Nonlinear Accounting, Concepts and Methods: Macro-Statistics in the Digital Age

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Analogue marco-accounts of the state, and change of state, of the Nation, such as the SNA, including the (satellite) System of Environmental and Economic Accounts (SEEA), are non-integrable systems. We propose a new direction in development of concepts and methods in macro-accounts made possible by the emergence, and rapidly expanding, world of digitisation of data and the algorithms of nonlinear processes. The logic and the mathematics to construct nonlinear accounts, while still speculative, lies in unlocking statistics from its linear prison. The accounts are framed by hierarchical structures assumed by the algorithm of complex, recursive, systems and 'emergent properties of dissipative structures far from equilibrium,' (i.e., inputs ≠ outputs), (Prigogine and Stengers, 1989). At the core is the set theoretic structure of (space-time) data sets of objects and functions representing the dynamics of the (universal) entropic process. The data sets are distinctive with respect to the 'boundary conditions' of: (i) the economic cycling systems of the *Econosphere,* (ii) the social and demographic cycling systems of the Sociosphere, and (iii) the ecological cycling systems of the *Ecosphere*. The data sets, while identified to the 'sphere' by value functions, *exchange, use,* and *intrinsic,* are defined by symmetries in entropic processes (inflow-outflow parameters) and the end point described by the rate of replenishment of consumed low entropy fund, available for human consumption. The latter is the most generalised indicator of sustainability, (i.e., socially acceptable rate of entropy production(, (Mayumi, 2001). The paper explores the feasibility of constructing a system of nonlinear accounts in the 21 Century.

Introduction:

Saramago opening line 'All the Names' is an allegory, perhaps not too far fetched, of the reduction by the modern state of their citizens to a statistic,[1] (see *The Unknown Citizen* in the Appendix). In Saramago's world statistics are reduced to smell, and decay, of old paper:

Above the door frame is a long, narrow plaque of enamelled metal. Th black letters set against a white background say Central Registry Office of Births, Marriages and Death. Here and there the enamel cracked and chipped. The door is an old door, the most recent layer of old paint is beginning to peel, and the exposed grain of the wood is reminiscent of a striped pelt. There are five windows along the façade . As soon as you cross the threshold , you notice the smell of old paper. It's true that not a day passes without new pieces of paper entering the Central Registry, papers referring to individuals of the male sex and of the female sex who continue to be born in the outside world, but the small never changes, in the first place, because the fate of all paper, from the moment it leaves the factory, is to begin to grow old, in the second place place, because on the older pieces of paper, but often on new paper to, not a day passes with someone's inscribing it with the causes of death and the respective places and dates, each contributing its own particular smell, not always offensive to the olfactory mucous membrane, a case in point being the aromatic effluvia which, from time to time, waft lightly through the Central Registry, and which the more discriminating noses identify as a perfume that is half rose and half chrysanthemum.(Saramago, 1999).

The protagonist of the novel Senhor José, inscribes the 'name' and fills-in the blank spaces the *information* of interest to the State. The Registry Office is the *dead archives* of the three most important *events* in the human life-cycle -birth, marriage and death, the latter includes a certified *cause*. This abstract data is an analogue of a real-world event, and thus a *Statistic*. Senhor José removes from the archives, at his peril, one piece of paper which records the *name*, *sex, name of two*

[1] The following observation is attributed to Stalin: "the death of one person is a tragedy, the death of a million, is a statistic."

parents and *the date* and address of *place of birth*. The piece of paper records the name of a girl born 36 years ago? The story is about bringing to life, one statistic, on one piece of paper, in a dusty file!

