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Writing forward Georgescu-Roegen's critique of Marx:

Implications and analytical advantages of situating capital as a flow-fund element

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Introduction

While the study of economics is presented in neoliberal theory (i.e. Walras, Coase, Friedman, Beckerman, etc.) as an exact science, its basic subject, described so succinctly by Marshall (1920[1890]), is anything but.

"Political Economy or Economics is a study of [hu]mankind in the ordinary business of life; it examines 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."
(Marshall, 1920[1890]:1)

This observation of Marshall´s, every bit as pertinent today as it was in 1890, obliges the student of economics to remain attentive to the peculiarities of the human condition, not least among these being the epistemological constraints associated with humans attempting to make sense of anthropogenic phenomena (Dewey, 1958 [1929]). Encumbered by hermeneutic distortions, both economists and the objects they study are subject to cultural bias, political disposition (Mirowski and Plehwe, 2009) and the inescapable positioning of the observer within space/time. Certainly, the Cold War origins of the project of neoliberal formalization, described by Mirowski and his colleagues, intended as it was to move economic planning out of the political and into the technical realm, is one factor contributing to its decreasing relevance in a world that today is no longer defined by the capitalism/communism juxtaposition which fueled that effort (Hodgson, 2015; Marcuse, 1978; Pikkety, 2014).

The failure of neoliberal theory to take into account the complexities of the contemporary global political economy, dominated as much by state capitalism as by free markets, globalized, digitized, diversified and integrated, has been painstakingly demonstrated in the resounding failure of mainstream academic economics, not only to predict but even to explain, the global financial crisis of 2007, while, in the real world, private investors cashed in on their bets that a derivatives-backed cheap mortgage boom in the United States was on the verge of collapse. In these complex times that have followed, a global pandemic has disrupted supply chains and is dramatically widening income and education gaps within and between nations, multiple simultaneous climate catastrophes have taken many lives and are disrupting 'the ordinary business of life' for many more, while growing worldwide political and economic instability conspire to uproot expectations and overturn standard explanations: old rule books are being abandoned as obsolete (Steffen et al., 2018; Walker and Holling, 2013). As if to bring the point home, at the G-7 Summit this June 2021, in the United Kingdom, finally there was acquiescence that a neoliberal Laissez-Faire attitude toward coordination of national tax regimes is, at present, counter-productive, even to the interests of the global capitalized elite (Milliken and Holton, 2020).

Arguments concerning the consequences of failing to update neoliberal theory are plentiful and well documented by better scholars than I, several contributing toward this collected edition. Here I wish to focus on a related issue, less concerned with how and why neoliberal theory has become passé, turning instead to consider some central features of an alternative, proffered up some time ago by Nicholas Georgescu-Roegen (1999[1971] hereafter NGR71), which Farrell and Mayumi (2009) have called his "general theory of economic production." In the coming pages it will be argued that the paucity of

practicality exhibited by neoliberal theory is not merely a matter of neoliberal largesse, nor solely attributable to the Cold War project described by Mirowski and his colleagues but also a direct result of poorly formulated model ontologies, which fail to treat the factors of economic production, and in particular capital, as components of complex living systems. As an alternative, the analytical advantages and theoretical implications of positioning capital, a cherished feature of both liberal and neoliberal economics, within the flow-fund ontology at the heart of Georgescu-Roegen's general theory of economic production, will be explored.

