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# A MODEL OF THE TECHNO-ECONOMIC SYSTEM

## What is a "system"?

System: "..an inclusive organization of many and diverse interlocking ... processes, **interdependent** and balanced among themselves in such a way that the due working of any part of it is conditioned on the due working of all the rest."[1]

Systems are arranged in **hierarchies**. Every system contains a number of subsystems and is itself a subsystem of a larger system (see Pirsig in *Zen and the Art of Motorcycle Maintenance* for a succinct example).

The third important characteristic of a system is **feed-back**. This is the mechanism through which one part of the system acts upon other parts. In general terms, feed-back is the coupling of the output of a process to the input. In negative feedback a rise in the output level of some variable causes a reduction in the input level. The domestic thermostat is a physical example; the law of diminishing returns is a social example in the field of economics where increase in the production of a commodity causes market saturation and reduced profit margins and leads to cut-backs in production. These can be called self-limiting systems.

In positive feedback, a rise in the output level of some variable causes an increase in the input level. Power assisted brakes or steering provides a physical example. A socioeconomic example is provided by the placement of a new software program in the market at or below cost; as more people acquire it, ever more hear about it and need to have it. A demographic example is provided by population growth as a result of improved sanitation. These could be called self-reinforcing systems.

Over time all self-reinforcing systems become self-limiting, either gradually or through collapse.

It is important to observe that the terms "negative" and "positive" have a purely mathematical connotation in this context. They do not imply moral judgement or social benefit/disbenefit. A positive feedback mechanism such as that giving rise to population growth may be most undesirable with very "negative" long term social consequences. For that reason, the terms "self-limiting" and self-reinforcing" are preferable for use in a social context. The subject of feedback is more fully discussed and illustrated with examples in an Appendix to this lecture.

Many systems, including the techno-economic system which is our particular focus of study, are self-organizing. This is a concept that has emerged from complexity studies, although it is already implicit in the idea of "the invisible hand" which the father of modern economics, Adam Smith, introduced in order to explain the workings of the Market. We may expect a paradigm shift from Systems Theory to some new theory (pattern theory?[2]) incorporating Chaos Theory and Complexity theory.

## Industrial Society as a System

An advanced industrial society is a system consisting of two principal subsystems: the social-and-institutional and the techno-economic[3]. A special section later in this chapter is devoted to the institutional complex known collectively as "the State". The term "techno-economic" refers to the fact that technology and the economy are indissolubly

linked in our social system. Winner's term "socio-technical systems" is even broader in its embrace and I have no quarrel with it: the "socio" part obviously includes the economy. Leading scholars[4] in the field of metatechnics insist on this term..

The intimate union of technics and economics has been recognized at least since the time of Karl Marx. His was not only an economic but a technological conception of history[5]. In Canada this union was apparent since the earliest studies in technology by Harold Adams Innis. For the United States it is noteworthy that in 1950 Life magazine published a mid-century issue in which economic history was reduced to the history of technology. The overarching purpose of a capitalist system is to produce the most rapid possible increase in the rate of production of artifacts and cultural goods expressed as growth in GNP.[6] and, in recent years, technological innovation has been assumed to be the engine of growth. It is appropriate at this point to insert a cautionary quotation from Simon Kuznets, the architect of the GDP, who observed that "The welfare of a nation can scarcely be inferred from a measurement of national income as defined (by the GNP). Goals for 'more' growth should specify of what and for what."[7] Needless to say, they seldom are.

## The circuit of capital

The diagram fig. 107 shows the circuit of capital. Since it is a circuit, it can be entered at any point. One cannot say that the process starts with consumer demand, since consumption at an appropriate level occurs in a pre-capitalist society. The essence of a capitalist society is that, in accumulating capital, production and its necessary complement, consumption, are maximized without any planning ("as if by an invisible hand"[8]) At least, that was the claim of the nineteenth-century economists whose theories still dominate the profession. It is certainly true that capitalist economies produce a volume of goods and services that command economies have been unable to equal.

