into the social spheres too. On the one hand, the rapidly advancing information technologies clearly pack the promises to link everybody, rich and poor, at unprecedented low costs and bring them benefits in unimaginable ways. But, can everyone benefit? Would the information economy bring benefits to all and narrow the gaps between the haves and the have-nots, or are the benefits merely the forbidden fruits of the privileged few? The troubling thing is we are already witnessing evidences that the "digital divide" is getting wider and wider as the information economy pushes forward and there is no conceivable mechanism within the market economy to narrow it.

In America since 1980, the year many designated as "year one" of the information age, real wages for the lowest paid 10 percent has declined 20 percent, while the highest paid 10 percent gained 10 percent, with the top 1 percent actually gained 100 percent [14]. In Frances Cairncross' *the Death of Distance*, a book about the future of telecommunications, the author anticipates that "20 percent of the American workforce will be marginalized by the move to an information-based economy" [15]. In the US, where the growth of Internet businesses is enriching a large number of net-treprneurs and their stock-optioned employees, 50 percent of American families still have less than $ 1,000 in total financial assets. Seven million American families don't have basic telephone service. Ten million Americans don't have enough to eat. The gaps between the haves

and the have-nots are not closing. The median household income in America in 1996 was actually 4 percent below where it was 1989 [16].

While the gaps between the haves and the have-nots are widening in the rich economies, the gaps between rich and poor countries are widening even faster with no signs of closing in sight. The richest 15 percent of all humans now account for 88 percent of the world's Internet users. At the same time, 65 percent have never even made a single phone call. While the developed economies take economic growth for granted, economic "decline" is actually the norm for more than 100 countries with a combined population of 1.6 billion in the developing world. In Africa, for example, the average households consume 20 percent less today than it did 25 years ago [16].

One of the benefits of the rapidly advancing information age technologies is supposed to be its power to linkage and integrate not only the rich but also the poor countries, thereby improving their lots substantially. This we hear frequently in the speeches given by the captains of the information industry. Lets take a closer look at "how" the information economy will spread to the have-not world.

Many people would think that once we have the technology it just spread automatically. Well, not exactly. First of all, technology transfer is probably the least understood topic in international environmental politics (I shall not get into that, as it would take up at least another paper to cover it). Secondly, the mere existence of the Internet doesn't guarantee that all countries, rich and poor, will get their rightful shares in the riches. A country has to do more than having its government and academic institutions put up web-sites. The web-sites need to make enough money to keep their presence on the Net, and to make money these web-sites have to have business models like any other kind of business. This is not only true for American Internet startups trying to make it with the Nasdaq, it is also true (and probably a lot tougher) for the startups in third world countries.

A part of my job is to dream up and start up new Internet companies in Taiwan. Not long into this work I came to the realization that copying what's been done in America doesn't work, and it is important to find niches that are right for Taiwan. You see, there are close to 100 million Internet users in America, but only 3 million in Taiwan which is a much smaller country. Each of these users also has on the average only one-third the buying power (based on per capita income ratio). These numbers are important: If a Net startup's

chances of survival are proportional to the total potential buying power it is exposed to (number of Internet users multiplied by income per user), then the same Internet business model would have about one-one hundredth the chance to work in Taiwan as compared to America. The proportionality isn't even linear, as a matter of fact. Under a certain critical mass you don't even get on the curve.

Luckily for Taiwan, it is one of the world's manufacturing centers and has one of the world's strongest small and medium-sized enterprise bases. So there will be quite a bit of room to play in the B2B domain. Still, our lives are getting tougher, not easier. With the advent of the Network Economy, the global competition barriers are now that much higher and we will have to scratch and claw that much harder just to maintain our old stations in the order of things. But what about the truly have-not economies, those with per capita income far less than Taiwan and a human resource base a lot less knowledge-based?

If we don't do something about it (what? I don't know), the Network Economy is going to be the ultimate trickle-down machine for the majority of countries and the majority of humans. The trickles will rain riches on the rich like never before, and dry up a lot faster than before.

CAN WE SAVE OURSELVES FROM OURSELVES?

We are all very familiar with the promises of the information economy now. There is no need for me to add to the euphoria. That's why I have focused on its side-effects and risks. The opportunities of the Network Economy are huge and unprecedented. So are its risks. The only things that are powerful enough to control the risks of tomorrow's technologies are tomorrow's technologies themselves. With so much to be gained as the huge opportunities of the Network Economy unfold before their eyes, would enough of the most gifted and talented amongst us be diverted enough to think about the unprecedented side-effects? The only force powerful enough to solve the problems created by creativity would be creativity itself. Men create. Men create problems. Men must solve these problems. It's that simple, and that tough.

REFERENCES

(1) Judson, B., *Hyperwars*, Touchstone Books, 1999

(2) “Internet Exchange 2000”, *the Keenan Report,* April 2000, http://www.keenanvision.com/html/content/ex2000/exchange2000.htm

(3) Energy Commission, Ministry of Economic Affairs, Taiwan, ROC, *International Energy Statistics*, 1997

(4) Daly, H. E., *Beyond Growth*, Beacon Press, 1996

(5) Adriaanse, A. et al, *Resource Flows: the Material Basis of Industrial Economies*, World Resources Institute, 1997

(6) Ausubel, J. H., “The Environment for Future Business: Efficiency will Win”, Pollution Prevention Review 8 (1): 39 – 52, Winter 1998

(7) Ayres, R. U., et al, “Achieving Eco-efficiency in Business”, World Business Council for Sustainable Development, March 1995

(8) Schmidt-Bleek, F., “Increasing Resource Productivity on the Way to Sustainability”, *UNEP Industry and Environment*, October - December 1995

(9) Von Weizsacker, et al, *Factor Four*, Earthscan 1997

(10) Faruqui, A. et al, “Efficient Electricity Use: Estimates of maximum Energy Savings”, CU-6746, Electric Power Research Institute (EPRI), 1990

(11) Energy Commission, Ministry of Economic Affairs, Taiwan, ROC, *Evaluations on the Effects of Energy Audit and Energy Conservation, the Midterm Report*, December 1998

(12) Energy and Resources Laboratories (ERL), Industrial Technology Research Institute (ITRI), *Technical Report: Taiwan Area Industrial Water Investigation and Databank Establishment*, MOEA 008174870091, 1997

(13) Schwartz, P. and Leyden, P., “The Long Boom: A History of the Future 1980 – 2020”, *Wired*, July, 1997

(14) Perkins, A. B. and Perkins, M. C., *The Internet Bubble*, Harper Collins Publishers, 1999

(15) Cairncross, F., *The Death of Distance*, Harvard Business School Press, 1997

(16) Rifkin, J., *The Age of Access*, Tarcher/Putnam Books, 2000