The impossibility of wholesale arithmetization of economic processes

A scholar of remarkable mathematical prowess (Mayumi, 1995, 2001), Georgescu-Roegen (NGR71) dedicated a considerable part of his master work – *The Entropy Law and the Economic Process* – to questions concerning philosophy of science and in particular the construction and configuration of mathematical representations of reality in general, living systems, in particular, and most specifically, the living systems of which economic production is comprised. This brings us back to Marshall: life is complex. If economics is indeed concerned with how humankind goes about sustaining its own life, day to day, then representing that complexity must be built into the ontology of economic models. Adjustments to variables, parameters and reference data can all contribute to improving models, but they do not necessarily address the ontological limitation that, in the original liberal theory "representation, [read that of Jevons and Walras] the economic process neither induces any qualitative change nor is affected by the qualitative change of the environment into which it is anchored" (NGR71:2). This limitation is carried forward, in neoliberal theory, which continues to rely on the mechanical-physics-based mathematics of Walras, albeit with permutations and sometimes remarkable arithmetic acrobatics, and, it must be said, also much of heterodox economics, which continues to seek out ways to adjust and correct the math, in lieu of engaging with this root problem. The brunt of the problem is, as described by Georgescu-Roegen, that "in the long run or even in the not too long run the economic (as well as the biological) process is inevitably dominated by a qualitative change which cannot be known in advance" (NGR71:17) and which "eludes arithmomorphic schematization" (NGR71:63). In other words, this particular limitation in both liberal and neoliberal theory, that they fail to include the process of becoming, of causing to come into being, is not a limitation in the calculations but rather in the configuration of the mathematics underlying them (Mayumi, 2001).

Moving to the specifics of Georgescu-Roegen´s flow-fund theory, in defending his invention, at the close of his master work, the author reminds his reader of its mathematical and epistemological origins:

"If our knowledge of a certain domain is not compressible, i.e., if its logical filing results in a very great number of w-propositions [consolidated – or generalized propositions NGR71:47], Aristotelian comprehensibility does not obtain" (NGR71:322) and the "…statement that the fundamental principles of economics are universally valid, therefore, may be true only as their *form* is concerned. Their *content*, however, is determined by the institutional setting. And without this institutional content, the principles are nothing hut 'empty boxes,' from which we can obtain only empty generalities." (NGR71:324 *emphasis original*)

In this respect, it is perhaps a misnomer to refer to flow-fund theory as a general theory of economic production, as it is precisely his conviction regarding the impossibility of constructing a general theory that brought Georgescu-Roegen to propose this replacement of the foundational Wicksteedian formula with a relational modelling approach. But it is precisely therein that the remarkable potential of this approach is revealed: flow-fund theory, applied as it was designed, provides an ontological standardization focused not on individual instances, which are subject to novelties that cannot be

predicted using conventional linear or even non-linear mathematics (Prigogine, 1997). Instead, it seeks to represent the mechanisms through which the change in question comes about, i.e., the form of fundamental principles, to paraphrase the quote above. Take surfing as an example of how this kind of causality can be modelled, in practice. Although no two ocean waves break onto the shore with an identical shape, there are, nonetheless, predictable attributes for how a wave will break, related to the mechanisms of the irreversible process 'wave breaking on the shore.' These predictable attributes make expert surfing, which depends on modelling waves in real time, including predicting their trajectory, possible: because all waves have the same basic dynamic shape. As Prigogine (1997) puts it, for thermodynamically open systems, of which living systems are a type, "[w]e can only achieve a formulation of sufficient conditions for stability… This requires specifying the mechanisms of irreversible processes. Near equilibrium laws of nature are universal, but when they are far from equilibrium, they become mechanism dependent" (Prigogine, 1997:65, emphasis in original).

Here, Georgescu-Roegen's flow-fund view of time, incorporated into the math as a relational factor associated with delimiting the duration of the economic process in question, and the association of that duration with the specific aim of a given economic process (Farrell and Mayumi, 2009; Silva-Macher and Farrell, 2014), provides a basis for specifying, generally, precisely these types of mechanisms, with respect to the thermodynamically open, living process of converting raw materials into desired products – that is to say, with respect to economic production.

Social construction, as if reality mattered

While it is mostly likely the case that Georgescu-Roegen would have considered himself more of a classical, than a post-modern thinker, the vision of his early works concerning production, starting from the early 1960s, effectively introduces *perspective* and *difference* squarely and quite literally, into the economic equation. As such, it could be argued that his flow-fund theory work, toward which he dedicated the majority of his academic career, offers an even more promising basis for advancing post-neoliberal economics than do his, to date more widely discussed, diatribes of the late 1980s, taken up by the so-called "Degrowth" discourse, in which he rails against blind adherence to the growth paradigm among his contemporaries of that period (Georgescu-Roegen, 1986; 1988).

