

Producing ecological economy

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Introduction: Georgescu-Roegen unheeded

Economic analyses and conclusions are intimately bound up with judgements regarding the human condition. They are concerned with the study of what Marshall (1947, p. 1) referred to as “[hu]mankind in the ordinary business of life,” and dedicated to examine “that part of individual and social action which is most closely connected with the attainment and with the use of the material requisites of wellbeing,” (*Ibid.*). In that respect, economics is, from first principles, a normative enterprise.

While the idea that wellbeing and monetary wealth are so tightly correlated that the latter may be used as a proxy for the former was not an original premise of the early versions of economic analysis in European academic circles, and is today, increasingly brought into question not only from without but also from within mainstream economics, the presumption continues to influence the analytical apparatus used at all times by most, and at least sometimes by almost all scholars who understand themselves to be aligned with this field of enquiry. This is, as Georgescu-Roegen (1971) has noted, closely related to methodological choices made by some of the most important founding thinkers of this modern, euro-descendent, discipline: not least among them Pareto, Walras and Marshall himself. He argues (Georgescu-Roegen, 1971, Introduction) that their aspiration to secure economics a place at the table of the “hard sciences”, led them to adopt an analytical approach of arithmetic fetishism (my words, not his) that leaves unattended the qualitative aspects of purposiveness and biodynamic transformation that lie at the heart of economic process: ignoring, thereby, aspects central to defining what constitutes the material requisites of wellbeing and to identifying viable means on the basis of which these may be attained and effectively used.

Notwithstanding the notable contributions of Herman Daly, an early student of his, and consistent engagement within the trans-discipline of ecological economics, Georgescu-Roegen’s life work, like that of other heterodox economists, while taken up in part, within a variety of discourses, has generally been marginal to mainstream economics in the 20th and 21st Centuries. While the general disposition toward heterodox economics arguments has warmed considerably since the 2008 international financial crisis, adoption of radically distinct modelling approaches, such as those proposed by Georgescu-Roegen (1971) has not been forthcoming. The response has been, instead, mainly one of tweaks, focused either on correcting failures in the construction of GDP measures, through satellite accounts, the addition of compensatory sector variables or, in perhaps its most extreme form, the reactionary discourse on degrowth or, as in the case of post-Keynesianisms and much of behavioural and evolutionary economics, on the introduction of recalibrations, additional variables, reconfigurations and the incorporation of non-linearities into models that remain, nonetheless, at their core, closely aligned with the conventional structures of Walrasian analyses.

Georgescu-Roegen’s response to this, which he calls “wholesale arithmetization” (Georgescu-Roegen, 1971, p. 15), constructed through the elaboration of a wide range of

arguments, over a period of decades (Georgescu-Roegen, 1960; 1965a; 1965b; 1966; 1968; 1969; 1975; 1976; 1977; 1981; 1986; 1988; 1999[1971]), includes detailed attention to two interrelated points:

1. That economic processes are essentially biological in character.
2. That institutions constitute a core and critical aspect of human biology.

These provide, in my view, an excellent reference structure for considering all three questions that have been posed for this brief intervention:

1. How and to what degree is the economy changing the ecosystem?
2. How must economics change if it is to become a force for leading us away from catastrophe rather than toward it?
3. How can the global economy be changed so as avoid ecological collapse?

How and to what degree is the economy changing the ecosystem?

I would argue that our ability, from within an economics based approach, merely to grasp the information required to address this question is severely constrained, precisely by the two limitations observed by Georgescu-Roegen. That is to say, this question cannot be answered without structured reference to the biophysical characteristics of economic process and due attention to the role played, within those processes, by the human characteristic of using institutions to organise economic activity.

Again, with reference to the complexity of the problem, here, I think it is also important to distinguish, before proceeding, between different economies and different ecosystems. Some ecosystems, such as sustainably harvested temperate forests, are in quite good condition, in spite of having been changed dramatically by human economic processes; others, such as the tropical belt of mangrove forests, are in grave condition, in part due to changes caused by humans, but also in part due to their unfortunate positioning, at the mouths of rivers, where the ecological stress of upstream changes is concentrated and amplified. Similarly, not all economies are changing ecosystems in the same ways, and finally, not all changes are reified in the immediate surroundings of the economies that are causing them to occur. This give rise to a plethora of related social justice questions which fall not within the remit of the economist but of the social theorist and the body politic proper and cannot be addressed in an appropriate way here. Nonetheless, they should not be overlooked. Happily, there are a growing number of examples across the world of economic activity leading to ecological recuperation, not only to destruction. That said, destruction is clearly still the norm.

