SCALE, or the fact of[1]

Prologue: Answers I have gotten to the question "Where is the internet?"

1. It's the little cloud in my diagrams of networks.
2. It's everywhere.
3. It's in those mysterious humming boxes you see on the street-corners.
4. It's in my head.
5. Omnipresent and spreading.
6. There is no there there.
7. The internet is where your money is.
8. It's a consensual hallucination.
9. It's somewhere in the vicinity of Jupiter, approaching Earth.
10. The internet is in my beer. The more you have, the more you want. The bigger it is, the better it gets.

one.

Some words seem too rich, taking more than their share of coincidence and teaching too much by their usage. *Scale* is such a word. Noun, it strings at least three distinct meanings across a semantic sea that begins with balancing machines, covers fish and snakes and crescendos with music. Verb, dictionaries generally authorize transitivity, linking the action to mountains and ladders or walls and weights. A scale: a shell or a cup, eight notes, a precise instrument, imbricated skins. To scale: a ladder, rungs spaced like marks on a ruler, a tiny train station, with tiny regular trees.

The richness of these overlapping meanings all concern measuring, spacing, evenness, overlap; figurative uses are rare. The cup, as in "ay, there's ale in the scale," shares its containing with the scale-pans hung for comparison's sake. My beer is bigger than your beer. Always a pair of scales in this sense, purposing fairness, implying decision. Here the word shares a strange etymological connection to another decisive word abundant in the twentieth century: *test*. Tests were once shells, cups of clay used as a crucible for purifying metals[2]. Testing is a ubiquitous aspect of scientific technology, as indispensable as the scaled tools of measurement leading up to it. Scales for testing evenness share the dictionary entry with the scales of fish, reptiles, sometimes butterflies. Molting, unveiling (Acts ix. 18 "He removeth the

[1] Written in 2000 for the conference “Travelling Facts” organized by Vinh-Kim Nguyen at the Wissenschftskolleg, Berlin.

[2] *test, OED, 1991.*

scale from our eyes, the veil from our hearts."), revealing the truth. Scales— of salt, metal, armor, skin— also protect, though from what is never clear. Richer by far are the wealth of uses for ladders, Jacob's holiness, an instrument's range, an arbitrary tool of amounting.

Somehow the binary balancing of scale pans opens out onto lines of all lengths, chopped up, finely or grossly, but always evenly. A scale of notes, scale of life, scale of intensity, bases (binary, ternary, decimal) in mathematics. The Richter scale of earthquakes, the Fujita scale of tornado intensity, the Hubble constant. Among its verbs, one can weigh and one can skin. Add to the cup or remove from the body. Only the latter suggests anything unusually messy in the world of scales, even though, in English at least, we refer to this action as 'cleaning' a fish. We could even make a scale of these meanings, test texts or usage for the most or least, the strongest or weakest. Already we often find ourselves 'weighing' the meaning of things.

This precious semantic-etymological crystal is cracked in the 20th century, where innumerable local measurements, octaves of evenly spaced notes practiced on carefully measured staves give way to new abuses. Under noun, the scale of something comes to indicate its pure size, especially its largeness. A 'large-scale' undertaking rarely means more than a 'large' undertaking. Economics knows this use promiscuously as 'economies of scale' ("short for Economies of Large Scale Production" quotes the OED from an economics textbook, though the difference between 'economies of scale' and 'large scale' will be important), where fixed costs are distributed over ever larger number of products. Totally paradigmatic, perhaps, is the visual exponentiation of Charles and Ray Eames *Powers of Ten*,[3] a film that ranges from stars to cells, with the Earth dead center, balanced precariously on the pintle of this new scale of totality. Can the toy train and its industrial original still meet in this usage, or are they consigned to different frames?

Under verb, a still worse permutation, a new intransitive monstrosity appears: ‘it scales.’ It is this abuse that is most interesting. Not 'it scales' as in the Rock-It fish scaler, which claims in gloriously industrial language that "Rock-It scales up to 50 fish in 2 minutes. It's built entirely of galvanized steel with no moving parts to wear out, no batteries to go out, no electronics to fail. Unlike complicated so called 'state-of-the-art' fishing gear, Rock-It is built for a lifetime of utility."[4]

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[3] *Powers of ten : a film dealing with the relative size of things in the universe and the effect of adding another zero* made by the office of Charles and Ray Eames for IBM, 1978.

[4] See Rock-It homepage: http://www.dmi.net/rock-it/

No, not the industrial scale scaler of personal mass production, but a verb of a different order. An intransitive verb that suggests the cancellation of the imprecise use of scale to mean bigness, and substitutes instead a delicate notion more appropriate to the word's polysemy. A building and a train may be large or small— may be built, as one says, to scale. But, when something is *both big and small at the same time*, then *it scales*. Still, buildings and trains are too tangible for this intransitive miracle, it is a use of the word that could only find subjects in the twentieth century. Here the OED tips the balance: "To alter (a quantity or property) by changing the units in which it is measured; to change the size (of a system or device) while keeping its parts in constant proportion."[5] Scale the amount, add a zero, measure in gigabytes. What could be more familiar in the world of measurement than the convenience of exponentiation. But consider the second usage, where things— significantly systems or devices— become larger, but their parts stay the same. It is a familiar usage today:

"Does your business scale?" "Yes, our product scales," "this web server is scalable." No need for a billion servers to serve a billion hamburgers, because this baby scales. Microsoft hosts a yearly "Scalability Day," advertised by banners that say things like: "Did somebody say Scalability?" (Ears brimming with American media will hear a quote of a McDonalds advertisement, perhaps too subtly connected to the billions and billions of that old-economy model of scale.) Scalability is defined on hundreds of mailing lists, technical and otherwise. "Scalability, reliability, security" form a buzzword triumvirate second in ubiquity only to the kingly trio "products, services, solutions." Servers should scale, or succumb to too much traffic, but business plans should also scale, or risk the shame of missed market opportunity— regret does not scale. People warn of 'scalability myths,' there are helpful programming hints and "Scalability Killers"[6] to avoid. One can try to write algorithms that scale (i.e. that can solve problems of arbitrary size), or try parallel processing (i.e. scale resources to help a non-scaling algorithm solve problems). "Clustering" is a popular solution that allows for scalable web-sites that access growingly large databases of material.[7]

The subtlety of 'to scale' often gives the slip to journalists and PR agents, who try returning scale to pure size, or pure speed; an example from The Standard, January 3rd, 2000:

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[5] *scale*, OED, v. XIV p. 563, 1991

[6] George V. Reilly, "Server Performance and Scalability Killers," Microsoft Corporation, February 22, 1999, http://msdn.microsoft.com/workshop/server/iis/tencom.asp

[7] A cluster generally means any number of computers hooked together to act as one, as in 'parallel processing' however, it has recently come to be used more specifically with the connection of any number of servers such that visitors see one site and access only one database, even though they might be connected to any of the computers. Load balancing, fault tolerance, error correction are all given as reasons to cluster.

> On the Internet, if you can't scale – *if you can't get really big really fast* – you're nowhere. And it's not enough for just your technology to be scalable. Your entire business model has to have scalability, as well; you need to be able to quickly extend your business into new markets, either horizontally or vertically. "Will it scale?" is one of the first questions venture capitalists ask.[8]

Interesting choice of words, "if you can't scale, you're nowhere". True, it implies the opposite, that if you can, you will be everywhere. The world, your oyster: bon appétit. But the choice indicates something else, you are no *where*, not no *thing*. This is a story, a word, a metaphor maybe, of the internet as industrial market, geographical manufacturing region, *cyber-space*. A topical imagination where fastness and largeness make more sense than in the pure scripts of a world that is both big and small at the same time, which precludes it from being precisely some *where*. Such a topographical insistence is a result of weak language, less than of weak imaginations; not a result of the actual strangeness of a world saturated by computing, yet indifferent to its physical organization, because language itself forces spatial figurations, prepositions serve topoi on top of topoi. Fact is, if you can scale, you could be *any* where.

Try another example on for size. *Gnutella*, named for GNU (of GNU's Not Unix fame, from the Free Software Foundation)[9] and the tasty hazelnut-chocolate spread "popular with Europeans" is a simple elegant tool for creating your own instant mini-internet, in order to share anything you want: music, movies, porn, pictures, data. Its self-description:

> Gnutella client software is basically a mini search engine and file serving system in one. When you search for something on the Gnutella Network, that search is transmitted to everyone in your Gnutella Network "horizon". If anyone had anything matching your search, he'll tell you.
>
> So, time to give a brief explanation of the "horizon". When you log onto the Gnutella network, you are sort of wading into a sea of people. People as far as the eye can see. And further, but they disappear over the horizon. So that's the analogy...
>
> And what of the 10000-user horizon? That's just the network "scaling". The Gnutella Network scales through segmentation. Through this horizoning thing. It wouldn't do to have a million people in the horizon. The network would slow to a crawl. But through evolution, the network sort of organizes itself into little 10000-computer segments. These segments disjoin and rejoin over time. I leave my host on overnight and it will see upwards of 40000 other hosts.