## Production

"Economic production can be ..viewed as the process of upgrading matter into highly ordered (thermodynamically improbable) structures, both physical structures and information....[W]here one speaks of adding value at successive stages of production one may also speak of adding order to matter through the use of free energy. (available work)."[9]

This **transformation is a partition**. (Fig. 108 ) The cost of producing the highly ordered product is the co-production of some less ordered matter. The energy is degraded to a higher entropy state - a state of greater molecular disorder which is less useful, or even useless. The output of such a process might be described as in-formed or ordered matter and de-formed or disordered matter which we call waste. In an isolated system, disorder increases with time but our system is **open** to the sun which provides us with (limited) renewable energy.

The principle of partition is of fundamental importance to the problem of sustainability. Technical efficiency can change the ratio of useful product to waste - it cannot change or eliminate the principle.

It is an unfortunate characteristic of the system that, in order to maximize profit and remain competitive, industry, while keeping control of the good things (goods), must strive to dump the inevitable bad things (bads) into the public domain. This is called "treating them as externalities"[10]. These bads then become social costs and there is no incentive on

the part of industry to reduce them. The production process therefore gives rise not only to products (goods), but to waste, and social costs (human and physical). These have to be dealt with (forestalled by legislation or mitigated) by the State. The power of the State thus tends to expand (see below).

## Consumption

For the production process to continue, the goods have to be consumed. This too is a form of partitioning and produces inevitable bads which we may also call social costs. They include health costs, addiction, crime and so on in addition to further waste.

A paradox develops because technological change designed to cheapen consumer goods may replace workers with machines and thus reduce their purchasing power. This is a negative feedback, i.e., self-limiting, effect.

The consumption of the goods gives rise to satisfaction for the consumers and profit for the owners of capital.

In the ideal circuit, this profit would be reinvested as capital for another round of growth.

In fact, part of it has to be diverted to the state, in the form of taxes, to deal with the social costs which were externalized in the production process. For example: to pay unemployment insurance to those thrown out of work by new technology; to clean up polluted rivers; to plant eucalyptus groves where there used to be forests etc.

Another part is diverted from useful investment into conspicuous consumption, gold-plated bumpers, currency speculation, junk bonds, trophy salaries etc.

Profit itself is subject to the law of diminishing returns under the pressure of competition. As a result, then, of lower profits, diversion to non-productive activities, and increased taxes, insufficient capital becomes available for growth and the process tends to come to a halt. This is a complex negative feedback effect.

There are several ways out of this. Josef Schumpeter, the great economist, showed how entrepreneurs were able to team up with inventors, develop new technology and with it attract some of the wealth back into circulation with the promise of even greater profit. In the lectures on innovation we shall see this process in action. Other traditional ways of getting the economy moving are to open up new markets (19th C.) or to join a war (1939).

## Technology and the state

At several points in the above discussion, I have made reference to the growing power of the state, in other words to the close coupling between the techno-economic system and the socio-institutional system. In this section I shall elaborate on the role of the State.

John Kenneth Galbraith[11] has specified five conditions of the growing industrial system (capitalism plus technology) that gave rise to increased state intervention:

| NEW CONDITIONS | STATE RESPONSE |
|---|---|
| Industrial development and urbanization replacing full employment agriculture | Unemployment compensation |
| Advances in medical knowledge and in surgical procedures | Medicare |

| | |
|---|---|
| Great proliferation of goods and services in consumer society | Governmental regulation of trade and commerce |
| Mass production's effects on the environment | Environmental regulation |
| Mass migration to the cities | Welfare |

Galbraith points out that these state interventions were not the result of liberal ideology but of necessity in response to industrial development.

Galbraith did not cover the more recent phenomenon of "the welfare corporation" -- the enormous apparatus of government subsidy to business. The State, which has already assumed responsibility for the externalities, is under constant pressure from business interests to assume responsibility for capital generation too. In the United States, the role of the Defense Industry as a general supplier of capital to industry is well known. In Canada a favourite channel for this is the megaproject. Billions of dollars of taxes are siphoned off into these, which almost without exception prove to be economic disasters for the country but sources of still more wealth for those who egged them on. Subventions on a smaller scale are part and parcel of every political platform. In early 1995, loans to small business were the flavour of the month. By the end of the year a Superfund was being discussed, to hand out largesse to defence contractors in Canada.