This Paper "Nonlinear Accounting, Concepts and Methods: Macro-Statistics in the Digital Age" is primarily concerned about space-time events and the corresponding statistical algorithms constructed from real-time, continuous, computerised digital databases. With some stretch of the imagination, Saramago's Registry Office represents the Bureau of Statistics stuck in the analogue method to measure state, and change of state, of the Nation in three fundamental domains, the economic, the social and the environmental. We proposed a shift in the paradigm *statistics* by eschewing the quantitative method without qualities and embracing the qualitative method with quantities. Our objective is to construct a system of I/O accounts of the boundary conditions of processes described in Geogescu-Roegen Flow-Fund Model (FFM), (Geogescu-Roegen, 1971), (see Appendix II).

The data sets are entailed by hierarchical structure of processes representing the domain of the Econosphere, measuring economic events in *money-values*, the Sociosphere, measuring social events in *use-values*, and the Ecosphere, measuring ecosystem events in *intrinsic-values*. The Ecosphere of fast moving events is a proper sub-set of the Sociosphere of slower moving events, which in turn is a sub-set of the very slow moving events of the Ecosphere. The accounts are a mapping of the algorithm of the 'events' in the domain and/or across the domains.

The Algorithm is a device for correspondence mapping of: (i) objects on objects, (ii) objects on functions, (iii) functions on objects, and (iv) functions on functions. The mapping can be either horizontal where the objects and functions belong to the same structural level of the accounts, or hierarchical, where the objects and functions belong to different structural levels. While the former is represented by commutative mathematics, (i.e., the resulting data are indifferent to the order of mapped objects/functions), the latter is represented by non-commutative mathematics, (i.e., the resulting data change with respect to the order of mapped objects/functions).

Macro-Statistics in a Digital World

The Paper, ostensibly a discussion of algorithmic methods to construct nonlinear accounts, offers a glimpse into the future direction of national statistics in topological space, where objects/functions are transformed by the instructions of the algorithm on (computerised) data sets.[2] This may be contrasted to the 'analogue methods' that require the pre-conceptualisation of statistical objects/functions. Thus, the inquirer constructs the database *ad novum,* custom made so speak, for the inquiry. Again this may be contrasted to analogue methods where statistics are constructed by the Statistical and the inquirer develops new data sets through statistical methods, such as correlation coefficients or regression analysis. A familiar example of the capacity of the inquirer to create his/her own data from computerised digital data is the application of 'Google Earth' technology. In essence, an algorithm of a hierarchical structured, user-controlled, 'search engine' for a (pre-constructed) mosaic of digitised spatial data of the Earth's surface. The future Statistical Office, like Google Earth, will offer the

[2] **Topological spaces** are defined as mathematical structures that allow the formal definition of concepts such as convergence, connectedness, and continuity. They appear in virtually every branch of modern mathematics and are a central unifying notion, (Wikipedia)

inquirer the 'search engine' for the constructed real-time databases of the econosphere, sociosphere, and ecosphere.[3]

Accounting objects and functions of 'analogue statistics,' being pre-defined, assume invariants with respect to change in qualities from one period to the next. 'Digital statistics, constructed from more primitive data, permits, in some cases, to monitor feedback loops which may change the qualitative properties of the accounting objects over time. [4] At some point in time, given sufficient difference, the objects/functions may themselves transmute into a different objects/functions. [5] In the world of increasing uncertainty, increasing complexity, and increasing globalisation, the qualitative algorithmic description of the production, consumption and capital accumulation functions is no longer a luxury, but a necessity for the critical assessment of holistic, and sustainable, socio-economic systems, (Funtowicz and Ravetz, 1991).

Data Sets of the Econosphere, Sociophere, and the Ecosphere

National statistics represent a numerical record of the state, and change of state, the Nation. While constructed as a multi-purpose information system, and with exception of economic statistic which are integrated into the conceptual framework of the SNA, the data remain essentially fragmented in subject matter social, (i.e., eduction, health, justice etc.,) and environmental, (pollution, land-use, natural resources etc.,) domains. Further each domain has its own syntax and highly specialised analytical domains. The result that, while there are overlapping domains, the data sets are dependent functions of their own domain. We propose a method of integration by defining a universal domain, and a nested, hierarchical-structured, system of subsets to the universal set. The syntax for the integration across domains is that of entropy production.