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[8] http://www.thestandard.com/ archives from January 3, 2000, my italic.

[9] http://gnutella.wego.com . The Free Software Foundation: www.fsf.org and www.gnu.org., Nutella, by the way, is a product of WWII war shortages of chocolate, originated in Italy and now, by its web-address, appears to be head-quartered in Argentina (www.ferrero.com.ar) but these are precisely the kinds of assumptions that are dangerous on the internet. "Worldwide, it outsells all peanut butter brands combined." In my next paper I will tell the history of the twentieth century through the epic struggle between Nutella and Peanut Butter.

Here the where of there is earthly, it is the size of the planet, and divides into horizons, time-zones of a sort, a metaphor of spatiality familiar to pilots and phenomenologists alike. This horizon, however, is by no means geographical, but simply numerical. It is as one color thread in a tapestry, distributed throughout the landscape connected by a quality. It is a statistical distribution, dotting a sample of billions with 10,000 dots. The crucial difference here, is that everyone's horizon is different— not completely, but enough that the horizons 'scale' to include the whole internet. What connects people first is not a physical network, not a system of wires that has a necessary geographical component. What connects people is a script, an instruction, a set of commands, a question and answer (or a 'negotiation' in telecommunications terms, specifically, a 'ping' and a 'pong' that contain minimum information about origin and destination, IP address and connection speed. It is nonetheless these pings and pongs that make up more than 50% of the data on the Gnutella network, making scaling a serious problem for the designers. Imagine if everyone were to ask their neighbors that question, and ask them to ask their neighbors, and so on— the world would quickly end in queries without answers...). What connects people is not propinquity, not community, what connects people in the world of tasty hazelnut spreads is, in short, a programmed language.[10] A protocol, a simple script, a set of messages. Your IP address can be static or dynamic, a proxy or a masquerade, but it doesn't matter where it is, or how long it exists, only that it be connected to others, which are connected to others, which are connected to others. This is the non-spatial space of 'it scales.'

The cliche of air-travel shrinking our world in bringing the remote close has nothing to do with this kind of scale. Rather, if you must think of planes, think instead of the tall Texan crammed in the seat next to you, and the conversation that will lead to the person you both have in common, and the meaning of the inevitable phrase "it's a small world." These conversations are the new scale of the twentieth century[11].

Scale is not just size, therefore, or extent. The system can be any size, only its parts need be correctly measured. So this intangibility of size that is both big and small at the same time includes markets and economies that scale as much as it does ideas, technologies and networks that scale (or in the language of the OED, 'systems and devices'). In the long twentieth century, 'large-scale economies'

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[10] On the subject of programmed languages, please see my thesis, *Scale and Convention: Programmed languages in a regulated America,* available at http://www.kelty.org/or/thesis.

[11] Indeed, one of the more libertarian futurist manifestos of the internet— *The Cluetrain Manifesto*— uses precisely this language: the internet is a giant conversation. The metaphor doesn't imply anything about size, however, and the rebellion is a very Lutheran one, read its 95 theses here: http://www.cluetrain.com.

become 'Economies of scale' which become 'economies that scale'— economies that digital prophets love to herald, where markets are scaled to order and profit is pure. True, there is rarely talk of something scaling *down*, rather than *up*, but implied in the intransitive usage is that should demand drop precipitously, production can match it, and profits survive. Scale is unbounded potential size.

To return to the opening question, it is a matter of beer, or more precisely of drunkenness. "The bigger it gets, the better it is, or perhaps "the better it is, the bigger it gets". I fear the person who gave me this answer was quite drunk. It hardly matters, because what it says about the internet, read in either direction, is that *it scales.*

I suppose for the engineer— the sober engineer— the scalability of the internet is a merely technical question. A technical question. Which is not to say a question of technology. Rather, it implies that there is nothing mysterious in the phenomenon of scalability. Instead, it is simply a question of building something like the internet (i.e., a distributed system of computers all sharing a single connection and transmission protocol), creating some software to implement the protocols, and voila: scalability. Sure, there may be some hard questions that linger about compatibility, about security, or amount of traffic, or even some 'theoretical' questions about the hardness of certain problems. Yet these are still 'technical' questions, no mystery, just math. They are not philosophical.

But I should be clear. This question, my *technical* question about scale is not *only* about the internet. And if this scalability is something other than just the internet— the computers that make up the internet— if it is also markets and economies that scale by virtue of being connected to the internet and to the people who are “on” the internet; if the internet is in my head or in yours, in our beers, or no where at all, then this question is suddenly much more difficult, and perhaps, more important than simply a 'technical' question, or even a question of technology. When I ask “where?” my interlocutors almost always double-take. It is strangely phrased. Some seem to think I know where it is, and am not telling; others take it as an occasion to joke, seriously. If the internet scales, if it is simple to say that it is everywhere, then surely we should ask “just how big can it get?” Surely there must be limits— bigger than the world, as big, or smaller? Bigger than society, bigger than the market, bigger than the economy?

This is a serious question both theoretically and for designing empirical research. It is not possible, for example, to have a 'sociology of the internet' without returning to the question of what and where society is (not to mention an anthropology without questioning *anthropos*). Or put differently, this is not only a question of research, because it is research that is in question. So my question is larger than

the internet, if I can put it that way. For lack of a better word, I say 'scale'[12].

Felicitously, scale means a few other things. In one precise way it refers to scientific research through the notion of the scale-model. Scale here is *measured representation*. It is a question of the relationship between something and something else *calibrated* by some totality, usually called 'the world' or 'reality'. The world, it is presumed, does not scale— it's just there. I find this a dangerous assumption, however, because we encounter many things today with the names "global models" and "world models" that might suggest that the relationship between the model and the world are not so straightforward[13]. The fact that environmentalists, economists, physicists, biologists, sociologists, anthropologists et. al. concern themselves with models and representations of this incredibly huge thing, this planet-sized or larger reality, should militate against the assumption that the world calibrates the model, rather than vice-versa. These miniature worlds are no longer scale models, no harmless representations of a world too big to be grasped without reduction. They are more like scale-realities, or even, model-realities. But don't take *my* words for it.

two.

> Use the program to try worldwide strategic plans. Plan a strategy, and make any necessary changes to the model. For example, you might want to try developing new farming technologies. But don't start the model yet! First think through what you expect to happen. Draw graphs or make notes about how population, industrial output, and other variables will change over time. Why will they change this way? Then start the model. Do the results differ from your expectations? If so, why? Adjust your mental model appropriately.
>
> —A description of *World3* model software from *Beyond the Limits*[14]

In 1956 and 1957 the first mathematical macroeconomic models of growth were proposed by Robert Solow, the first man-made miniature moon left the earth carrying a man, and Jay Forrester was

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[12] In addition, I cannot say that this is simply a question of a 'new' reality that requires new words, or that this very twentieth century use of an old word simply indicates some general thing that already has a million new names ('information revolution,' 'computerized society,' 'network society,' 'information age,' 'new economy' etc.), none of which, to my taste, clarifies things at all. I have dwelled on this to no particular effect in the 'monounsaturated introduction of my dissertation, op cit. http://kelty.org/or/thesis/

[13] Perhaps the most suggestive and sophisticated producer of models of all sorts is Herbert Simon, who has published collections called *Models of Discovery, Models of Thought (2 vols.), Models of Man, Models of Bounded Rationality and Models of My Life* (an autobiography). His work does not figure in this paper even though his notions of 'bounded rationality' and 'satisficing' pose the questions of just how complex scale-models of decision-making can be. There is a reason he is at a strange intersection of economics, artificial intelligence, management theory, and decision analysis.

[14] Meadows, Donella H., Dennis L. Meadows, and Jørgen Randers *Beyond the Limits*, Chelsea Green Publishing (Post Mills, Vermont): 1992. More at http://www.sun.rhbnc.ac.uk/~uhss021/ESP/BTLHandbook.html

shelving his war work and his patent on magnetic core memory and moving over to the Sloan School of Management at Massachusetts Institute of Technology[15]. I hope one day this set of events will be the proper allegory for the period leading from WWII to WWW. Until then, it will just be coincidence subordinate to a time period we call, for no particularly good metaphorical or meteorological reason, The Cold War. Yuri Gagarin will have to stay in orbit, and I will return to Solow in section five, below.