While critiquing neoliberal economics theory was certainly 'on the agenda' for Georgescu-Roegen, his flow-fund theory goes well beyond critique, effectively engaging with and disarming the elephant in the classical (and neoclassical) economics' room – the presumption, first formally postulated by Vilfredo Pareto (1896; 1897), that inequality is somehow an inherent feature of a natural process of economics that is based in market exchange, as opposed to an anthropogenic artefact, characteristic of configurations of economic process that prioritize the accumulation of wealth among a few over the achievement of well-being for the many. In this, Georgescu-Roegen is quite specific, when summarizing his theoretical position, at the close of *The Entropy Law and the Economic Process*. There, he specifically points to the ontological limitation of treating economic purpose as a given, and to associated implications of attempting to use conventional classical and neoclassical economic theory to make sense of the culturally diverse range of economic processes that comprise today's globalized economy:

"This is not to say that standard [read classical and neoclassical economic] theory operates with 'empty boxes.' On the contrary, as we have seen, those boxes are filled with institutional content distilled from the cultural patterns of a bourgeois society" (NGR71:324).

"The egregious sin of the standard economist … [is that they deny] the necessity of paying any attention to the evolutionary aspects of the economic process, …[they are] perforce obliged to preach and practice the dogma that his theory is valid in *all* societies" (Ibid:325 *emphasis original*).

While there have been important advances in evolutionary economics in the intervening period, which merit their own place within the discourse on post-neoliberal economics, it is not only the study of economic processes as evolutionary phenomena to which he is referring here, but also to *the evolutionary process of studying economic phenomena*. Pioneering as it was, in 1971, this position is now part and parcel of Anthropocene thinking (Crutzen and Stoermer, 2000; Haraway, 2015; Latour, 2013; Steffen et al., 2018; Waters et al., 2016; Zalasiewicz et al., 2011) and fits remarkably well within the positivists post-modern discourse on post-normal science (Allen et al., 2001; Funtowicz and Ravetz, 1991, 1993; Funtowicz and Ravetz, 1994a; Funtowicz and Ravetz, 1994b; Mayumi, 2017; Mayumi and Giampietro, 2006), which calls upon scholars concerned with the study and resolution of the complex social-ecological problems of the late 20th and early 21st century to seriously take into account the epistemological and ontological implications of their own temporal and spatial positioning, as individuals and as communities, within the processes of human and planetary evolution within which the economics of daily life are embedded.

Responding to that call is, as Allen et al. (2001) point out, a tricky business: one in which the scientific conclusion is that the puzzle cannot be solved scientifically: "we have seen the man behind the curtain and objectivist realism is now compromised" (Allen et al., 2001: 476). This is not to be confused with radical relativism, nor with Critical Realism, neither of which provide sufficient ontological footing to merit the label positivism (Popper, 1968[1959]). It is, instead, an epistemologically agnostic (Cilliers, 2003; Dewey, 1958 [1929]; Light, 2002) but ontologically firm position, in which the impossibility of resolving what Cilliers (2005) refers to as 'the performative contradiction of complexity' is placed front and center in theory development – namely, that we are absolutely certain that we are not absolutely certain as regards what we know about the complex systems of which we form a part.