We shall define domains in terms of analytical spaces with respect to: (a) economic cycling systems, (b) social cycling systems and (c) the natural cycling systems. We further propose that concepts of the accounting objects and functions be well-formulated in a set-theoretic matrix representing the material stock and flow of: (A) the ECONOSPHERE, (B) the SOCIOSPHERE and (C) ECOSPHERE. Further,

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[3] Statistical Offices routinely collect data from administrative databases in the public sector, and apply survey methods to the private sector and to individuals. Some countries, such as Denmark, no longer collect data on the population and obtain, and thus continuously up-date, data from public sector computerised data files. This, referred to as data mining, is simply a cost-cutting means to produce analogue statistics. What is proposed here is the computerised construction of statistics from any available source.

[4] Analogue statistics a change in object properties require an external reference to reclassify, and/or introduce, a new class of objects. The internal reference of change in qualitative properties is perhaps the most important distinction between analogue and digitised statistics.

[5] The concept of a feedback loop of data in memory influencing the next predicted value of the statistical time series was already anticipated by Allan Turing in 1936 and who formalised in a mathematical model of an automated computable machine as follows: *"...an infinite memory capacity obtained in the form of an infinite tape marked out into squares, on each of which a symbol could be printed. At any moment there is one symbol in the machine; it is called the scanned symbol. The machine can alter the scanned symbol and its behaviour is in part determined by that symbol, but the symbols on the tape elsewhere do not affect the behaviour of the machine. However, the tape can be moved back and forth through the machine, this being one of the elementary operations of the machine. Any symbol on the tape may therefore eventually have an innings."* (Turing, 1948: 31)

the sphere representation enables an accounting system of well-defined 'processes' (flows) and a corresponding 'fund' (stocks) in a three dimensional, nested, space-time structure. [6]

The core accounts, the econosphere, a sub-set of the sociosphere, represent values conserved-in-exchange (or money-value) of objects and functions and are subject to fast-moving events and quick feedback loops. (e.g., stock markets). The sociosphere accounts, a sub-set of the ecosphere, represent values conserved-in-use (or use-value) of objects and functions and are subject to medium-moving events and medium feedback loops, (e.g., educational cycles). The ecosphere accounts, the universal set, represent values conserved-in-themselves, (or intrinsic-value) of objects and functions and are subject to slow-moving events and very slow feedback loops, (e.g., climate change).

While each of the spheres represent a well-defined, and distinct, domain of processes and the corresponding funds, the mapping of values over domains transmute the objects and functions from one, to the other account. For instance, the same set of ecosystem services are intrinsically valued in the ecosphere, but money-valued in the ecosphere. Any intrinsically valued object in the econosphere or the sociosphere, are by this argument, are transmuted into ecological object. At first this may sound weird, but is in the logic of set theory. However, this method of transfer of objects from one account to another makes sense if one considers the value-mapping on human life. The death of an individual in the economic accounts may be recorded as a money-value of a life-insurance to heirs and successors, in the socio-demographic accounts it may be recorded as use-vale at the end-point of an individual's life-cycle, i.e., mortality statistic. In the ecosystem accounts the individual death is treated as a loss of one in the species population. It's intrinsic value is purely genetic, is it passed on to future generations? or has it stopped?

Social and economic analysis apply different value-measures on the same phenomena, natural cycling systems apply the same value-measure on different phenomena. The latter represents the statistics of the material state, and change of state, of systems, (i.e., number, area, weight, volume etc.) whereas the former represents the statistics of the immaterial state, and change of state, of systems, (i.e., exchange-values, use-values, intrinsic-values etc.,).

This paper is a demonstration of the space-time statistical integration in three fundamental domains, which we shall refer to as the: A Domain or the Econosphere, the B Domain or the Sociosphere. and the C domain, or the Ecosphere.

observed in the real-world of complex, adaptive, systems. The distinction, however, should be made between the measurement of physical objects, such as the population in city x, and abstract objects, such as the per capita income in city x. While the latter assigns a subjective human-value to objects, and thus qualitative in nature, the former assigns an objective physical metric to objects, and thus quantitative in nature.