There are of course legitimate channels for state intervention, mainly in the fields of education and training but they do not prove very popular with business governments since they operate over a time-frame with which the managers of large enterprises are unfamiliar.

There has, since the nineties, been a growing backlash against the growth of the regulatory functions of the state. Actions to protect the environment are regarded as threats to the economy (just as they are regarded as threats to "jobs" by organized labour). The following effusion puts it well[12]:

> "..the underground state, the vast array of bureaucrats, politicians, enviro groups and industry representatives who are constantly and secretly beavering away on new plans to load more costs on an unsuspecting public.
>
> Recycling rules, hazardous product regulations, site cleanup laws, new substance bans, zero-chlorine targets -- in all areas, governments are continuing to build up regulatory burden, at huge costs in jobs and growth."

In the United States the world-famous Office of Technology Assessment was abolished in 1995. Canada's Environmental Council had already been abolished by the Mulroney government.

Moreover, there are technological forces at work to destroy the power of the state - a situation not foreseen by the pioneers of metatechnics. The control of the state over global financial transactions has vanished overnight with the development of the network of high-speed communications. A former British Foreign Secretary wrote:
"Year by year technology is removing sector after sector of modern life from the control or even the guidance of the nation-state. Politicians who pretend otherwise are a fraud."[13]

The following quotation is from two avant-garde Canadian critics[14]. I regret that I cannot provide a translation:

***The Disappearing State***

> Under cover of the GATT negotiations, with their ideological recuperation of the obsolete dogma of "free trade" (itself a mise-en-scène for the disappearance of merchandise capitalism), a struggle is waged to destroy the internal integrity of the interventionist state and to free up labor as a fully mobile, fungible and, hence, virtualizable commodity. Here, the liberal-democratic compromise of the "welfare state" is swiftly and decisively pushed aside in the interests of the virtualization of economic space. The state that cannot plan in the interests of its own social economy and that cannot act on behalf of its own political economy is also the disappearing state. It is a perfect subordination, therefore, of the manufacturing phase of capitalism before the transnational interests of process economy, of (local) property before relational knowledge, and of bounded political sovereignty before the primogeniture of the recombinant commodity.

The foregoing discussion has put the spotlight on the political and economic aspects of the techno-economic system. Let us turn now to the technical side of things.

The diagram (fig. 106) shows the interconnections between the principal subsystems of the techno-economic subsystem.

## The endowment

Each generation arrives on this Earth with a dowry or patrimony --our endowment. And like any heir we have the choice to squander it, to preserve it or even to increase it for the enjoyment of future generations. There are two broad categories of endowment. The natural, divided into the physical spheres and the biosphere, and the artificial or technosphere.

On the whole, the sphere of nature contracts and the sphere of artifice expands. It is now widely believed that we are drawing on the natural endowment at a dangerous rate. Not just using it by breathing the air, but polluting it so that it is unbreatheable. Not just drinking the water but fouling it; not just eating the animals but exterminating them. There is no need to belabour the point.

On the other hand, the Technosphere is a domain of net accumulation. We accumulate capital goods, artifacts, and knowledge, both theoretical and practical, including every aspect of technique; and we accumulate the symbolic goods that constitute the arts and letters.

## Transportation and communications

The lines joining the boxes on Figure 106 represent the movement of matter, energy and information between one part of the system and another. In the classic studies of "Communications" by the Canadian historian Harold Adams Innis, both embodied and disembodied types of communication are included. Many of the information links are "closed", which means that they involve feedback loops. Others are "open". An "open loop" is a control system in which actions are made without reference to the present output of the system. The technology of communications is a huge subject and right at the centre of modern social problems. A chapter is devoted to Information Technology but a chapter in Transportation has yet to be prepared. This is a very serious gap, considering the enormous social impact of the railway, the automobile and the airplane.