That Georgescu-Roegen was engaged in the work of constructing precisely this new type of epistemologically reflexive ontology is clear, both from applications of his theory that make good use of this feature (Farrell and Löw Beer, 2019; Giampietro and Mayumi, 1997; Giampietro and Mayumi, 2000a; Giampietro and Mayumi, 2000b; Mayumi et al., 1999; Moreau et al., 2017; Silva-Macher, 2016; Silva-Macher and Farrell, 2014), and from his own words:

"Analysis cannot accept a penumbra between one individual process and "its other." For if it does, it must set it as another partial process and then it ends with three partial processes instead of two. We would thus be drawn into an infinite regress… The first element, therefore, that the analytical picture of a process must necessarily include is the analytical boundary. *No analytical boundary, no analytical process*…Plato to the contrary, there are not even joints in actuality to guide our carving. One may slice actuality anywhere one pleases. This does not mean that any boundary cut by mere whim determines a process that has some significance for science… [but rather, that] a relevant analytical process cannot be divorced from purpose and, consequently, is itself a primary notion - that is, a notion that may be clarified by discussion and examples but never reduced to other notions by a formal definition" (NGR71:212-213 *emphasis original*).

While the above citation is rather long, without the associated context, it is difficult to unpack the significance of its final assertion: a relevant analytical process cannot be divorced from purpose; it is itself a primary notion. That is to say, that which is selected for analysis by the economist is not something that can be derived from a set of stable predetermined variables, with stable, predetermined relationships between them, such as is assumed by the Wicksteed production function, $P = f(a, b, c, \ldots)$,

and in turn almost all others. Rather, it is a choice, made not only by the economist, but also by those individuals and groups engaged in generating the economic process to be studied (Farrell and Mayumi, 2009; Silva-Macher and Farrell, 2014). Without delving into the details of Georgescu-Roegen´s long standing criticism of the Wicksteed function, which he once referred to as "an acme of imprecision" (Georgescu-Roegen, 1990:205), to sum up in just a few words, an argument to which he dedicated several chapters and various publications, the basic problem with this function, and with variations on the theme, is that they fail to take into account the impact that qualitative change has on the characteristics of specific factors of production and on the relationships between them. The observation is similar, in many respects, to Holling and Meffe´s (Holling and Meffe, 1996) critique of the concept of Maximum Sustainable Yield, a simple resource economics model that balances extraction and reproductivity rates, in order to specify the optimal rate of extraction from a regenerative resource, such as a population of fish or a forest: the very process of production/extraction generates changes not only in the quantity but also in the quality of the very variables that comprise the production function is itself.

Adding in economic *Anschauung*

The empirical observation that economic variables are both socially constructed and subject to qualitative change, over time, informs the epistemological foundations upon which the ontology of flow-fund theory is based. Assuming that economic processes are intentional processes that induce qualitative change, also affected by qualitative change in their environment, models of economic process need be able to represent not only changes in quantity (accumulation and decumulation) and spatial-temporal change, but also intent and qualitative change, which determine how the process is configured.

Taking up the analogy of a recipe, introduced by Boulding (1955 [1941]) and elaborated by Georgescu-Roegen (NGR71:234-236), the point can be illustrated by considering the difference between a custard pie and a pound cake (Farrell and Mayumi, 2009:303). The ingredients used to produce the two are the same. However, two different results arise from the two different recipes, each of which includes three distinct types of information: ingredients, measures for these ingredients and mixing instructions. As Georgescu-Roegen has pointed out on many occasions, the basic production function used in both classical liberal and neoclassical neoliberal economics, employs, at best, the first two, which indicate only that it is possible to "obtain the quantity *z* of product by using the quantities *x*, *y*,… of this and that factor" (NGR71:235), telling us not what the process in question does, but rather, what it may do, the "variables involved… describe the process in the same manner in which the inscription '40 watts, 110 volts' on an electric bulb or 'B.S. in Chemical Engineering' on a diploma describes the bulb or the engineer. Neither description informs us how long the bulb burnt yesterday or how many hours the engineer worked last week" (NGR71:239). In order to depict these aspects of a production process, the mixing instructions, which are what make it possible to distinguish between different outcomes associated with use of the same resources, are needed: mix together the flour and sugar in a bowl; knead together the flour and butter, to make a crust, and so on.

In the flow-fund theory ontology, this additional information, which Farrell and Mayumi (2009) refer to as *Cuisine*, is provided by replacing a fixed set of point function factors of economic production, assumed to be stable in their own right and to have unchanging relationships among each, with a complex variable set of functional elements of production, the characteristics and composition of which depends upon the economic process in question.