Taking then, rather a broad view, and working from within a social, historical frame of reference, I would suggest, following on from arguments presented in the late 1970s by the German Democratic Republic dissident Rudolf Bahro (1977; 1987), that the most far reaching and deeply seated way in which the contemporary global, late-industrial economy is changing the ecosystems within which it is embedded is by systematically and collectively ignoring its biological and social relationships to them. Following Faber *et al.* (1995; 1996), we might refer to this as an extreme deficiency in what they refer to as the third *tele* of living organisms: service. The label “third *tele*” is based on a teleological taxonomy, borrowed from biology, which they employ to help make sense of the blatant disregard that industrialised humans seem to have for the negative ecological impacts they cause, while going about the “ordinary business of life.” Drawing on the Aristotelean concept of *entelecheia*, which means, literally,

to have one's *telos* (or final cause) as a characteristic of one's self (e.g. it is in the *entelecheia* of a bird to fly), they propose "a teleological terminology to characterise living beings (i.e., organisms)... [which enables them] - to emphasise the uniqueness of a living being; - to consider the relationship of a living being to its species; - to represent its integration into the oneness of Nature" (Faber et al., 1996, p. 45). They propose that the fulfilment of purpose of a living organism, and by association, with a few logical degrees of differentiation, of a biological species, can be described through reference to the internalizing of three basic *tele* (plural of *telos*), which pertain to "What aims (tele) can we ascribe to a living being?" (Ibid.):

1. Self-maintenance, development and self-realisation;
2. Replication and renewal;
3. Service to other species and or the whole of nature.

They then go on to argue, much in keeping with Bahro (1977), that deficiency in the third *telos* – service – is a basic a feature of industrial societies, which have become disassociated from the biological systems that surround them, leading to ecological imbalance, as the ecological impacts of industrialised humans fail to contribute toward the flourishing of the ecological systems of which they form a part. One clear example of this is the excessive entropy production of the industrial economy. A necessary correlate to the massive production rate exhibited during the 20th and now 21st centuries, this implies a problem of system overload, where the entropy production associated with human activity has exceeded the entropy processing capacity of the ecosystems upon which we are dependant. Resolving this will require more than improved efficiency, which would carry with it yet more entropy production. It will require that we are able to understand and improve our relationships with the entropy processing systems of the planet (Mayumi, 1995; Tsuchida and Murota, 1985) and perhaps that we discover new ways of processing entropy and/or rediscover ones that industrialised humans have ceased to practice.

The lack of attention to the contribution that human actions make toward maintaining or diminishing the wellbeing of our non-human neighbours is bound up with the logic and history of industrialisation. The aim to liberate man, and I do mean man, from the caprices of nature, implies that the whims of nature can thus be ignored. While such disregard could be maintained for some time, during the early stages of industrialisation, as both ecosystems and human populations adjusted to the changes in their relationship, the now accelerating cascade of global impacts (Steffens et al., 2018) illustrates the temporary character of that charmed position. On an optimistic note, if one of the main problems is our lack of attention to impacts, this would seem to imply that increased awareness, combined with moral motivation to act appropriately, might help to address the problem. Unfortunately, awareness, in humans, is a rather complicated affair, which implies engaging with everything from public education, to the business models of Google and Facebook.

On the question of degree, I am inclined to demure, referring the reader instead to the myriad of documentation, which, sadly, is readily available, concerning the extent to which human economic activity is compromising the viability of many forms of life across the planet earth, including, all too often, human life. That said, the simple answer would seem to me to be: to an unacceptable degree. However, bearing in mind that humans, like our biological companion species, the rat, the pigeon, the dog and the cockroach, are remarkably versatile, we should take into account that "unacceptable to humans" might well be a degree of change far beyond the level of contamination and habitat destruction that other species can support.

So, I would settle here then on the following: wildly beyond that which the ecosystems of the planet can reasonably support while continuing to generate habitat suitable for humans.

How must economics change if it is to become a force for leading us away from catastrophe rather than toward it?