## Social-Institutional system

A similar systems network must be imagined for the social-institutional subsystem. A complex network of information channels (feed-back loops) links the two subsystems

into a model of society.[15]

### Missing elements in Figure 106.

In order not further to clutter the diagram, a number of important elements have been left out. They include the following:

1. **Money, credit and finance**. These comprise an ensemble of cultural techniques that facilitate the accumulation and flow of material, energy and knowledge throughout the system. In general the flow of money is in the reverse direction to the flow of goods. These instruments are essentially repositories of information. Their role as speculative commodities is secondary.
2. **Motivation or will**. Without the human impulse the system would be frozen in time. Although much of the system is becoming automated, human will is still essential for its functioning and determines its effectiveness. Maynard Keynes referred to "animal spirits" as a primary motivator of capital accumulation.[16] They seem to wax and wane without obvious cause. It must be remembered that "the economy" can be thought of as a vast collection of beliefs or hypotheses forming "an ocean of ever-changing predictive models of the world."[17]
3. **Creative impulse**. The system is dynamic rather than static because of the constant interjection of novelty, generated by the human psyche. Arrow points out that: "Innovations, almost by definition, are one of the least analyzed parts of economics, in spite of the verifiable fact that they have contributed more to per capita economic growth than any other factor" (Rosenberg might argue that organization may have contributed more). These innovations are heavily dependent upon conditions fostered in the social-institutional system (compare Japanese small improvements with Euro-American leaps).
4. **The sport and entertainment industries**. These very important industries have an equivocal status. Are they ends for which all other activities exist -- in other words, part of the consumption system? Or are they part of the repair system -- Re-creation?

## Production subsystem.

The heart of the techno-economic system is the production subsystem which can be thought of as consisting of millions of transformation cells within which matter is transformed (undergoes a change in form or state) as a result of the input of energy and knowledge, using capital goods as means. (Fig. 109 "Material Transformation Subsystem")

### Inputs

The inputs to the production system are traditionally known as "factors of production." Originally, they comprised "land, labour and capital." In modern terms, suited to a study of technology, the inputs to this system are:

**capital goods (factories, machines)**
**material (raw, or processed in a prior cycle)**
**energy**
**mental capital or technique (knowledge, data, theory, skills or dexterity and organization)**
**motivation**

Note that in this schema the factor called "labour" in classical economics is divided

into an energy component, a knowledge and skill component and a motivation component. Whereas in the Industrial revolution the energy component and the skills associated with dexterity were decisive and led to Marx's labour theory of value, in post-Industrial society knowledge and theoretical skills are predominant. In all stages of human development, the presence of motivation is an absolute necessity. Organizational skills are characteristic of authoritarian technologies. Self-motivation is characteristic of holistic technologies[18].

The source of the capital goods is the technosphere or built world accumulated as part of the Factor Endowment[19] of a specific society.

The source of the material is either the physical endowment[20] (comprising the atmosphere, hydrosphere, lithosphere); the biological endowment (biosphere); another transformation cell producing intermediate goods; or the repair subsystem producing recycled goods.

The source of the energy is either the sun (directly as in solar heating, fruit drying; indirectly as in biomass, wave and wind power and hydro), the moon (tidal power), the deep crust (geothermal), or the shallow crust (fossil fuels, fissionable minerals).

The sources of knowledge include: the Information component of the Factor Endowment comprising the stored outputs of the following: the knowledge factories that form part of the social-institutional subsystem (research labs, universities); and personal creativity at all points of the human-technics interface.

### Output.

The outputs of a transformation cell are:

**artefacts** in final or intermediate form, including:

**capital goods** that will reproduce and accumulate i.e., augment the artificial factors of the endowment of the society. (note that production must exceed consumption for accumulation to take place.)

**commodities** both material and symbolic that will be **consumed** for the re-production of the human race.

**commodities** that will go to **waste**

fashion

armaments

**human waste**: people damaged by industrial accidents, pollution, psychic damage by work conditions, simply used up. These are the human equivalent of entropy at the molecular level. They are the social cost of the production system.