Jay Forrester's move resulted in the creation of a field of research— System Dynamics— that is no less lively today than it was between 1957 and 1973, when his literary output was obsessed with one same thing: systems that change dynamically based on the feedback loops of their factors. Sure, Forrester wasn't the only person using these words during this era of cybernetic promiscuity, the summers of system love, but he was alone in creating something very specific: computer-models of systems with dynamically related factors that could be observed in and out of equilibrium. Forrester began with industrial dynamics, moved on to cities and urban environs and by the end of the sixties, he had grown his models to the size of the world.[16] He named them *World1, World2,* and *World3*. These models of the dynamics of inputs and outputs, resources and products, ends and means were handed off to his graduate student Donella Meadows who took them to Rome with her. By 1972, the models had produced not just answers, but millenarian predictions of their own end. That is, of the now famous report of the Club of Rome called *The Limits to Growth.*[17]

Global models begin here. Not just models of the world (on this subject, there is Heidegger ahead), but *dynamic* models, which means models that constitute a certain kind of automated experiment with the reality they describe, and live and die inside computers. A certain brand of fact-saturated environmentalism also begins with these neo-Malthusians and their transmissions from Rome.[18] The wash of emotionally hyperbolic literature (for, against, and other) that followed this book belies the

[15] For an excellent account of Forrester's activities before his move, see Paul Edwards, *The Closed World: Computers and the Politics* of Discourse in Cold War America (Cambridge, MA:MIT Press, 1996). Also see Edwards on Global Models: "The World in a Machine: Origins and Impacts of Early Computerized Global Systems Models," in *Systems, Experts, and Computers: The Systems Approach in Management and Engineering, World War II and After*, eds. Thomas P. Hughes and Agatha C. Hughes (Cambridge, MA: MIT Press, 2000).

[16] Jay W. Forrester, *Industrial Dynamics,* Cambridge, Mass.: M.I.T. Press, 1961, *Urban Dynamics*, Cambridge, Mass.: M.I.T. Press, 1969, *World Dynamics*, Cambridge, Mass. : Wright-Allen Press, 1971, *Principles of systems; text and workbook*, Cambridge, Mass.: Wright-Allen Press, 1968.

[17] Donella H. Meadows, Dennis L. Meadows, Joergen Randers, William W. Behrens III, *The Limits to Growth*, New York: Universe Books, 1972. All references this edition.

[18] The Club of Rome was a closed group, and their self-importance was an important factor in their capacity to speak for the world: "The Club of Rome is limited, and will not exceed one hundred, it is being expanded to include representatives of an ever greater variety of cultures, nationalities and value systems. (x)"

studied seriousness with which the Club of Rome and the authors go about justifying their apocalyptic pronouncements. They insist that the model, the small-scale representation is the only way to trade sensibility for intelligibility (on this subject, there is Levi-Strauss ahead), and that this has to do with nothing less than the progress of science:

> We, too, have used a model. Ours is a formal written model of the world. It constitutes a preliminary attempt to improve our mental models of long-term global problems by combining the large amount of information that is already in human minds and in written records with the new information processing tools that mankind's increasing knowledge has produced— the scientific method, systems analysis, and the modern computer. (26)

Note here (and also in the above quote from the sequel— still going strong 20 years later) the continuity drawn between "mental models" and the models outside minds. *Where* models are is a troubling question not broached, but wherever they are, two things are true: they are *written* and they are necessary spurs to decision— they are facts. The Club of Rome insists that their findings are fundamentally sound, even if the details are not quite exact. Their conclusions, however, are in a delivered in quite the biblical tone: "...join us in understanding and preparing for a period of great transition— the transition from growth to global equilibrium.(29)"

The difference between growth and global equilibrium is not one of scale, but rather one of quality. It is not the case that economic models of growth such as Robert Solow's (or Paul Romer's, see section five below) are unconcerned with equilibrium, but equilibrium in economics does not have the same moral force that it has here. Equilibrium in economics is a pure problem of balanced forces and a question of prices. It is not opposed to growth, but rather conceived as a prerequisite of growth.

It is these models of equilibrium, and not the models of *Limits to Growth*, or any of its descendents, that, for example, central banks, federal reserve boards, international financial investors, or multinational corporations concern themselves with when they concern themselves with growth and its limits.

The model of the Club of Rome, Forrester's *World3*, on the other hand, concerns the equilibrium of all factors. It is also avowedly closed. Only scarcity governs it. Neo-classical and contemporary economics remain ambivalent to the nature of growth, and ponder the possibility of sustainable, but infinite growth, but *World3* is an equilibrium model of total accounting dependent on absolute assumptions of scarce raw materials that decrease exponentially and populations that increase exponentially[19]. To follow its flow charts is to move through a looping and mazed world that is connected

[19] Among others, there are actually five principle factors in the model: population growth, industrial growth, food

to itself in dashed, dotted, and bold lines. It is a flow-chart world constructed from logarithmic curves that frighten as they steepen. It is a model of a world in which scarcity governs first and last instances, where allocation can be improved only within a global bound set by limits on the tangible, thumpable, depletable world around us and where all actual factual growth is exponential. Inputs and outputs to the system exist only as tiny clouds marked "sources or sinks that are not important to the model behavior." Poof.[20]

It is a world of insurmountable scarcity, like that of a certain classical economic consensus that earned itself the epithet of 'dismal science.' *Limits to Growth,* however, is a very late drinker at this dreary water cooler, and in seeing the bottle half empty, piously warns us of what is most obviously our impending, thirsty doom. The global equilibrium they speak of is one particular kind of equilibrium: global stability, sustainable levels of production and consumption. The scarcity they speak of insists without argument that the world is a zero sum game, dynamic, yet ever diminishing. Their model proves it, even if the details are fuzzy. They call this the "predicament of mankind."

A predicament is something predicated. This 'predicament of mankind' is a familiar state today, perhaps it even forms a certain kind of consensus that only greed and madness would seriously dissent from. Extinction, nonrenewable resource destruction, inadequate environmental risk-management, global warming are all the subjects of this predicate, and warnings of catastrophe have tempered only the subtlety of the measurements we are presented, only the specificity of the syntax. What sentence is this we are under? No doubt it is a question of facts, and especially, of the statement of facts. Noun, verb. However, what does it mean to state these facts as a problem of *growth?* Do we understand this word, or even how we represent it? Is scarcity so simple a problem as to give the apocalyptic pronouncements of the Club of Rome immediate meaning? If, as I would suggest, the notion of scalability has a definite, but non-obvious relationship to the programmed languages of engineering, legal regimes, regulatory mechanisms, economic and institutional design disciplines and technical standards, then the nature of the relation between what we call ‘growth’, how we represent it, and how those representations in turn scale should be our question. It should be not just how we model growth but just what these models do, what they predicate.

three.

Claude Levi-Strauss has something to say about scale and reality. I reproduce it here full-size:

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production, pollution, and consumption of non-renewable raw materials.

[20] the World3 model is on p. 110-112

> Clouet is known to have liked to paint at less than life-size. His paintings therefore, like Japanese gardens, miniature vehicles and ships in bottles, what in the "*bricoleur's*" language are called "small-scale models" or "miniatures" [*modèles réduits*]. Now, the question arises whether the small-scale model or miniature, which is also the "masterpiece" of the journeyman may not in fact be the universal type of the work of art. All miniatures seem to have intrinsic aesthetic quality— and from what should they draw this constant virtue if not from the dimensions themselves? — and conversely the vast majority of works of art are small scale. It might be thought that this characteristic is principally a matter of economy in materials and means, and one might appeal in support of this theory to works which are incontestably artistic but also on a grand scale. We have to be clear about definitions. The paintings of the Sistine Chapel are a small-scale model in spite of their imposing dimensions, since the theme which they depict is The End of Time. The same is true of the cosmic symbolism of religious monuments. Further, we may ask whether the aesthetic effect, say, of an equestrian statue which is larger than life derives from its enlargement of a man to the size of a rock or whether it is not rather due to the fact that it restores what is at first from a distance seen as a rock to the proportions of a man. Finally, even 'natural size' implies a reduction of scale since graphic or plastic transposition always involves giving up certain dimensions of the object: volume in painting, colour, smell, tactile impressions in sculpture and the temporal dimensions in both cases since the whole work represented is apprehended at a single moment in time.
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> What is the virtue of reduction either of scale or in the number of properties? It seems to result from a sort of reversal in the process of understanding. To understand a real object in its totality we always tend to work from its parts. The resistance it offers us is overcome by dividing it. Reduction in scale reverses this situation. Being smaller, the object seems less formidable. By being quantitatively diminished it seems somehow qualitatively simplified. ...
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> I have so far only considered matters of scale which, as we have seen, imply a dialectical relationship between size (i.e. quantity) and quality. But miniatures have a further feature. They are 'man-made' and, what is more, made by hand. They are therefore not just projections or passive homologues of the object: they constitute a real experiment with it.[21]