In the digital world, statistics are freed from the rigidity of pre-defined analogue entailed in statistical surveys. While this makes very little difference with respect to physical object measurement, since a rose, is a rose, is a rose, the world of the abstract objects, like income, can be redefined to fit the objective function of the analyst. This paper is a demonstration of the potential to reduce digital

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[6] While hinted in this Paper, the concept of the sphere opens an exciting field of mathematics, referred to as 'topology,' for the construction of (statistical) algorithms of state, and change of state, of complex adaptive systems. This is a study of the spatial properties that are preserved under continuous deformations of objects, for example, deformations that involve stretching, but no tearing or gluing. It emerged through the development of concepts from geometry and set theory, such as space, dimension, and transformation, (Wikipedia).

macro-statistics of economic, social and ecological functions into a set theoretic system of entropy accounts.

What is meant by Nonlinear Accounts?

Nonlinear systems describe discontinuous processes characterised as '*emergent properties of dissipative structures far from equilibrium.'* While Schumpeter (1934) expressed the formalism of nonlinearity entailed by the social dynamics of capitalism, (i.e., creative/destructive process), Prigogine experimented with the fundamental laws of 'thermodynamics' in chemical oscillations to identify, in a formal system, the determinants of 'emergence,' (Prigogine and Glandorf, 1971). The observation that *emergent properties* are entailed, and thus deterministic, in initial conditions of the system, fits well with our hierarchical-structured, three sphere system, of set-theoretic accounting structures. In the (thermodynamic) chemical reactive process the determinants can be controlled under laboratory conditions, this is not the case for thermodynamic, large-scale, entropic processes. The method we propose, in terms of equivalency to the laboratory experiment, is the computerised algorithm of recursive complex systems, (Rosen, 1991). The latter represent formal relationships, and thus well-defined, entailment properties (inference systems) assumed in hierarchical-structured continuous space-time data stream, (Friend and Friend, 2009). The essential accounting concept is to define the bifurcation points, *within the region of instability,* of the boundary conditions of entropic processes. In other words, to predict, in a stressor-response feedback loop the next event in any well-defined continuous data stream.

The region of instability is defined by the resilience of the particular entropic process being investigated, (Holling, 1973). Stability of large-scale entropic processes, like the economy, are structural, and for the most part resistant to small scale perturbations. However, in practically all cases, the great disturbance to the system entail the seeds of destruction in the initial conditions. The problem of large-scale structural stability is described as follows in Prigoginean model of emergent properties:

"... the new constituent, introduced in small quantities, lead to a new set of reactions among the system's components. This new set of reactions then enters into competition with the system's previous mode of functioning. If the system is "structurally stable" as far as this intrusion is concerned, the new mode of functioning will be unable to establish itself and the "innovators" will not survive. If, however, the structural fluctuation successfully imposes itself -if for example, the kinetics whereby the "innovators" multiply is fast enough for the latter to invade the system instead of being destroyed -the whole system will adopt a new mode of functioning: its activity will be governed by a new 'syntax.' " (Prigogine and Stengers, 1984: 189)

The accounting is a linear organisation of data with plus signs (credits), minus signs (debits), difference (balance sheets), multipliers (price per unit), nonlinearity appears in the accounts as limit functions, bifurcation points, and, in the case of non-entropic processes, the sudden appearance, and disappearance in the accounts of *abstract objects/functions*. Like in Lewis Carrol's Cheshire Cat, disappears with only the grin left.

What is meant by Accounts of Entropy Production?