**waste matter/energy** that has no further utility for the process to which the transformation cell is dedicated. This material, having less order than the input to the system, may be said to have **lower utility** or, if the disorder is molecular (as in the case of chemicals such as rust or energy) we can say it has a **higher entropy**. It includes gases, liquids and solids all requiring greater or less treatment by passing through the repair subsystem. Much of the lost utility is in the form of energy converted into low quality heat not available as a useful re-input to the system. This heat is generated by mechanical friction, electrical induction, exothermic chemical reaction etc..

**waste capital goods** including machinery rendered obsolete by technological change.

**waste knowledge** in the form of obsolescence, lost arts and forced retirement.

The output of a production subsystem becomes the input to one of the following:
the artificial endowment (technosphere) in the case of reproduced capital goods.
another transformation cell (in the case of intermediate goods)
the consumption system
the repair system
wastage sinks (material, thermal, human)

## The consumption subsystem

This subsystem consists of billions of consumption cells. Inputs include energy (heating, cooking, shopping etc.); knowledge (skill in food selection and preparation, domestic arts generally); capital goods (appliances) and artifacts from the production subsystem and food (raw and processed) from the provisioning subsystem. Note that knowledge is unique in that it is not used up in the process of being consumed. In fact, it is nearly always enhanced through the experience of being applied.

**Outputs** include: psychic satisfaction
diseased or addicted bodies and minds
sewage
garbage and other forms of waste
waste heat (entropy) in large quantities from all activities including human metabolism. The utility is consumed and the entropy excreted from the subsystem. [Other subsystems could be added].

## The repair system

In the course of producing and consuming the goods and services of our economy, harmful products and effects are also inevitably produced. The repair subsystem is an essential part of the total system. It comprises:

- the prison system and its auxiliary legal and social activities utilizing increasingly sophisticated technologies of surveillance and control
- the hospital system and its associated health care activities concerned with repairing bodies ravaged with diseases (mental and physical), many of which are the direct product of industrial activities.
- the social welfare system.
- material recovery systems concerned with re-use and recycling. Included are pollution control systems aiming to reduce the inputs to the recovery system.
- toxic waste management systems have to be established to deal with materials that cannot be recycled. This is a field of growing technical sophistication.

Other subsystems listed below will receive some attention in the chapters devoted to energy, (Energy Supply and Demand); agriculture (The Green Revolution), Information technology, and genetics (Human Reproductive Technology)..

## The energy system

## The provisioning system

## The knowledge system

## The genetic engineering system

### Appendix on Feedback (UNDER CONSTRUCTION)

In general terms feedback simply means **the coupling of the output of a process to the input**. In negative feedback a rise in the output parameter causes a lowering of the input parameter. In positive feedback a rise in the output parameter causes a still greater rise in the input parameter. The first table shows the meaning of feedback by means of mechanical examples.

| Device | Sign | Output behaviour | Input behaviour |
|---|---|---|---|
| Domestic furnace thermostat | negative | Room heat exceeds reference temperature | fuel supply to furnace reduced |
| Power assisted brakes | positive | hydraulic fluid fed to brakes under pressure | weak mechanical force applied to brakes |
| Watt's governor | negative | angular velocity of governor raises a mechanical linkage | steam valve closed |
| Electronic amplifier | positive | output energy rises/falls | energy of earlier stage is caused to rise or fall |

In the following table analogous examples are taken from sociotechnical systems.

| System | sign | Output behaviour | Input behaviour |
|---|---|---|---|
| Infant mortality | positive | Mortality reduced, by supply of fresh water. Population increases | Breeding stock rises |
| Technology development | positive | increased technology and wealth | increased R&D |
| Synergistic combinations | positive | increased number of combinations | increased number of possibilities |
| Technological innovation | positive | increased number of innovations gives rise to increased number of problems requiring fixes | Increased number of required fixes generates increased number of innovations (safety devices and remedial technologies) |

| | | | |
|---|---|---|---|
| Innovation | negative | consumption of increasingly large amounts of risk capital. Creation of increasingly costly externalities (pollution etc.) | scarcity of risk capital, and use of available capital for environmental protection reduces funding of potential projects |
| Resource development | negative | unsustainable rate of extraction reduces resource base | unattractive rate of return reduces investment: substitutes are developed. |
| Invention | negative | increasing sophistication drives up research costs | drying up of research funds lowers rate of invention |
| Invention | negative | technological impulse drives research into economically unproductive spheres e.g. space, star wars. | risk capital becomes unavailable for productive investment |

Since the analogy between socio-technical systems and purely mechanical systems is not always perfect, and because the moral value of a positive reinforcement is often negative, it is better to speak of self-reinforcing and self limiting socio-technical systems.