Small scale representations of reality test reality by reversing our relationship to it. Man and his hands. It is first and foremost a question of Man making models, representing and thereby testing reality. Models experiment with constraints, see the whole before its parts, make amends between aesthetic contemplation and scientific understanding. They exchange sensibility for intelligibility. This is a familiar — classical perhaps— use of the word scale: a noun that is intermediary, not a single-valued quantity; a verb struggling up an object, not itself magically expanding. The scale of the scale model is a pure relation— one where the sensible of the huge is traded for the intelligible of the tiny. In Levi-Strauss' case, however, the model is always a miniature. Nature, or the object, is always more complex than it's representation, even in the odd case that a statue is actually a model of a rock. But there is no mystery in this assertion, even if we want to believe in an non-representational art, or when we ask questions about

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[21] Claude Levi-Strauss, *The Savage Mind*, Chicago: University of Chicago Press, 1966, p. 24. Subsequent page references refer to this edition.

theater, about television, about *Big Brother* (and all such satisfactions to voyeurism that disavow their fundamentally *representative* characteristic are precisely an *experiment* with reality)[22] it is still, I hope, not difficult to understand Levi-Strauss' experimental miniatures.

Levi-Strauss is interested in something else, however, in the difference between the open and the closed, or in his terms, between the *bricoleur's* savage mind, and the scientists probing one. Levi-Strauss' scale is calibrated by structures and events. Structures are the province of scientific thought, events those of magic and the *bricoleur*. In the middle lies art: the miniature. On the far side, mythical and magical thought lie trapped beneath the debris of history and contingency, ceaselessly transforming the layout, configuration and time tables of their miniature train set, the world of mythical thought; on the other end, scientists, slide rule and IBM punch card in hand, ceaselessly chart the limits of the possible. *Bricoleurs* dwell in combinatorially rich, history-encrusted signification; scientists swim in pure concepts freed from contingency. Closed world, open world.

For both, the art of the miniature serves a purpose, situated halfway between science and magic, pulling in opposite directions, but never entirely disconnected from either activity. *Bricoleurs* create structures by means of events, and scientists, events by means of structures. The division is never so clean in Levi-Strauss, and he would have us put the two in some other relation, magic as 'prior' [*première*] science. The 'prior' science of Levi-Strauss' *bricoleurs* casts shadows everywhere on the event-producing structures, hypotheses and theses of modern scientists.

Avowedly, Levi-Strauss intends to induct the primitive into the orbit of science, but it never quite makes it: there is something that maintains a difference, a 'characteristic feature' that is precisely, its boundedness:

> The characteristic feature of mythical thought is that it expresses itself by means of a heterogeneous repertoire which, even if extensive, is nevertheless limited. It has to use this repertoire, however, whatever the task in hand because it has nothing else at its disposal (17).

The universe of mythical thought is closed; myth is the endless reorganization of signs and images. Only true science lives in an open universe, free from this scarce economy of meaning, manipulating concepts, free to make something from nothing:

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[22] For the rest of the world: *Big Brother* is Germany's spring 2000 obsession, a 'reality-TV' show in which 14 participants live together in a house covered with video cameras. They vote every two weeks to determine who gets kicked out, the remaining members win 200,000DM. www.big-brother.de

> Concepts thus appear like operators opening up the set being worked with and signification like the operator of its reorganization, which neither extends nor renews it and limits itself to obtaining the group of its transformations (20).

This split between open and closed universes is never only an ideological one. It is just as difficult to make magic a fallen, supplemental, or incomplete version of science, as it is to say of science that it is simply glorified *bricolage*. What shall we insist on that maintains this boundary, that sends the scale-model in the direction of magic or in the direction of science? How is that nothing *new* ever happens to the *bricoleur*?

It is safe to say that there is nothing, nothing at all, that allows scientific thought simple escape from history and contingency, or that the other half of the world—whatever that is— is trapped in history. It is also safe to say that the 'engineers' (among which I will count economists and social scientists) of today seem ever more at home in a kind of technologically high-powered *bricolage*, in a world piled high with events, archives and memories, and of course *facts*, that need transforming; they are confronted with a complexity and a specialization that is so wide and deep that they can only look into the pantry of scientific tools, images, signs and concepts and try a new configuration. Or to put it another way, the generation of events, the movement of history, is not the creation of the new, but simply one kind of technoscientific object, one kind of tool that the scientist of today can harness.

In any case, one thing is clear about the scale of the world to which we refer here, which was occasionally clear to Levi-Strauss as well. It is no longer possible, if it ever was, to take seriously any division of the world that would allow one side to be outside history: primitive and civilized, ancient and modern, first and third, West and rest, or East and rest, Orient and Occident, North and South, developed and developing. Events— history, the given— are no longer, if they ever could be so thought of, the province of particular peoples. They are distributed like junk mail, indiscriminately to everyone. Everyone now, if they weren't always, is part of *this* world.

So it is today that economists, environmentalists, physicists, biologists, sociologists, in addition to the Club of Rome and their 'primitive' models, all work to understand something huge, gigantic, bigger than any one culture, nation, history. Levi-Strauss' closed sets of *bricoleurs*, primitive peoples and myth makers are inducted into a much larger *open* set that puzzles and intrigues everyone. It is a totality like that of Charles and Ray Eames, exponentiated to include all that which was divided before, given its place on the scale. The miniature of moment today is huge, it is a 'global model.' A world where one can add

nothing (a zero) to something, and make it fantastically larger. These are the man-made, hand-made simulations that live in computers and drape events on a globe that hangs on its every output. Pause.

four.

Some words seem too poor, trailing platitudes behind them or propped up for support against others. *World* is one. Every addition seems to worsen the situation, its generality tends to be its only striking feature: "Human existence; a period of this," "A state of (present or future) existence," "The earth or a region of it; the universe or a part of it," "The universe or cosmos; everything in existence," "A complex united whole regarded as resembling the universe."[23] It is a word that has received a relatively large amount of attention, despite its diluted and dissolute existence. It doesn't have, for instance, that sense of essentialness that an over-extended word like 'being' has, without which language just wouldn't go. *World* can go, for all language cares, we still have planets and realms and globes and universes and cosmos and stars and life and earth and geo-this and geo-that. Nonetheless, there is a rich tradition of interrogating the duller *world.*[24]

Since I have raised the question of scale, in particular the scale of something not simply material, and of the model, or representation as scale-model, of the scalability, size and location of the internet, and of the models it circulates, I would therefore hang all these things (world, scale, model, representation, science, size, technology) in a constellation— a particular kind of very large miniature— and take solace in narrating the incredibly distant as an incredibly large story. By the light of this constellation, I want to read a tiny Heidegger on this problem of the scale of the *world*.

"The Age of the World Picture" tells us in that artless English translation of his prose:

> A sign of this event [the conquest of the world as picture] is that everywhere and in the most varied forms and disguises the gigantic is making its appearance. In so doing, it evidences

[23] *world*, op. cit. OED, 1991.

[24] There is to begin with the tradition of phenomenology, which has conjoined *world* with another poor word, *life*, to make *life-world* (Husserl, Merleau-ponty, Alfred Shutz, etc.). On the question of world and universe, there is of course Alexandre Koyre, *From the Closed World to the Infinite Universe*. Jean-Luc Nancy has recently published a book called, *Sense of the World*. Among others that Nancy lists are Hans Blumenberg's *Legitimacy of the Modern Age*; under the label of Cosmopolitanism goes Benjamin *Passagenwerk*. I would add the essay by Roland Barthes called "World as Object" in *Critical Essays*; Hannah Arendt's *Human Condition* (which is concerned in a roundabout way with the spaces of the public, the private, and the social); Niklas Luhmann's *Social Systems*, on the nature of open and closed worlds. Not to mention world systems (Immanuel Wallerstein, Frederic Jameson), new world orders or world governments, world trade organizations or world intellectual property organizations, or finally, the Wide World of Sports (the World cup as cosmopolitan substitution for patriotic nationalism, as displacement of identification onto a mediatized and bounded 'imagined world').