All physical accounting objects, and by extension all physical processes, are subject to the Second Law of thermodynamics. It is a measure of 'disorder' in the universe as a whole and tends towards a maximum. The physical *flow accounts* describe material/energy inflows and outflows across the boundary of any well-defined *entropic process*. The *production function*, both in its biological and mechanical manifestation, describe (local) reversal, and the *consumption function* (local) acceleration, of the *entropic process*. Since entropy production, in itself, is irreversible, the account's objective function is to define, and measure, the net rate, which could be in deficit, surplus or stead-state, of the data sets describing the rate of entropy production for the whole system. [7]Therefore, consumption, in order to be sustainable, must be equal to, or less than, the rate of replenishment of the consumed low entropy fund over some well specified time-period. In emergent systems, the fund itself changes form and physical substance. The physical accounts may thus be viewed as a complex algorithm of renewal, and change, entailed by the I/O parameters of the Leontieff-Sraffa circulating capital model, (Sraffa, 1960, Friend 2005). Note that the great English economist, Alfred Marshall (1842-1924), similarly considered *consumption* as *negative production* and the rate of *entropy production*, while clearly not in his vocabulary, as an entailed property of time, to wit:

> *Consumption* may be regarded as negative production. Just as man can produce only utilities, so he can consume nothing more. He can produce services and other immaterial products, and he can consume them. But as his production of material products is really nothing more than a rearrangement of matter which gives it new utilities; so his consumption of them is nothing more than disarrangement of matter, which diminishes or destroys its utilities. Often indeed when he is said to consume things, he does nothing more than hold them for his use, while, as Senior[8] says, they "are destroyed by those numerous gradual agents which we call collectively *time*." As the "producer" of wheat is he who puts the seed where nature will make it grow, so the "consumer" of pictures, of curtains, and even a house or a yacht does little to wear them out himself; but he uses them while time wastes them. (Marshall, 1920:64).

All abstract accounting objects, and by extension all abstract processes, while not directly subject to the Second Law of thermodynamics, nonetheless decay over time.[9] The reversal process is a function of *service flows* drawn from institutional organisational structure of society, or social regulations, such as property rights, drawn from cultural heritage entailed by social structures. A careful distinction must be made, however, between 'services' which flow from, and are thus proportional to, material world, and 'services' in which inputs and outputs are themselves defined as abstract objects, like financial, administrative, and educational services. In this case, the material inputs of the process is non-proportional to any arbitrary valuation of its outputs.[10] The latter, while free from the direct effect of the entropy law, are not freed from indirect effect, manifest in fear, uncertainty and human psychic satisfaction. Indeed, abstract objects, unlike physical objects, are non-locational in space, and exist only in present time, and memory. The very nature of ephemeral properties identified with abstractions, like confidence in the financial market, allow *abstract objects* to be produced, and consumed, at an instant-in-time.

Abstract objects are distinct entities, with their own emergent properties, in entropy accounts but are lumped into a broad category of the 'tertiary sector' of the SNA.The so-called 'service industry' is defined by its output, (i.e., product sold in the market) which is non-tangible. This primitive definition

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[7] Net entropy production is ultimately reduced to the 'free entropy' available from the solar energy inflow to the planet Earth. Although other sources of 'free entropy' is the heat available at the core of the Earth.

[8] William Nasseau Senior (1790-1864), British economist who wrote on the theory of economics. In his view the verb 'to use' is synonymous with the verb 'to consume.'

[9] Unless one believes in a parallel spiritual world, abstract objects require a material media, like educational institutions, communication and information technology, and, in natural systems, genetic material of individual species, to describe the capacity of the transformation of: (i) *abstract objects* into other *abstract objects,* (e.g., financial transactions), *abstract object*s into *physical objects*, (e.g., price per unit of resource commodities) and *physical objects* into *abstract objects,* (e.g., valuation of resource commodities).