The total techno-economic system is, in the short term, self reinforcing and, in the long term, self limiting. Some self-limiting occurs in the short term as capital and knowledge resources are temporarily used up and before substitutes can be developed.

## Self-reinforcing tendencies

It is self reinforcing in the short term because of

1. The beneficent (or "virtuous") spiral of wealth creation

Only rich economies can afford the forced obsolescence (a form of waste) which is a necessary condition for rapid technical change, leading to greater wealth production. Heilbroner, paraphrasing Adam Smith says "Thus technological advance is not only conceived as a basic source of technological progress, but one which is continuously refreshed by the consequences of progress itself."

2. The self-reinforcing nature of technological imperfection.

Every new technique requires technological fixes and remedial technologies: air bags, helicopter ambulances and emergency wards.

3. The self-reinforcing nature of complementary products.

The stereo player gives rise to music recording studios, specialist magazines, racks and holders, new types of amplification, as well as the discs. Cameras called for developing and enlarging technology; production of specialized magazines etc. Video recorders give rise to the videotape industry. The building of the information highway will call for the production an enormous amount of specialized material, entertainment,

educational etc., much of it using new technologies, to generate the income required to sustain the system.

4. The growth of enabling technologies.
As explained by James Beniger (Teich, 6th Ed. p.61) "each new technological innovation extends the processes that sustain life, thereby increasing the need for control and hence for improved control technology" these include
(i) technologies of control through information processing and communications
(ii) the concomitant growth of technologies for information storage and retrieval.
(iii) Their elaboration in systems of technical education.

5. Exponential growth of combinatorial possibilities.

This was rather well put in general terms by Spengler fifty years ago (p.70 ) " it is an essential characteristic of the personal and modifiable technics of man,.... that every discovery contains the possibility and necessity of new discoveries, every fulfilled wish awakens a thousand more, every triumph over Nature incites to yet others". More self-reinforcing feedback.
More specifically, if you have two technical objects like a telephone and a computer they may be combined to make a third, the network. With three objects like a computer, a telephone, a copying machine, you can get a fax (telephone plus copying machine), a laser printer (computer plus copying machine), a network. The complex technical objects may themselves be combined to give newer yet more complex objects such as a combined fax and voice mail system. Microsoft chief Bill Gates has high hopes for some sort of wallet sized personal communicator combining all these functions with a credit card and bank card. Every combination gives rise to new possibilities of combination. This is one of the meanings of "convergence" - a nineties buzzword.
6. The policy of continuous improvement (kaizen)
7. The self-fulfilling nature of technological prophecy.

Business people are great trend-watchers. Futurists such as Naisbit (Megatrends) and Faith Popcorn (the Popcorn Report) are studied intensely and their findings are used to plan market strategies.
8. Government intervention.
The (probably false) belief on the part of governments that technological innovation "creates jobs": hence its artificial stimulation.

## Self-limiting tendencies

The system has to be self-limiting in the long term because it results in more people using more energy and more material in a strictly finite world. Human beings have to decide whether this limit is to be overshot with catastrophic collapse or whether a soft landing can be achieved. There is serious concern that an overshoot has already taken place.[21]

Historically, some scholars have denied that there is any feedback in the socio-technical system. Lewis Mumford seems to have been the first (1938)[22], followed by Jacques Ellul (1954). However they probably did not recognize that self-reinforcing systems were analogous to "positive feedback". Ellul remedied this in 1988[23] with a chapter entitled "le double feed-back" from which some of the negative feedbacks in the table above were taken.. Meanwhile Arnold Gehlen (1957, trans. 1980) had described

what we would now call feedback as a "Handlungskreis" or "circle of action" - action capable of correction on the basis of its outcome. Here is a list of possible self-limiting mechanisms:

1. Capital shortage

The economy, although accelerated by the ideology of growth, is unable to generate the capital required by an expanding technology. Instead of every new opportunity being exploited, stringent choices have to be made.