Georgescu-Roegen's call, echoed by many of his contemporaries, and today paid lip service to by most, if not all economist, was to give serious analytical attention to representing the role of biological dynamics in economic process. It was expressed in large part through his detailed and repeated reference to the second law of thermodynamics, which served as the basis for his proposal to radically reconfigure the mathematical foundations of economic analysis: because economic process is *intended* to bring about qualitative change, which is frequently irreversible and which "eludes arithmomorphic schematization" (Georgescu-Roegen, 1971, p. 63). This means that accurate representation of the *dynamics* of economic process must include theory that addresses the structure of the *relationship between* qualitative and quantitative elements. While there is not sufficient space to unpack the point here in detail, that position, which includes postulates regarding the relationship between time, space and human intentionality, is closely linked to a second position that underpins his elaboration of an alternative analytical economics methodology – the flow-fund theory.

Using flow-fund theory, which replaces the stock, flow, fund distinction used in conventional economic analysis, with a flow-fund distinction that depends on the spatial and temporal boundaries of the economic process in question (Farrell and Mayumi, 2009; Silva-Macher and Farrell, 2014; Farrell and Silva Macher, 2017), makes it possible to construct complex, functional analyses that continue to represent the basic features of economic process, while making explicit the role of intentionality in their delimitation and also providing a means to include ecological elements and dynamics, which cannot be accurately represented in monetary units. The two propositions at the heart of Georgescu-Roegen's flow-fund theory, to make analytical space: 1) for the representation of biodynamics and 2) for the role of purpose in delimiting the boundaries of an economic process, rest at the core of what he referred to as "bioeconomics", (Georgescu-Roegen, 1986; Mayumi and Gowdy, 1999). Mayumi (2009, p. 1237) describes this as "a new style of scientific thought... that combines elements of evolutionary biology, institutional economics and biophysical analysis associated with energy and mineral resources." At a most basic level, I would say, the work of Georgescu-Roegen needs to be taken far more seriously by mainstream and conventional heterodox economists than it has been to date. Precisely because it implies the need for a radical break with convention, it has been left to the side or cherry picked. It is well past time for that to change.

More generally, following on from these observations, a further suggestion, regarding how economics must change, if it is to become a force for leading us away from catastrophe, rather than toward it, is that arithmetic fetishism must be jettisoned, and way made for the development of completely new types of inter-and transdisciplinary models, in which economic analysis is subordinated to a larger goal: representing the social-ecological and biophysical complexity of the human driven biological processes currently wreaking havoc across the planet earth.

While it has become fashionable to blame economic growth for the current ecological woes of the planet, and there is, of course, much evidence to support that position, I believe the problem is not so simple. Growth is a natural biological process, employed by all living organisms on the planet earth in order to resist the inevitable and constant deterioration that

is implied by their inherently entropic nature (Schroedinger, 1944). It comes in many forms, from maturation, to regeneration to cancer, which are distinguishable through reference to their qualitative differences. It seems illogical to me to propose that growth, in itself, is inherently a problem and irresponsible to attempt to analyse economic processes without having a plausible theory regarding the role and function of growth within them. Rather it is the pursuit of growth for growth's sake, and the associated construction of models that presume the realization of growth to be a suitable measure of utility, that seem to me to be the problem. This implies a need to redesign economic models in a way that situates growth as *one among multiple economic phenomena* involved in regulating the viability of an economy: others being, for example, ecological impact and social acceptability. Taken as an end in itself, as opposed to being treated as a means to a more humane end, growth serves growth, not society (Raine et al., 2006). Considered in the absence of attention to the associated phenomena of waste production and death, analyses focused only on the quantity, as opposed to also including attention also to the *quality* of growth and deterioration, are incomplete.

While Georgescu-Roegen's work is discussed at present, more often than not, in the context of the contemporary discourse on degrowth, which claims him as a founding thinker, his position on the question was arguably more conservative than is often assumed and is perhaps better described as advocacy of "agrowth" (Missemer, 2017) or balanced development (Georgescu-Roegen, 1965b). His position can be understood in terms of the simple matter of resource allocation trade-offs, where economic actors, in choosing what economic process(es) they undertake, are situated somewhere along a kinky, multi-dimensional, production possibility frontier, where the allocation and distribution of available resources may be configured to produce final goods and services, productive capacity or some combination of the two (Georgescu-Roegen, 1965b; 1999[1971], pp. 239-240 and 274-275; Scheidel and Farrell, 2015, p. 231).