[10] The distinction must be maintained between an abstract object in the material world and an abstract object in the nonmaterial world. In the latter case the proportionality assumption does not hold, in the former it depends on the correspondence relationships. For instance, financial investments (an abstract object) in resource exploitation correspond to a mirror image of some well-defined set of 'entropy production' functions.

of 'services' has its roots in classical economics where distinction was made between the 'product' of the soil, and the 'product' of industry. The latter embodied the value of work (kinetic energy) in the transformation of physical objects into other physical objects, while the former embodied the value of nature (solar energy and the 'free gift' of nature-produced resources). In this schema of the economic product 'services,' while necessary to provide the conditions for the circulating flows of production, consumption and capital formation, or wealth, were unproductive. The original distinctions made by the classical economist between 'tangible' and 'non-tangible' resonate in the distinction between 'abstract' and 'physical' objects and functions assumed in the methods this presentation of concepts and methods in nonlinear accounts.

Adam Smith, in the colourful language of his day, had this to say about the contribution of 'services' to the 'Wealth of Nations:'

> The labour of some of the most respectable orders in society is, like that of the menial servants, unproductive of any value, and does not fix or realise itself in any permanent subject, or vendible commodity, which endures after labour is past, and for which an equal quantity of labour can be procured. The sovereign, for example, with all the officers both of justice and war who serve under him, the whole army and navy, are unproductive labourers .... In the same class must be ranked, some both of the gravest and most important, and some of the most frivolous professions; churchmen, lawyers, physicians, men of letters of all kinds; players, buffoons, musicians, opera-singers, opera-dancers, &c. ...Like the declamation of the actor, the harangue of the orator, or the tune of the musician, the work of all of them perish the very instance of its production, (Smith, 1994:361).

The SNA makes no distinction between 'income' generated from 'abstract processes,' (i.e., input coefficients are not proportional to the output), and from 'physical processes' (i.e., input coefficients are proportional to the output). Income is merely a generalised function of 'surplus' (wages & profits) defined by the boundary conditions of the market. In econosphere statistics, abstract processes is a purely accounting object, and are not observable as physical object in time and place. re separate functions described by correspondence mapping Income from the latter is subject to the entropy law and thus regulated by the laws of Nature. In the econosphere accounts the entropy law is translated into the rate of replenishment of low entropy (physical) stocks. Income from the former is not subject to the entropy law and thus regulated by institutional laws, such as property rights.

What is 'replenished' at the rate of consumption of abstract objects/functions in the immaterial economy? Clearly these are not physical objects but replenishment of abstract objects. Nor are these are consumed in the conventional sense of the 'entropic process' but may represent loss, i.e., destruction of the physical object containing the abstract object, like libraries, or renewal of the abstract object itself -knowledge and know-how. The accounts of the latter are ultimately set of agreed conventions defining the indicators of quantity, (e.g., per cent of the population with university degrees) an/or quality (e.g., test levels in education) of human and social capital - defined as low entropy stocks.

What is meant by Structural Hierarchies?

Hierarchical structures in traditional macro-accounting systems, like the SNA, are entailed by the concepts, definitions and classification systems of the accounts themselves.[11] In other words, data categories are pre-determined by the accountant, rather by the observer. It should also be noted, that unlike the ordinally-structured data sets of nonlinear accounts, the linear macro-accounts are

[11] Contrast the self-defined hierarchies to natural structures in biological and/or mechanical systems. Whereas the latter are observed empirically, the former are arbitrarily defined, such as administrative structures.

commutative accounting structures.[12] For instance, the familiar measure of GDP, adds the output of all categories of producers, (i.e., primary, secondary, and tertiary industries) to produce a 'gross product.' This 'product,' by definition, is equivalent to 'gross consumption,' and is mapped in market-prices on distinct arbitrary category set of final consumers, (i.e., households, government, NGO's, new capital formation and trade with the rest-of-the-world). Note that 'production processes,' while entailed by the 'final product,' are cancelled out of GDP. Further, the SNA makes no distinction between material product, and its rate of consumption, and immaterial product, (i.e., services) consumed the instant it is produced. Thus, the SNA represents a special *category set* of *physical/abstract object* and *functions* of conserved values-in-exchange, distinguished by single objective function defined by the parameters of 'economic performance' and correspondence mapping of GDP over the population, (i.e., per capita income).