> itself simultaneously in the tendency towards the incredibly small.[25]
>
> Ein Zeichnen für diesen Vorgang ist, daß überall und in den vershiedensten Gestalten und Verkleidungen das Riesenhafte zur Erscheinung kommt. Dabei meldet sich das Riesige zugleich in der Richtung des immer Kleineren (87).

Heidegger's giganticism takes as empirical evidence the conquering of distance by airplanes, and the presentation of everyday life in "foreign and remote worlds by radio" [*fremder und abgelegneter Welten*]. Examples often counteract thought, if we are to judge by their rarity in Heidegger, and even though signs of this largeness can be pointed to in the sky and through a flick of the wrist [*durch einen Handgriff*] the nature of the gigantic exists not only in this empirical novelty: he tells us that we "do not think at all if we believe we have explained this phenomenon of the gigantic with the buzzword 'Americanism'(135)." "Man denkt überhaupt nicht, wenn mann dieses Erscheinung des Riesenhaften mit dem Schlagwort Amerikanismus gedeutet zu haben glaubt (88)."[26]

Heidegger's gigantic, like the 20th century use of 'scale', is also big and 'incredibly small' at the same time. However, it is the very specific form of largeness, a largeness specific to this age Heidegger calls the "Age of the World Picture":

> The gigantic is rather that through which the quantitative becomes a special quality and thus a remarkable kind of largeness. Each historical age is not only large in a distinctive way in contrast to others; it also has, in each instance, its own concept of largeness (135).
>
> Das Riesege ist vielmehr jenes, wodurch das Quantitative zu einer eigenen Qualität und damit zu einer ausgezeichneten Art des Großen wird. Jedes geschichtliche Zeitalter ist nicht nur verschiedenen groß gegenüber anderen; es hat auch jeweils seinen eigenen Begriff von Größe (88).

The giant-ness of this age— it's concept of largeness— is the size of the picture of the world within which we place ourselves. However, this notion is complex: it is not the case that each age simply has its own picture, as if in some kind of taxonomy of world-views (even though the question remains open who belongs to Heideggers 'modern world picture' and who, by the ghostly strains of radio, belongs to 'foreign and remote worlds'). If there are ancient, medieval and modern world-views, they are not

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[25] Martin Heidegger, "The Age of the World Picture," in *The Question Concerning Technology,* New York: Harper and Row, 1977 p. 135. Subsequent citations this edition. German original "Die Zeit des Weltbildes," in *Holzwege*, Frankfurt am Main: Klosterman, 1950.

[26] It would suffice for updating to replace the buzzword 'Americanism' with our current most meaningless and forceful buzzword 'globalization' to catch the force of Heidegger's impatience with words, and a sense of what it means that we do not think. To do so, however, would miss the specificity of the Weimar meaning of *Amerikanismus*, and especially the tantalizing remark in the appendix that "The American interpretation of Americanism by means of pragmatism still remains outside the metaphysical realm." Tantalizing given Heidegger's own torturous path through the destruction of metaphysics. I can only wonder if this suggests that American pragmatism is primitive philosophy or rather the proper domain of the post-metaphysical.

created equal. It is the modern world view that has the distinctiveness of including in its world picture, that it is a *new* world picture, not to mention the very fact that it is a picture. "The expressions 'world picture of the modern age' and 'modern world picture' both mean the same thing and both assume something that could never have been before, namely a medieval and an ancient world picture (130)." "Die Redewendungen 'Weltbild der Neuzeit' und 'neuzeitliches weltbild' sagen zweimals dasselbe und unterstellen etwas, was es nie zuvor geben konnte, nämlich ein mittelalterliches und ein antikes Weltbild (83)." What is new is that the world is a picture. It is the age of man representing, the tug of subject and object as a war of control over Nature. The gigantic, the picture of the 'whole world' is precisely this function at work. It is a question of models that picture reality as smaller than it is, and treat it as something new. It is precisely 'newness' that allows this age to imagine itself as a world unfolding, a world with a structure as Hegel or Kant would have it, or one that would come to an end, as Nietzsche would have it.

It gets yet more interesting:

> But as soon as the gigantic in planning and calculating and adjusting and making secure shifts over out of the quantitative and becomes a special quality, then what is gigantic, and what can seemingly always be calculated completely, becomes, precisely through this, incalculable. This remains the invisible shadow that is cast around all things everywhere, whenever Man becomes *Subiectum* and the world, picture (135).
>
> Sobald aber das Riesenhafte der Planung und Berechnung und Einrichtung und Sicherung aus dem Quantitativen in eine eigene Qualität umspringt, wird das Riesege und das Scheinbar durchaus und jederzeit zu Berechnende gerade dadurch zum Unberechenbaren. Dies bleibt der unsichtbare Schatten, der um alle dinge geworfen wird, wenn der Mensch zum Subjectum geworden ist und die Welt zum Bild (88).

There is perhaps no word more problematic in this particular arena of Heideggarian thought than *Berechnen.* It is a word intended to capture the activity of science that is not thinking; instead it suggests too often some simple mechanical process. In English, 'calculate' doesn't capture it, and 'reckon' sounds almost too unmathematical. *Berechnen* does not mean only operating with numbers, but any activity of systematically ordering a field of objects. In "Science and Reflection" ('Wissenschaft und Besinnung')[27] science is "the theory of the real" and *berechnen* means "all objectification of the real" (170)— ordering and systematizing of the world as representation. This is no unusual characterization of science, certainly, and echoes Levi-Strauss who says :

[27] op. cit. p. 155-182. Original in *Vortraege und Aufsaetze, 1936-53,* Pfulligen, G.Neske, 1954.

> Any classification is superior to chaos and even a classification at the level of sensible properties is a step towards rational ordering... classification has its advantages even at the level of aesthetic perception.[28]

But to Heidegger, such classification is not thinking, but merely research and development. Heidegger's concern vis-a-vis R&D is that it would subordinate thinking to such a point that the 'world' would remain in this age, and never reach the next. It is the opposite of apocalypse, the fear that 'this world' may never end. This gigantic calculable [*berechenbar]* thing is balanced by the incalculable [*Unberechenbaren*], by an 'invisible shadow' that tails science everywhere, and emerges just when the gigantic seems calculable.

But how can a shadow be invisible? Isn't a shadow that exact black sign of where light is not? What casts invisible shadows? Invisible hands perhaps? The incalculable as the invisible shadow play of the hands of markets? Wherefore this double negative of the hidden hidden?

Never one to settle on one figure, Heidegger says in "Science and Reflection" that in every modern science (or at least those of Physics, Historiography, Philology and Psychology— biology and social science being notably absent), there is always something that science "cannot get around." Heidegger calls it the *Unumgängliche*[29]. Science, as *Berechnen*, can only order the field of objects, in evermore subtle ways (his example here is statistical mechanics in physics), but without reflection [*Besinnung*], there is always something it cannot get around. Heidegger names these things (Nature, history, language, and man for the sciences listed above), yet offers no solution for science, rather is content simply to point to something essential to science, that science cannot see: it's invisible shadow. The shadow science cast is invisible and *Unumgängliche*. Not for nothing are such double negatives as "invisible shadow" meant to be illuminating, so to speak, and the greater part of Heidegger's later writings seems to be concerned with this frustrating activity of attempting to not see what is in front of him. That is, the attempt to pint out what is not visible, constantly passed over yet can't be gotten around. Heidegger condenses it cleverly: *'das stets uebergangene unzugaengliche Unumgaengliche*' (179).

We started with a question of the gigantic, which Heidegger says is a sign of "the fundamental event of the modern age is the conquest of the world as picture.(134)" If he means by picture not just a passive image, but as with Levi-Strauss, a kind of miniature model of the world that thereby encourages

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[28] op.cit. p.26.

[29] "Nature thus remains, for Physics, that which cannot be gotten around (die *Unumgaengliche*).(174)" Similarly, for psychology- man, for Historiography- history, and for philology- language. Granted these sciences and their objects seem dated, renewed or destroyed by critique in the late twentieth century, but I wouldn't settle for so easy an answer.

experimentation,[30] then the particular picture we are concerned with her is the picture of the gigantic, the global model, which as we have already seen, has developed itself first as a model of a gigantic growing thing inside a computer, whose inputs are scarce and exponential, and whose outputs are apocalyptic.

Opposite the simple models of the Club of Rome, however, are some considerably more sophisticated models whose entire reason for existing appears to be their calculability, and these are the models of economics. In particular, models of 'growth', which is, as I said above, not the same thing as in the scarce models of the Club of Rome, yet connects directly and in at least two ways to the problem of scale as I have introduced it. Opposite Club of Rome, I offer the Club of Romer.

Via this example, I hope to show you a glimpse of the invisible shadow of scalability. Watch carefully. I have nothing up my sleeves.

five.