By retaining reference to both the purpose of the economic actors in question and the limiting factor of resource availability, the preceding conceptualisation of growth can include, for example, recovery and transformation, both of which would imply a shift deep into the domain of producing productive capacity but not necessarily an increase in the quantity of deterioration or in the quality of an economy's ecological impact. Linking that position directly to his flow-fund theory, Georgescu-Roegen (1968) would appear to have been most concerned with identifying the conditions required to ensure *balanced growth* of living economic processes, i.e. *to develop theory that would make it possible to explicitly link the rate of growth and productivity of an economy to the rate of growth and productivity of the biological systems upon which an economy's own productivity is inevitably, if only ultimately, dependent* (O'Hara, 1999; 2016). This, I would posit, is another aspect of how economics must change: a more nuanced and contextualised approach to growth is required on both sides of the growth/degrowth divide.

Taking up the idea of pursuing balanced, ecologically viable, embedded growth, which implies also taking into account deterioration and death, we can speak of a two strand research agenda which I would propose to call producing ecological economy:

1. Identifying local, regional and international modes of production, consumption, sharing and exchange that are both economically and ecologically viable;
2. Changing local, regional and international regulations and practices to facilitate the development and maintenance of these types of economic activity.

Both strands imply a need for economic research to open up to what Max-Neef (2005) calls strong inter-disciplinarity, where multiple disciplines are involved not only in the execution but also in the configuration of analyses and in the specification of analytical problems to be addressed. This, I believe, may be the most pressing and most challenging change that needs to be brought about in economics. In contrast to subsuming knowledge from other disciplines to serve the ends and means of conventional modern economic analysis, as is done, for example, in the fields of neuro- and behavioural economics, this implies situating economics as a contributor toward the collaborative project of developing multi-dimensional, complex representations of the social-ecological relationships and processes that both underlie and are impacted by late-industrial economic activity.

Producing ecological economy has both a descriptive and a normative aspect, regarding, in the first instance, the identification of social and material criteria suitable for establishing ecologically beneficial economic activities across the entire planet and in the second, the specification of means for realizing their operationalisation under humane and ethical terms, across cultures and social-ecological contexts. Much of that work is of a political, rather than a scientific nature. And although I will address here only the latter, it should be noted that the former is also of vital importance for achieving lasting social change of any sort, not least such as might serve to halt the steady march through calamity in which humanity would appear to be engaged at present. The multiple statuses of politics in this process - within and across inter-disciplinary teams and between research teams and their clients, in some instances the public - must be taken into account when developing comprehensive models and analyses. This too implies a radical reconfiguration of the analytical basis upon which economic models are constructed.

Farrell and Silva Macher (2017, p. 167) have described attention to this contextualised and relational character of economic process as work focused on the ecological economic *Gestalt*: i.e. on the relationship *between* ecological and economic systems. Such work requires effective integration of insights deriving from a myriad of disciplines and applied to contextualised research questions related to the ordinary lives of many different types of economic and ecological communities. Here there is some ground for optimism, as there are a growing number of examples of such work (Bischi, 2018; Farrell and Silva Macher, 2017; Farley and Malghan, 2016; Moreau et al., 2017; Rincón Ruiz, et al., 2018; Wilson and Kirman, 2016). Nonetheless, this is still a project in the early stages of development and much of the attention of environmental and ecological economists continues to be dedicated to identifying ways to estimate the “real” costs and benefits of environmental externalities and to develop strategies to internalize them into price based decision processes. The persistence of such work illustrates the momentum of arithmetic fetishism, in which processes that do not easily lend themselves to quantification are arithmetized for the purpose of forcing them into the existing, quantitative analytical rubric. It is, I would posit, largely a waste of time and resources, as the resulting data are not only meaningless but also distracting (Farrell, 2007).

Work reaching beyond that fetishism, into the conceptual domain of the ecological economic *Gestalt*, has tended, up to now, to be in the area of institutional economics, where there is more openness to structural critiques of conventional modelling approaches. In the case of Mayumi (1995; 2001; 2009; 2017), Georgescu-Roegen’s last student, the focus has been on questions of epistemology and mathematical formalisation. Both Gowdy (1994; Gowdy and Mesner, 1998; Mayumi and Gowdy, 1999), picking up on Georgescu-Roegen’s attention to the exosomatic evolutionary dynamics of technological and institutional change, and O’Hara (1997; 1999; 2016), picking up on his attention to the relationship between economic process

and both social and ecological context, have developed interpretations of his work that can be linked with contemporary institutional economics and I would suggest that this is an important way forward for changing economics. Here the early work of Nobel Laureate Elinor Ostrom (1990) and more recent works by Vatn (2005) and Hodgson (2015) provide quite a comprehensive, environment-oriented, complement to the existing body of Classical Institutional Economics contributions, suggesting a promising route for developing the situated economic theory that is needed.