Hierarchical structures regulating the physical relationships of objects and functions in nonlinear macro-accounting systems are either entailed by physical processes, and thus subject to the Second law of thermodynamics, or are abstract processes, and thus free from the direct physical manifestations of entropy. However, abstract processes are not isolated from the physical environment, and are thus all processes are, in some sense, entropic. While normally not considered hierarchical structured, we have introduced a set of protocols for the evaluation of state, and change state, of systems. Thus, introduced to the accounts *intrinsic-values conserved in ecological processes, use-values conserved in social processes,* and *exchange-values conserved in economic processes*. Since we have nested the econosphere in the sociosphere, and the sociosphere in ecosphere, the value protocols fall naturally into hierarchical system of values.

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APPENDIX I

The Unknown Citizen

W. H. Auden

(To JS/07/M/378/ This Marble Monument Is Erected by the State)

He was found by the Bureau of Statistics to be
One against whom there was no official complaint,
And all the reports on his conduct agree
That,in the modern sense of an old-fashioned word, he was a saint,
For in everything he did he served the Greater Community.
Except for the War till the day he retired
He worked in a factory and never got fired
But satisfied his employers, Fudge Motors Inc.
Yet he wasn't a scab or odd in his views,
For his Union reports that he paid his dues,
(Our report on his Union shows it was sound)
And our Social Psychology workers found
That he was popular with his mates and liked a drink.
The Press are convinced that he bought a paper every day
And that his reactions to advertisements were normal in every way.
Policies taken out in his name prove that he was fully insured,
And his Health-card shows he was once in hospital but left it cured.
Both Producers Research and High-Grade Living declare
He was fully sensible to the advantages of the Installment Plan
And had everything necessary to the Modern Man,
A phonograph, a radio, a car and a frigidaire.
Our researchers into Public Opinion are content
That he held the proper opinions for the time of year;
When there was peace, he was for peace: when there was war, he went.
He was married and added five children to the population,
Which our Eugenist says was the right number for a parent of his generation.
And our teachers report that he never interfered with their education.
Was he free? Was he happy? The question is absurd:
Had anything been wrong, we should certainly have heard.

APPENDIX II

The G-R Flow-Fund Model, (FFM), a method of representation of de-growth in the production function

The neoclassical concept of the production function, as expressed by Samuelson, is that of a catalogue of all recipes found in a cookbook of the prevailing state of the art for obtaining a *given* product out of *given* factors (Samuelson, 1947). G-R observed that this static vision, while a useful heuristic device for developing the Leontief I/O matrix of an economy, had no explanatory value of the qualitative change of the *production process.* The latter are *given* as exogenous variables in the analytical framework. A production function envisaged in FFM is defined as the *process* that *participates* in the Fund. The concept of participation is that of an *entropic process* (i.e., active elements) to describe the Fund's change in its state condition. Note that the Fund itself, is a stock of (available) low entropy, and thus represents analytically the *passive element* of the production process.[12]

The G-R representation of *process* is exactly that of Samuelson's cookbook of the list of ingredients and its quantities, but expands the concept to include combinations, mixing, cooking time and heat temperature. While these properties of *process* can be described by the external inflow/outflow equations (i.e., list of ingredients) and the internal qualitative change of the entropy algorithm, the residual 'black box' is the real-time molecular-chemical processes of cooking which changes the qualities of the finished product.[13] However, the size of the black box is relative to the analytical description of the boundary conditions of the process, the smallest unit being the elementary process in which the inflow and outflows can be recorded. For the analyst the choice of elementary process depends not only on the data, but appropriateness to the component parts of the analytical (entropy) space. SNA defines the elementary processes by the standard industrial classification, and the accounting objects by the standard commodity classification. The 'entropy space' to be analysed is thus the national economy as defined by the national statistical office.