2. Diminishing returns of R&D.

3. Growth of non-wealth-generating sectors

The service sector; space industry; and armaments grow at the expense of the Manufacturing Sector of the economy.

4. Consumer saturation.[24]

5. Cost of pollution abatement.

6. Government intervention as price mechanism fails to signal resource exhaustion.

## Review questions

1. What are the two main system components of the modern industrial system?
2. Through what institution does "society" attempt to regulate technology?
3. Describe three self-reinforcing and three self-limiting mechanisms operating in the techno-economic system.
4. Describe the outputs of a transformation cell in the production system.
5. What are the main institutions administering the repair system.
6. What part of the endowment is growing and what part is shrinking?
7. How do "positive", "negative", "self-limiting" and "self-enhancing" feedbacks relate to each other?

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[1]Thorstein Veblen (fide Thomas Hughes "American Genesis" p.247-8.
[2]James Foley in letter to Utne Reader No.73 (Jan.-Feb. 1996), p.8.
[3]C. Perez, 1983.
[4]Bijker & Hall 1992
[5]Jon Elster *Explaining technical change*, p.158
[6] A group of economists centered in Stanford (Kenneth J. Arrow, 1988) is studying "The economy as an evolving complex system"
[7]New Republic, Oct.20, 1962.
[8]Adam Smith in The Wealth of Nations.
[9]Roberts (in Cutler, 1984)
[10]The fact that the Alberta taxpayer has to bear the unrecovered costs of the Swan Hills hazardous waste treatment plant is an excellent example of the meaning of "externality".
[11]Professor emeritus of economics at Harvard. "Blame history, not the liberals." G&M 21 Sept 1995 A23.
[12]Terence Corcoran in G&M ROB 17 Oct 1995 B19
[13]Douglas Hurd, in G&M Oct 16, 1995.
[14]Arthur Kroker & Michael Weinstein *Data Trash*, 1994, p.79.

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[15] Traditionally the social-institutional subsystem has had a very different structure to the techno-economic. This is changing. Ellul`s whole point, in his book *The Technological System* is that the social-institutional system becomes technicized or, if you like, that the technological system expands to embrace part of the social system such as education and religion which at first stood outside it. The technological system is primarily concerned with material production. But, by extension, the cultural system comes to be thought of as engaged in the production of symbols (Sybille Kramer-Friedrich).

[16] Although "Will" no longer has for us the almost mystical character that it did before technology. I am referring to Schopenhauer "The World as Will and Idea" for instance (1819). About that, George Grant (Thinking p.18) has said: "But who has succeeded in laying before us in a convincing unity what it was that gave the Europeans their special destiny, what primal affirmation penetrated their life and thought? Without denial of the unfathomedness of this affirmation, I would be willing to say that Europeans somehow seem to have come to an apprehension of the whole as "will"."
Stuart Hampshire, the philosopher describes the will as pure choice.

[17] W. Brian Arthur in *Complexity*, v.1, no.1 (1995)

[18] Ursula Franklin

[19] Term used by Michael Porter

[20] Giarini refers to the Dowry and Patrimony; this may be a trick of translation.

[21] Meadows, Donella H., Meadows, Dennis L., Randers, Jorgen (1992) Beyond the Limits: Confronting global collapse: Envisioning a sustainable future. Toronto: McClelland and Stewart.

[22] *Vital Speechesof the day*, IV 64

[23] This was apparently unknown to Barry Cooper when he wrote *Action into Nature*, 1991.

[24] "Industry analysts and insiders now talk openly about saturation of the PC market, which means that most people who want - and can afford - computers already own them." "PC workers' screens show limit to sales growth." *Globe and Mail*, 27 Feb. 1996, C7.