How can the global economy be changed so as avoid ecological collapse?

This question, I think is basically impossible to answer I find it decidedly uncomfortable to even attempt to answer such a general and far reaching question directly and so will proceed through reference to a metaphor. Many years ago, in conversation with a colleague, at a conference, we imagined the following image to represent this challenge: what would it imply, to transform a jet airliner, full of passengers, into a flock of birds, in mid-flight? That is to say, to transform, while running, a mechanical system, dependant on inputs of fossil fuel and an individualist based organising principle, into a biological one, employing biodynamic energy sources and structured around an organising principle of cooperation and attention to one's relations to others. The level of coordination required to avoid a catastrophic collapse of the system, in-full-flight, is, on its own, daunting: not to mention the massive amount of diverse technical expertise that would be required to realize such a transformation. Then there is the magical element, of realising some form of biomechanical metamorphosis, transforming human beings using machine, into birds.

Taken lightly, for illustrative purposes, our metaphor suggests a few concrete criteria that might be applied to address this final question. First, handle with care. The chances of a misstep leading to a total system collapse are high. Looking into the specifics, we could say that there is a clear need to effectively manage the transition from a mechanically based to a biologically based operating system. This implies holding on to the knowledge that is presently available regarding how the mechanical system (i.e. the industrial, accumulation driven economy) functions and working with that knowledge, to identify ways of coupling that systems with a biologically based one, in order to maintain momentum and avoid system failure. It also implies, as has been mentioned above, a need for the coordinated effort of diverse inter-disciplinary teams, comprised of experts in everything from human behaviour to fluid dynamics, so once again, strong-interdisciplinarity. And finally, it implies a need to adopt a posture of humility in front of the life-giving capacity of the natural world, which modern industrial science has yet, for all its achievements, to replicate.

While I do not agree with all the propositions contained therein, I believe one would be hard pressed to find a more succinct and coherent articulation concerning how the global economy not only could but indeed, must, be changed if humanity is to even hope to be able achieve the transformation to an ecological economy, than the following statement, issued at Rio +20, by a coalition of leaders of indigenous communities from across the Americas and the world:

Mother Earth is the source of life which needs to be protected, not a resource to be exploited and commodified as a "natural capital". We have our place and our responsibilities within Creation's sacred order. We feel the sustaining joy as things occur in harmony with the Earth and with all life that it creates and sustains. We feel the pain of disharmony when we witness the dishonor of the natural order of Creation and the continued economic colonization and

degradation of Mother Earth and all life upon her. Until Indigenous Peoples rights are observed and respected, sustainable development and the eradication of poverty will not be achieved (Kari Oca II Declaration, 2012).