A partial process is defined by its *flow elements* $E_i(t)$, the boundary conditions which separate the part from the whole, and by the participation of the *low entropy stocks*, $!S$ (t) defined inside the process boundaries. The latter, represent the *agents* of the process, referred to in the traditional context as the factors of production, labour, land and capital, and the former the *elements* acted upon. The participation of a fund is not necessarily continuous stream, as for example a weather system, and may be characterized with periods of idleness, periods of different intensities and, above all, periods of different qualities. The labour fund, for instance, may be characterized by the average work week and holidays, the daily hours of work, periods of involuntary full, or partial, unemployment and differential skills and motivation factors such as average earnings. This general concept of elements (i.e., objects) participating in a fund, (i.e., functions) allows for an analytical representation (!) which may expand, contract, and change in qualities, yet represent the same process over some well-defined time integral.

Processes may also be defined at different levels of the hierarchical structure of any well-defined complex adaptive system, $!S$ (t). The *flow elements* are increasingly endogenised in the analytical representation as it expands horizontally over geometric space and/or vertically over hierarchical structured space. The exogenisation of the flow elements represents a reverse process as the system contracts geometrically and/or is simplified in its complexity of structures. Shown in Figure 1, is the representation of $!S$ (t) as the whole Earth with one inflow element, solar radiation, and one outflow element, heat dissipation. Figure 2, illustrates equivalencies in spatial hierarchical structures. Column

1 represents horizontal structure classified to biological processes, starting with the basic element of the cell and ending holistic complex structure of the Biosphere. Column 2, while more arbitrarily defined, shows a hierarchical nested structure of ecosystems.

G-R presented the essence of the analytical coordinates of a *partial process* as follow:
While the *flow elements* enter, and exit, the *fund element* efficiency remains intact during the process. Specifically, we can represent the participation of a fund $_{!}C$ by a single function $_{!}S\ (t)$ showing the amount of services of $_{!}C$ up to the time *t. 0 ! t " T.* The analytical presentation of a Process can thus be written: $[E_i(t);\ S_!(t);]$ *i* subscript represents input or output and ! represents both inputs and outputs. At this juncture, analysis must make some additional heroic steps all aimed at assuming away dialectical quality. Discretely distinct qualities are still admitted into the picture as long as their number is finite and each one is cardinally measurable. If we denote the elements that may cross the boundary of a given process by $_{1}C$, $_{2}C$, $_{3}C$ ..., $_{m}C$, the analytical description is *complete* if for *every* $_{i}C$ we have determined two non-decreasing functions $F_i(t)$ and $_{i}G\ (t\ )$, the first showing the cumulative input, the second, the cumulative output of $_{i}C$ up to the time (*t*). Naturally, these functions must be defined over the entire duration of the process which may be always represented by a closed time interval such as [*0, T*]. The question of whether this analytical model is operational outside paper-and-pencil operations cannot be decided without an examination of the nature of the elements usually found in actual processes. Such an examination reveals that there exists numerous elements for which either $F_i(t)$ or $_{i}G\ (t\ )$ is identically null for the entire duration of the process. Solar energy is a typical example which is only an input for any terrestrial process.
The various materials ordinarily covered by the term “waste” are clear examples of elements which are only outputs. In all these cases, we may simplify the analytical picture by representing each element by one coordinate only, namely, by

(1) $E_i(t) = {_i}G\ (t)\ "\ F_i(t)$.

For an output element $E_i(t) = {_i}G\ (t)$ # 0; for an input element. $E_i(t) =\ "\ F_i(t)$ \$ 0 . The sign of $E_i(t)$ suffices to tell which is actually the case. (G-R,1971:215)

G-R further distinguishes $E_i(t)$ which are (basic) elements necessary to maintain the production cycle at steady-state, (e.g., seeds % crops) and $E_i(t)$ which are (non-basic) elements that are surplus available for consumption, $E_i(t) = {_i}G\ (t)\ "\ F_i(t)!0$.