In economics, *scale* has a series of meanings. Models, of course, are the alpha and omega of both academic and applied economics. Models and their assumptions are always weakly defended in mainstream economics: they stand-in for what is felt to be absent: total knowledge of the system. Thus the prescriptive is the accidental but thereby necessary outcome of a dismally realist description. We have to do something, but our knowledge is incomplete. Of course, we can model this state as well (and many have, calling it alternately, 'uncertainty', 'incomplete information,' 'bounded rationality' etc.) and reel ourselves into the picture, comically, like a shadow casting a person. Then it is possible for scale-models, miniatures to find themselves a part of the system, an active experiment, a scale-reality.

Consider the FCC's game-theoretic experiments in allocating spectrum licenses in the US, or the National Residency Match Program, or the various procedural modes of allocation that go under the heading of 'fair division' and its metaphors of cake-cutting (I cut, you choose) such as the UN Convention on the Law of the Sea, or the *fact* of an entire sub-field of economics that is devoted to the *design* of markets, following a fashion for auctions, bidding, and negotiation that come as a result of the massive withdrawal of the state from decision-making. All of these examples suggest that the models in use are

[30] And he does: "The word picture [*Bild*] now means the structured image [*Gebild*] that is the creature of man's producing which represents and sets before (134)." Or much more economically, if not lyrically, in German: "Das Wort Bild bedeutet jetzt: das Gebild des vorstellenden Herstellens.(87)" In either case it involves the creation of a word, *Gebild*, that Heidegger intends to mean something more than simply *Bild*. Adding the particle ge- could give it the sense of a participle (as most german participles are constructed) and implying an action of pictur-*ing*, but this doesn't capture also the sense of a collection of things, a structured or ordered collection of pictures, that the nominative *Gebilde,* possesses..

the models of best use. They provide not just a reduction of the parts, but an active experiment with them.[31]

But scale also has another role in economics that connects directly to the internet and its invisible shadow. This role is that of limits and growth, and the relationship between inputs, outputs and feedback and the place of people, money, information, and technology in that growth and of those limits. It concerns that picture of the world called macroeconomics and its cousins development economics and international trade; it concerns the role 'technology' plays and whether it is more or less than knowledge, more or less than thought, more or less than science, or perhaps most importantly, whether it is something that can exist without humans. In particular, my entry comes via two uses of the word *scale* that circumscribe a small bibliographic horizon: *Economies of scale*, and *increasing returns to scale*. [32]

The term 'economies of scale' hearkens back to a late nineteenth century Anglo-American moment in the growth of growth. Alfred Marshall's *Priniciples of Economics*, the Sherman Anti-trust Act, the *Santa Clara* court case (which declared corporations persons) frame the notion academically, institutionally and legally, while debates about the difference between mental and manual labor, about the limits of consumption and the creation of demand, and about the nature of property (as a bundle of rights rather than a tangible item) give it quotidian edges. [33]

Marshall didn't call them 'economies of scale,' however. His interest lay solely in that weakened use of the word *scale* to suggest "large": large-scale economic activity. Nonetheless, it is the relations between inputs and outputs and the growth of economies that fascinates him. Most economists would draw a bold thick line from Marshall to Adam Smith, as the origin of this notion; in particular, Smith's wickedly simple idea that "the division of labor is limited by the extent of the market." Smith's pins define division, a 'technical' question of parts, and the population of great cities makes a 'market,' a

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[31] Game Theories offspring in this realm include 'experimental economics' and 'market design' as well as varieties of strategic behavior, incentive structures and negotiation design. See "Al Roth's game theory and experimental economics page" for introductions http://www.economics.harvard.edu/~aroth/alroth.html

[32] This paper focuses on only one of the members of this horizoned bibliography, Paul Romer, but any two degrees of separation will bring you back to the following names and a handful of papers by each: W. Brian Arthur, Paul David, Paul Krugman, Michael Katz and Carl Shapiro, Joseph Farrell and Garth Saloner, Stephen Margolis and S.J. Liebowitz. I know of only one critical article, from Charles Sabel, called “Intelligible Differences.” References are available in the bibliography to my dissertation, op.cit. http://www.kelty.org/or/thesis/

[33] Three indispensable sources: James Livingston *Pragmatism and the Political Economy of Cultural Revolution* Chapel Hill: University of North Carolina Press, 1997 and Martin Sklar, *The Corporate Reconstruction of American Capitalism*, Cambridge: Cambridge University Press, 1988. Morton J. Horowitz, *The Transformation of American Law.1870-1960*, New York and Oxford: Oxford University Press, 1992.

question of modernity, of propinquity and competition, not simply of upward sheering sizes or of numbering population. Marshall himself draws his own bold lines there, but to different ends, and in particular to the question of returns.

There are three kinds of returns, not counting that of the repressed: diminishing, constant, and increasing. Marshall lays down the first law— the law of diminishing returns— with respect to land: "The tendency to diminishing return was the cause of Abraham's parting from Lot, and most of the migrations of which history tells."[34] It may be worded thus, "An increase in the capital and labour applied in the cultivation of land causes in general a less than proportionate increase in the amount of produce raised, unless it happens to coincide with an improvement in the arts of agriculture."(150) Land is a body, and for Marshall, even the ingenuity of the agricultural arts will reach a limit with respect to cultivation and yield. Interestingly, Marshall uses the word *dose* to describe the application of capital and labour to land.[35] *Dose* is no vague word, and Marshall wants it to mean precisely the analogue of medicinal tolerance: that successive doses are less and less effective in yielding returns. It is in this pharmaceutical sense that the law of diminishing returns holds sway over the growth— and scale— of economies.

Increasing returns, on the other hand, depend the gains from organization, specialization and knowledge. In Marshall, such activities have no necessary institutional form, even though it might resemble the R&D departments of firms. Instead, Marshall's model divides between *internal* and *external* economies. The former more or less synonymous with 'firm', the latter more or less with 'industry'. The mutual gains of each from the other allow for growth to occur 'naturally.' Marshall, like so many English economists, draws directly on Darwin for the naturalization of economic transformations; little surprise there, but in Marshall's case, the degree to which growth and size are related is what he wants to specify:

> The general argument of the present Book shows that an increase in the aggregate volume of production of anything will generally increase the size, and therefore the internal economies possessed by such a representative firm; that it will always increase the external economies to which the firm has access; and thus will enable it to manufacture at a less proportionate cost of labour and sacrifice than before (318).[36]

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[34] Alfred Marshall, *Principles of Economics, 9th ed.* London: Macmillan and Co. 1920, 151. All citations this edition.

[35] "Making use of a term suggested by James Mill, we may regard the capital and labour applied to land as consisting of equal successive *doses*." Op cit. 151.

[36] The notion of representative firm is described above this passage, and the degree to which Marshall's notion of the whole economy depends on this abstraction is yet another interesting question of scale-models.

The Law of Increasing Returns derives from the organization and management of labor and the efficient use of capital for the purposes of increasing the scale of production: "An increase of labour and capital leads generally to improved organization, which increases the efficiency of the work of labour and capital."(318). And of course the Law of Constant returns follows: " If the actions of the laws of increasing and diminishing returns are balanced we have the law of constant return. (318)"

For Marshall, land, labor and capital are the primitives of his system. There is no leeching from land more than it can give, yet capital and labour can organize to counteract this. Therewith an epic struggle between Man and Nature can be made the subject of economics. "In other words, we say broadly that while the part which nature plays in production shows a tendency to diminishing return, the part which man plays shows a tendency to increasing return (318)."

One hundred years later, Nature has lost. Man, by all accounts has succeeded in turning increasing returns to his advantage, and our "New Economy" is the supposed proof of it. The questions have changed little, yet they now take on seemingly rigorous clothing of advanced mathematics. It is in this setting that Paul Romer, macroeconomist and chief representative of "New Growth Theory" can look back at Marshall and make some rather incredible claims concerning the existence of increasing returns to scale.[37] Contemporary mainstream macroeconomics, of which Romer is a part, places the origin of its mathematical models of economic growth with Robert Solow in 1956.[38] Solow's model of growth made use of aggregate production functions to model national and international economic growth. The context and conflict that surrounds the creation of such a model had everything to do with ideological ideas about growth, stability and governmental intervention. Cold War discussions in economic growth theory were inevitably concerned with every kind of fluctuation, especially any that might give signs of something like the 1929 disaster. Keynesian economics and its government interventions were backdrop while the successes of Arrow, Debreu and McKenzie's formalization of general equilibrium models offered motivation, insight and strategic blindness. Together they make for an epic play, and the economics profession likes nothing more than the theater of its own development. However, by the eighties, growth came to mean more than local fluctuations. Development economics, international trade and finance

[37] It's unclear whether the label "New Growth Theory" merits repetition (or whether it is the theory or the growth that is new), since Romer's interventions consist mainly of two papers: "Increasing Returns and Long Run Growth," *Journal of Political Economy*, 1986, vol. 94, no.5, p 1002; and "Endogenous Technological Change," *Journal of Political Economy*, 1990, vol 98, no.5, pt 2. p. S71. It has, however, been consecrated by that organ of cultural and ideological verification *Wired* Magazine, in an article by none less than Editor Kevin Kelly called "The Economics of Ideas," 4.06, June 1996. All references here are to "Endogenous Technological Change" unless otherwise noted.