References

- Bahro, R., (1977) *Die Alternative: zur Kritik der real existierenden Sozialismus*. Frankfurt am Main: Europäische Verlaganstalt.
- Bahro, R., (1987) *Logik der Rettung: Wer kann die Apokalypse aufhalten? Ein Versuch über die Grundlagen ökologischer Politik*. Stuttgart: Weltkreis Verlag.
- Bischl, G.I., (2018) Wilson, David S. and Alan Kirman (Eds) "Complexity and evolution: toward a new synthesis for economics." *Journal of Economics* 123, pp. 89-91.
- Faber, M., Manstetten, R., Proops, J. (1995) "On the conceptual foundations of ecological economics: a teleological approach." *Ecological Economics* 12, pp. 41–54.
- Faber, M., Manstetten, R., Proops, J. (1996) *Ecological Economics: concepts and methods*. Cheltenham, UK: Edward Elgar.
- Farley, J., Malghan, D. (2016) *Beyond Uneconomic Growth, Vol. 2: A Festschrift in Honor of Herman Daly*. Burlington, VT: University of Vermont.
- Farrell, K.N. (2007) "Living with living systems: The co-evolution of values and valuation." *International Journal of Sustainable Development and World Ecology*, 14, pp. 14-26.
- Farrell, K.N., Mayumi, K. (2009) "Time horizons and electricity futures: An application of Nicholas Georgescu-Roegen's general theory of economic production." *Energy*, 34, pp. 301-307.
- Farrell, K.N., Silva-Macher, J.C. (2017) "Exploring Futures for Amazonia's Sierra del Divisor: An Environmental Valuation Triadics Approach to Analyzing Ecological Economic Decision Choices in the Context of Major Shifts in Boundary Conditions." *Ecological Economics*, 141, pp. 166-179.
- Georgescu-Roegen, N. (1960) "Economic Theory and Agrarian Economics" (with Postscripts from 1966 and 1975). In: Georgescu-Roegen, N. (Ed.), *Energy and Economic Myths: institutional and analytical economic essays*. Oxford: Pergamon Press, pp. 103-145.
- Georgescu-Roegen, N. (1965) "The Institutional Aspects of Peasant Communities." In: Georgescu-Roegen, N. (Ed.), *Energy and Economic Myths: institutional and analytical economic essays*. Oxford: Pergamon Press, pp. 199-231.
- Georgescu-Roegen, N. (1965) "Process in Farming versus Process in Manufacturing: a problem of balanced development." In: Georgescu-Roegen, N. (Ed.), *Energy and Economic Myths: institutional and analytical economic essays*. Oxford: Pergamon Press, pp. 71-102.
- Georgescu-Roegen, N. (1966) *Analytical Economics: Issues and Problems*. Cambridge, MA: Harvard University Press.
- Georgescu-Roegen, N. (1968) "Structural Inflation-Lock and Balanced Growth." In: Georgescu-Roegen, N. (Ed.), *Energy and Economic Myths: institutional and analytical economic essays*. Oxford: Pergamon Press, pp. 149-197.
- Georgescu-Roegen, N. (1969) "The Economics of Production." In: Georgescu-Roegen, N. (Ed.), *Energy and Economic Myths: institutional and analytical economic essays*. Oxford: Pergamon Press, pp. 61-69.
- Georgescu-Roegen, N. (1999[1971]) *The Entropy Law and the Economic Process*. Harvard University Press, Distributed by Oxford University Press, London.
- Georgescu-Roegen, N. (1975) "Energy and Economic Myths." *Southern Economic Journal*, 41, pp. 347-381.