Since flow-fund theory looks to the purpose of an economic process in order to determine which elements to include in this representation, and to determine whether a given element should be

classified as a flow or a fund (NGR71:261), its ontology explicitly includes the role of human intent in defining the material characteristics and dynamics of economic processes. This is a decidedly constructivist position, one that Foucault (1984) formulates in quite similar terms, when considering how an enlightened being, faced with the observation that they are consciously participating in shaping the past of their own future, is to handle the crushing responsibility that this implies. In response, he proposes a "philosophical ethos appropriate to the critical ontology of ourselves as a historico-practical test of the limits that we may go beyond, and thus as work carried out by ourselves upon ourselves as free beings" (Foucault, 1984:47). Constructing such 'mature' ontologies, is, one might argue, 'the' challenge of the post-modern thinker. In much the same vein, so called "post-autistic economics," which I would rather call mature economics, bearing in mind that autism is a neurological condition and not a state of mind, calls upon the economic scholar of today to provide a rigorous ontological basis for representing economic process as a complex, living process, far from thermodynamic equilibrium, in which human choice is not only a factor driving allocation and distribution but also a parameter, determining how the process itself is configured.

Under present circumstances, which are, to say the least, alarming, clearly discerning precisely which representations of reality are robust, plausible, and empirically coherent, is a matter of pressing concern, as it is now immanently clear that 'something here has to give,' as the old saying goes.

There is both guidance and tools to be found in the bowels of *The Entropy Law and the Economic Process*. Far from being intended to address merely the specific question of whether or not economic growth is a good thing, Georgescu-Roegen's flow-fund theory was developed and offered up, in its day, as a new general theory of economic production, one that effectively handles 'the' dilemma of the post-modern thinker concerned with questions of economics in the 21st century, by effectively placing the reflexive human back inside the eurodescendent ontology of economic process that is being used to make sense of modern technological development, industrial progress and economic performance.

Elimination of an appeal to the universal truth of the divine was a moment of immense epistemological upheaval for those who lived through the European Enlightenment; and thinkers working today from within European philosophical traditions – as am I, as are we, contributing to this collection, and as are the neoclassical economists whose work is used to justify the now waning neoliberal global political economy – are faced with a choice (Camus, 1953[1951]): replace the demystified truth-sayer of divine authority with an appeal to a new set of universal natural laws, such as Pareto´s, or give up on the unruly demand that an ever changing and evolving world should conform to immutable standards of reference, seeking instead to develop standards of reference suitable for describing the characteristics and dynamics of an ever changing and evolving world (Prigogine, 1997; Prigogine and Stengers, 1984). I would argue that it is precisely the latter which Georgescu-Roegen has achieved with his flow-fund theory of economic production and that its mathematical foundations and structure hold out great promise for developing models that can indeed identify pathways out of the current catastrophic version of the Anthropocene, through which we are living today, and into a virtuous one, where the ordinary daily lives of humankind are situated within and contributing toward the well-being of the rest of nature (Faber et al., 1995).

In his search for a way to formalize the overall structure of this new economic analysis, Georgescu-Roegen arrived at the concept of "economic *Anschuaung*" (NGR71:362), which can be understood as the way in which an individual, community or analyst is thinking about the purpose of an economic process. It is a term he takes up initially from Veblen's (Veblen, 1934:251 f., 1964:64-66, as cited by NGR71:362) usage in constructing a critique of Leninism, and upon which he expands a great deal, along lines quite well in keeping with Kant´s (1990 [1787]) original use of the term, in his *Critique of Pure Reason*: i.e. *Anschauung* is understood as perspective, that aspect of human consciousness

related to interpretation and reflection, and is juxtaposed against *Verstand*, or understanding, that aspect of human consciousness related to discerning how the world actually is.