[38] Robert Solow, "A Contribution to the Theory of Economic Growth," *Quarterly Journal of Economics*, 70, Feb. 1956, p.65.

economics and business cycle theory all diverged in interesting ways from these cold war attempts.

Solow's model simplifies in a very significant and important way. Capital, labor and raw materials make up the production function that feeds the aggregated economy, but there is an exogenous factor, something generally treated as if it came from the sky, or at least the government: *technology*. In formal terms it is an 'exogenous' good. Here, the question of technology is yet unanswered, in any sense. It is Romer who makes the question of technology a *technical* question. His intervention is simply fascinating.

First, a warning. Reading Romer is vigorous exercise in momentous frustration. There are the standard, thick and generally impenetrable *non-sequiturs* that engulf the entire project— constant appeals to the authority of efficiency, competition and optimal allocation; unsolicited opinions on the just operation of price mechanisms, the effectiveness of unregulated foreign investment, and the backwardness of developing nations. This is however, more than ideology, and less than science, and must remain the frustration of an unwritten critique that would explain what can go unsaid in economics, but not outside it. Second, there the problem of formality, ambiguity, vagueness— in short, of *communication.* This is related to the first quasi-ideological problem: the self-definition of economics must insist that it is a true science, and to do this, must employ math. To give you a taste of the distaste Romer has for the non-mathematical:

> As a formal or mathematical science, economics is still very young. You might say it is still in early adolescence. Remember, at the same time that Einstein was working out the theory of General Relatively in physics, economists were still talking to each other using ambiguous words and crude diagrams. [39]

In fact, Romer's fear of the ambigous is downright neurotic:

> The growth guys talked math; the development guys still talked words. They diverged further and further apart because they could not understand each other.
>
> ...
>
> I have found it tough going. It is really hard to tell what guys like Schumpeter are talking about (laughter).
>
> ...
>
> But it is very hard to tell, quite frankly, when you go back and read economics that is stated in purely verbal terms. There is always the danger that you read between the lines and say, oh, they had it exactly right — here is this mathematical model which shows what they were

[39] From an interview with Paul Romer in *Conversations with Leading Economists: Interpreting Macroeconomics,* editedby Brian Snowdon and Howard Vane, Northhampton MA: Edward Elgar, 1999.

> thinking. But that is usually based on a charitable reading and one that ignores some of the ambiguities and confusions. [40]

Given this neurosis, it is perhaps unsurprising to discover just how confused Romer's own thinking is. Were it possible to write— but is that already the wrong word?— entirely in mathematical notation, possible to plug that vague dyke with a thousand sophisticated mathematical fingers, one suspects Romer would try it. Until such date, words will have to do. I will, in turn, in a very uneconomic manner, also try to be *charitable* to Romer. End warning.

Romer's intervention concerns the nature of 'technological change'. According to Romer, all previous macroeconomic models of growth, beginning with Solow depend on the existence of technological change. They assume that without it there would be no such thing as economic growth; there would be only the tedium of constant inefficient production. But all of these models, such as Solow's, have left technical change a mystery, a function of basic research, government funding, and a kind of ideological faith that 'technology drives growth.'[41] Romer wants to specify this: it is a result of active, intentional decisions by profit-maximizing agents. Romer is an anti-'technological determinist.' Technology does not determine anything— history, society, or economics— it is an input into something, that for the moment will have to remain even more mysterious than technology ever was: 'growth'.[42]

Before assessing what this means, we should attempt to clear up what technological change means to Romer: "improvement in the instructions for mixing together raw materials.(72)" All technical change is simply an improvement in efficiency. The string of associations that justify efficiency do lead to justice, not only to profit, yet what is significant about this attitude towards technical change is that it is fundamentally a question of R&D. (Parenthetically, I think it's safe to say that this notion of techno-scientific research is exactly the same as Heidegger's, encompassing both the attitude of systematic *berechnen* that makes up science, and the 'putting in reserve' that constitutes the relationship between man and nature).

Lest 'profit-maximizing agents' or the role of research be misunderstood, Romer clarifies: "This

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[40] ibid.

[41] Not that these things were by any means underspecified, only that in making technological change exogenous to a model of growth or to a production function, it makes it something whose development and provision is not under the control of humans.

[42] This is perhaps also a 'technical question' as the easy answer is that growth is simply 'change in per-capita GDP,' but this is another sealed can of worms, too much for this footnote.

does not mean that everyone who contributes to technological change is motivated by market incentives. (72)" Rather, he is concerned only with the use of technology as an input, and with the fact that regardless of whether science should or shouldn't be motivated by market incentives, people nonetheless make explicit and careful decisions about investment in research.

Now Romer has warned us against "reading between the lines" when looking at a "purely verbal argument"(though he also urges us elsewhere in the same interview "to look between the lines of that paper [his 1986 paper] at what was going on at the methodological level,"). Now, I have no intention of evaluating the soundness of Romer's mathematics here, but it is safe to say, in all charitableness, that regardless of how sound his math is, Romer is *unable to distinguish* between technology, knowledge, instructions, designs, recipes, and learning. Words are cruel to Romer, who so fears ambiguity. He mounts a defense that rallies impossible synonyms together to witness the anointing of new technical terms that allow conclusions that wouldn't otherwise follow.

Part of the problem, the most interesting part, is that Romer cannot think clearly about thinking. For Romer, technology is knowledge, but knowledge is not technology. In the paper we are reading here ('Endogenous Technological Change'), he defaults first to 'instructions', which then become 'designs.' Throughout, even though he uses the word *knowledge,* he insists that technical change means only the reorganization of matter. We are all, in some strange way, *bricoleurs* in Romer's world, constantly reorganizing things into better, more valuable, more efficient configurations.[43]

Thinking, then, could be an attribute of the accumulation of instructions, and have very little to do with humans. Thinking can be reduced to the activity of trial and error, based on the accumulated archive of existing instructions. Yet humans (or not quite humans, rather, 'human capital' which is not so much a 'man without qualities', as 'qualities without a man'), are still part of this model. Romer can make only the following promise in a premise: "the third and most fundamental premise is that instructions for working with raw materials are inherently different from other economic goods... This property is taken to be the defining characteristic of technology.(72)"

Even if *technology* has such a defining characteristic— a defining characteristic which simply that it is different from other goods— this does not yet say what it is, or where it is, or whether it is different than *instructions*. For this, Romer must conscript some technical terms to battle ambiguity: they are

[43] Indeed, Romer is very found of thinking combinatorially. His examples often include combinatorial chemistry, or continuous quality improvement, or other models of trial and error, for which the metaphor of natural selection inevitably suggests itself. His favorite example is that of a truly efficient milk-production facility: the cow.

rivalry and *excludability*.

"Rivalry is a purely technological attribute.(73)" This won't help, to replace vague terms with definitions that use vague terms. Technology here returns to the status of attribute, rather than subject of attributes, in this definition. Nonetheless, there is some sense here: that a good be rivalrous means that only one firm/person can use a good at one time: Either I drink the beer, or you drink the beer. Non-rivalrous objects know no such limitations: we can both make beer from the same recipe at the same time, and have twice as much beer. Non-rivalrous goods, although Romer does not say as much, can scale. However, something that we might common-sensibly call technology, such as a computerized machine for making beer, is in fact rivalrous, and therefore, no longer technology in Romer's world.

"Excludability is a function of both technology and the legal system. A good is excludable if the owner can prevent others from using it.(74)" Excludability can be a function of either the intellectual property system, or a system of copy-protection: you can make the beer only if I license the recipe to you. It is significant that this is a technical *and* legal problem. Of late, Larry Lessig among others has gleefully shirked restraint in revealing the impossibility of such a distinction with respect to the internet.[44] As Lessig has often insisted, the two are in fact difficult to distinguish today under a law such as the Digital Millennium copyright act.