- Georgescu-Roegen, N. (1976) *Energy and Economic Myths: institutional and analytical economic essays*. Oxford: Pergamon Press.
- Georgescu-Roegen, N. (1977) "Inequality, Limits and Growth from a Bioeconomic Viewpoint." *Review of Social Economy*, 35, pp. 361-375.
- Georgescu-Roegen, N. (1981) "Energy, matter, and economic valuation: where do we stand?" In: Daly, H.E., Umaiia, A. (Eds.), *Energy, Economics and the Environment*. Boulder, CO: Westview Press.
- Georgescu-Roegen, N. (1986) "The Entropy Law and the Economic Process in Retrospect." *Eastern Economic Journal*, XII.
- Georgescu-Roegen, N. (1988) "The Interplay Between Institutional and Material Factors: The Problem and its Status." In: Kregel, J.A., Matzner, E., Roncaglia, A. (Eds.), *Barriers to full employment*. London: Macmillan Press, pp. 297-326.
- Gowdy, J. (1994) *Co-evolutionary Economics*. The Netherlands: Kluwer Academic Publishers.
- Gowdy, J., Mesner, S. (1998) "The Evolution of Georgescu-Roegen's Bioeconomics." *Review of Social Economy*, LVI, 136-156.
- Hodgson, G.M. (2015) *Conceptualizing Capitalism: Institutions, Evolution, Future*. Chicago: Chicago University Press.
- Marshall, A. (1947[1920]) *Principles of Economics* 8th Edition. London: Macmillan & Co.
- Max-Neef, M.A. (2005) "Foundations of transdisciplinarity." *Ecological Economics*, 53, pp. 5-16.
- Mayumi, K. (1995) "Nicholas Georgescu-Roegen (1906-1994): An Admirable Epistemologist." *Structural Change and Economic Dynamics*, 6, pp. 261-265.
- Mayumi, K. (2001) *The Origins of Ecological Economics: The Bioeconomics of Georgescu-Roegen*. London: Routledge.
- Mayumi, K., (2009) "Nicholas Georgescu-Roegen: His Bioeconomics Approach to Development and Change." *Development and Change*, 40, pp. 1235-1254.
- Mayumi, K., Gowdy, J. (1999) *Bioeconomics and Sustainability: Essays in Honor of Nicholas Georgescu-Roegen*. Cheltenham: Edward Elgar.
- Missemer, A. (2017) "Nicholas Georgescu-Roegen and degrowth." *The European Journal of the History of Economic Thought*, 24, pp. 493-506.
- Moreau, V., Sahakian, M., Griethuysen, P., Vuille, F. (2017) "Coming Full Circle: Why Social and Institutional Dimensions Matter for the Circular Economy." *Journal of Industrial Ecology*, 21, pp. 497-506.
- O'Hara, S. (1997) "Toward a sustaining production theory." *Ecological Economics*, 20, pp. 141-154.
- O'Hara, S. (1999) "Economics, Ecology and Quality of Life: Who Evaluates?" *Feminist Economics*, 5, 83-89.
- O'Hara, S. (2016) "Production in Context: The Concept of Sustaining Production." In: Farley, J., Malghan, D. (Eds.), *Beyond Uneconomic Growth, Vol. 2: A Festschrift in Honor of Herman Daly*. Burlington, VT: University of Vermont, pp. 75-106.
- OECD, (2009) *Defining the Bioeconomy, The Bioeconomy to 2030: Designing a Policy Agenda*. Paris: OECD Publishing, pp. 19-30.
- Ostrom, E. (1990) *Governing the commons: The evolution of institutions for collective action*. Cambridge: Cambridge University Press.
- Raine, A., Foster, J., Potts, J. (2006) "The new entropy law and the economic process." *Ecological Complexity*, 3, 354-360.
- Rincón-Ruiz, A., Arias-Arévalo, P., Núñez Hernández, J.M., Cotler, H., Aguado Caso, M., Meli, P., Tauro, A., Ávila Akerberg, V.D., Avila-Foucat, V.S., Cardenas, J.P., Castillo Hernández, L.A., Castro,

L.G., Cerón Hernández, V.A., Contreras Araque, A., Deschamps-Lomeli, J., Galeana-Pizaña, J.M., Guillén Oñate, K., Hernández Aguilar, J.A., Jimenez, A.D., López Mathamba, L.Á., Márquez Pérez, L., Moreno Díaz, M.L., Marín Marín, W., Ochoa, V., Sarmiento, M.Á., Tauro, A., Díaz Timote, J., Tique Cardozo, L.L., Trujillo Acosta, A., Waldron, T. (2019) "Applying integrated valuation of ecosystem services in Latin America: Insights from 21 case studies." *Ecosystem Services*, 36, p. 100901.

Scheidel, A., Farrell, K.N. (2015) "Small-scale cooperative banking and the production of capital: Reflecting on the role of institutional agreements in supporting rural livelihood in Kampot, Cambodia." *Ecological Economics*, 119, pp. 230-240.

Schrödinger, Erwin (1948[1944]) *What is Life?* Cambridge: Cambridge University Press.

Silva-Macher, J.C., Farrell, K.N. (2014) "The flow/fund model of Conga: exploring the anatomy of environmental conflicts at the Andes–Amazon commodity frontier." *Environment, Development and Sustainability*, 16, pp. 747-768.

Tsuchida, Atsushi; Murota, Takeshi (1985) "Fundamentals in the Entropy Theory of Watercycle, Ecocycle, and Human Economy. Entropy Studies on Ecology and Economy." Unpublished booklet of two papers presented to the Institut de la Vie symposium Man's Coevolution with the Bioshpere in the Age of Advanced Technologies. 21-25 January, 1985, Strong College, Toronto Canada.

Vatn, A. (2005) *Institutions and the Environment*. Cheltenham, UK: Edwar Elgar.

Wilson, D.S., Kirman, A. (2016) *Complexity and evolution: toward a new synthesis for economics*. Cambridge, MA: MIT Press.

Zawojska, A., Siudek, T. (2016) *Bioeconomics as an Interdisciplinary Science*. Proceedings of the 2016 International Conference "Economic Science for Rural Development" 21-22 April 2016 (Volume 41), Jelgava, LV, pp. 273-280.

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