"Conventional economic goods are rivalrous and excludable. Public goods are non-rivalrous and non-excludable.(74)" Presumably, by conventional goods he means beer, and intends to exclude such things as software or movies, which are difficult to imagine as rivalrous. Similarly by public goods, he means things like laws, regulations, scientific formulae etc. and not some things that we might assume were 'public' yet certainly excludable such as parks, roadways, and perhaps, pollution.

Clarity issues from the substitution of these terms for the synonyms of technology, even if their meaning has become so emaciated as to require the life support system of technical terms and mathematical signs to allow them to go on: "Growth is driven fundamentally by the accumulation of a partially excludable, nonrival input.(74)" I.e. growth is driven by technology (or its synonyms). In the course of the article, however, empirical examples erode the graven images that Romer makes from technical terms, and the primary partially excludable non-rival input becomes 'designs' for the production

[44] Lessig, *Code, and other Laws of Cyberspace*, New York: Basic Books, 1999. Also, in order to emphasize that these seemingly highly theoretical issues are not unconnected to the 'real world' it should be noted that both Romer and Lessig have written opinions for the Justice department on the Microsoft case. Lessig as special master, and Romer with respect to the remedies.

of intermediate producer durables that can be used in the production of final-goods (goods that can be either "consumed or saved as new capital," such is the existential world of economics). Romer is in the business of simplification, so there will be no discussion of the market in designs for designs, or instructions for designs, which is left as an exercise for us, the Reader.

Nonetheless, perseverance is a virtue. Romer attempts an empirical differentiation between a design (a non-rivalrous good) and piece of human capital; his example: the ability to add. "The ability to add is inherently tied to a physical object (a human body) whereas the design is not.(74)" A footnote explains that he opted out of the use of the terms "embodied and disembodied" to distinguish intangible things because "embodiment has another meaning in growth theory" which is never explained, and we hope, is not ambiguous. Furthermore

> the ability to add is rivalrous because the person who possesses this ability cannot be in more than one place at the same time; nor can this person solve many problems at once. As noted above, rivalry leads to a presumption that human capital is also excludable. Thus human capital can be privately provided and traded in competitive markets (75).

One might have wished for a more example with more meat, perhaps a person with the ability to juggle, or a person with the ability to fire employees with grace. However, simplicity is also a virtue, and the example stands as a periscope that shows us just how perilous the importance of humans become when they are no longer the principle motors of growth.

Romer, however, avers: "Like any scientific concept, nonrivalry is an idealization." What is "unambiguously true" about nonrivalrousness is that the reproduction of, for example, a design is nearly costless, whereas the reproduction of "the ability to add" is just as costly in both cases. "For simplicity, the arguments here will treat designs as idealized goods that are not tied to any physical good and can be costlessly replicated, but nothing hinges on whether this is literally true or merely close to being true.(75)" True. Orbiting truth is the inessential question of whether information is matter or not.

For Romer there are two implications, the impact of which is that nonrivalry is "inextricably linked to non-convexities." The first is that nonrival goods can be "accumulated without bound on a per capita basis, whereas a piece of human capital such as the ability to add cannot.(75)" People die, instructions do not. "Second, treating knowledge as a nonrival good makes it possible to talk sensibly about knowledge spillovers, that is, incomplete excludability." Here, technology has become knowledge again, and the fact that one simply can't keep knowledge from spreading means that excludability can never be complete. Something about the simplicity of these assumptions, clear or not, is extraordinarily

satisfying. Texts, designs, all languages do in fact live on without us.[45] Thus expropriated, accumulation is only limited by physical constraints on the media, which are today, to put it oddly, immaterial. Thus expropriated and immaterial, they are like the flame in Thomas Jefferson's famous metaphor of ideas—incompletely excludable[46]. We can indeed "talk sensibly" about things. Talk, things, sense, ideas.

For Romer however, talking sensibly means the construction of mathematical equations. Specifically models of balanced growth equilibrium. By redefining the intentionally vague notions of technology/knowledge/instructions as partially excludable nonrival goods, and specifically, by treating these non-human, yet non-material goods as something that can never be exhausted, Romer can call on the existence of "nonconvexities" in his models. "Nonconvexities" means just that, that the variable that represents non-rival goods, *A*, is linear, neither convex nor concave functions. The impact is that by giving the model such an input, increasing returns to scale come to depend on the level of non-rival goods input, and growth is no longer restricted to the epic struggle of Man and Nature that Marshall insisted on: "If a nonrival input has productive value, then output cannot be a constant-returns-to-scale function of all inputs taken together." That is to say, it *can* be an increasing-returns-to-scale function.

For Romer, the point has been made many times before, and it is clear that his relatively tiny, but highly regarded audience of growth economists, the problem concerns whether one can treat knowledge as something that exists outside of the bodies of laborers, and if so, how to model such a thing. Previous attempts to solve this problem include Kenneth Arrow's notion of learning-by-doing and the various treatments of knowledge as a public good, whose provision is therefore a process of great mystery and speculation (perhaps it comes from governments and universities, places notoriously unamenable to the analysis of economists). Romer is unsatisfied with these various provisions for a very specific reason: "it rules out the possibility that firms make intentional investments in research and development." His response is to imagine a thing we are all familiar with: what I would call, under an imperative to use its old name, *writing*, rather than any of the synonyms that Romer uses: technology, knowledge, designs, instructions. Writing is what Romer calls a partially excludable, non rival good: it is material, but easily transmitted; it is 'usable' by each who possess it, regardless of who else does; it is something difficult, but

[45] Why the ability to add does not is yet another fascinating question beyond the bounds of this paper. Perhaps the most extended and sophisticated discussion is in Husserl's *Origin of Geometry* and Derrida's introduction to it. They both treat the question of how ideal objects such as 'the ability to add' must be transmitted and how they come into to being. But we stray from Romer's simplifications if we think to much on it...

[46] Thomas Jefferson's famous metaphor: "Its peculiar character, too, is that no one possesses the less, because every other possess the whole of it. He who receives an idea from me, receives instruction himself without lessening mine; as he who lights his taper at mine, receives light without darkening me." in *Writings of Thomas Jefferson, vol. 6*, H.A. Washington, Ed.,1854, pp. 180-181.

not impossible, to keep others from possessing, yet is the property of no one in particular. Romer's intervention is to turn it into a calculable input in a model of the economy, and give it a name that only Jacques Derrida could love: *A.*

> The model used here separates the rival component of knowledge, H [human capital as years of education and on the job training], from the nonrival, technological component, *A*. Because it has an existence that is separate from that of any individual, *A* can grow without bound (79).

It has become, however precariously, a *technical* question of scalability.

Epilogue: The matter of a fact

Some words are bullies. Push you around, take your money. And why? Because they can. *Fact* is such a word. It's meaning, in fact, is almost never at issue, because it is so easily and commonly used to force an issue. That's a fact. There's no disputing it. It picks on many an antonym- fiction, value, opinion, fantasy, falsehood, myth— and gets along with few. Comes with illustrations (facts and figures) and frightens Victorians (facts of life). Actually factually speaking, *fact* in the OED starts out as a doing, a deed: 'before and after the fact.' Doing and deeds, as we know from J.L. Austin, have a somewhat tortured relationship to Truth, requiring things like felicity and force to stay happy.[47] Let me repeat something our economist has asserted with respect to matter and truth:

> For simplicity, the arguments here will treat designs as idealized goods that are not tied to any physical good and can be costlessly replicated, but nothing hinges on whether this is literally true or merely close to being true.(75)

Do facts matter? Do they have matter? Does the internet matter? Does it have matter? What I have traced through the word *scale* and the seemingly impossible idea of something being big and small at the same time— scalability— is this question of the matter of fact. In some twisted way, Romer is absolutely right, increasing returns to scale *do* exist. He is wrong however to suggest that 'nothing hinges' on the truth of their materiality. In a very important empirical sense, Romer's conclusions about growth have very serious implications for how we think about things like copyright and patent. The excludability of these things is a pure question of power that means everything to the so-called 'developing' world, much less any other economy interested in growing. Excludability is a question of copying. All over the world, right now, internet companies are copying what American companies have done: Amazons, eBays, c|nets, pick your poison. In Romer's world, this might have once been called 'technology transfer'— the designed

[47] J.L. Austin, *How to do things with words,* Cambridge, MA: Harvard University Press, 1962.

sharing of technical knowledge (patents, designs instructions— or shall we just call it writing, and to what end?). This might have made sense, given geographic, political and technical distance, but now the copiers compete with what they copy. Romer's gigantic model provides a way to make this activity calculable, but every case, there will remain the question of the materiality of technology, or of knowledge, or simply, of writing. We live in a model full of worlds.