As Farrell and Mayumi (2009), point out, with its reliance on the referent of "economic *Anschauung,*" in flow-fund theory boundaries are not phenomenological but defined through reference to "the purpose setting complex of tradition, consciousness and abstraction through which societies conceptualise the structure of time (generally or for a specific bounded problem) – their economic *Anschauung*" (NGR71:362 as quoted in Farrell and Mayumi, 2009:304). "Where the traditional [economic] distinction between stocks and services is presumed to be phenomenological, under GR's flow/fund model, distinctions between stocks, flows and funds are made with regard to the boundaries of the specified economic process under consideration" (Farrell and Mayumi, 2009:303). Stocks, as a category, are eliminated from the analysis, and replaced by the flow-fund distinction between materials in stock, serving as a fund that makes possible future production, and materials functioning as flows, as they are either consumed or produced, during a production process.

The concept provides flow-fund theory with a stable anthropogenic referent, the purposive gaze of the economic actor or analyst, with reference to which the flow-fund status of any given element can be derived, while, at the same time, allowing for variability across cultures, in both the how, and perhaps more importantly the why of undertaking a given economic activity. Silva-Macher and Farrell (2014:751) illustrate the concept using the example of a fruit tree: depending upon whether it is approached from the perspective of a carpenter or that of a fruit grower, the tree will be assigned a different flow-fund status. For the carpenter, who will use the tree to make a table, it is an input flow, whereas, to the fruit grower, who will use it to cultivate fruit, the tree is a fund. Ultimately, what distinguishes these two basic statuses is the temporal relationship between the process and the object, in this case a tree. From the perspective of the carpenter, the tree is used up over the duration of the economic process in question, whereas, from the perspective of the fruit grower, it serves as an agent, facilitating the generating of the output flow of fruit.

With the addition of economic *Anschauung* the ontological shift of flow-fund theory is complete: the economic role of elements, unlike that of factors, depends not on the material characteristics of the object, per say, but rather upon the role that object is playing within a given economic process, which is, of course, encumbered, to a certain extent, by its material characteristics. While the difference is, as Georgescu-Roegen notes, of little consequence with respect to some elements, such as Ricardian land, which is quiet resistant to interpretations and will tend to occupy the same fund position in almost any economic process, this is not the case for all elements. In particular, it is not the case for capital, which can play any number of roles within a production process, simultaneously and consecutively: investment capital, spent (output flow at the level of the enterprise; input flow at the level of production) to buy input materials (input flows at the level of production) or equipment (funds at the level of production). While treated, in neoclassical mathematics as a homogeneous set of values, capital is, in effect, a combination of flows and funds, dedicated to starkly different parts of a complex process of economic production, leading to a "point [that] has often been missed. And it is not a point of minor importance[,… a] notable illustration [of which] is provided by the analytical difficulties into which Marx got himself by failing to distinguish in his diagram of simple reproduction between the fund-hammers and the flow-hammers" (NGR71:231): while capital and labor may be rendered homogeneous, and on that basis readily incorporate into classical and neoclassical calculations, this is only when their contribution toward an economic process is measured in terms of money (NGR71:244). If a flow or fund, such as sunlight or air, is not available for purchase on a market, then, leaving aside the moral issue as to whether or not it should be, it is not possible to clearly establish its so called 'real' price. However, this limitation in the formula does not somehow magically render these elements irrelevant for economic production. What it does do is oblige their exclusion from neoclassical economic

representations. While admittedly more cumbersome, in computational terms, the alternative, functional representation of that same process, under flow-fund theory, can and does provide space for tracing the economic contribution of priceless phenomena.

Once formalized in this way, flow-fund distinctions can be applied to all elements of production, providing a completely relational representation of ecological economic processes, which is no longer beholden to the assumption that it is only through reference to market price that relationships between the factors of production can be defined (Farrell and Löw Beer, 2019; Farrell and Silva-Macher, 2017). This has a range of implications, but the most far reaching of these is most certainly a complete reconfiguration of how we talk about capital and its role in economic production.

Contextualizing capital: a companion position to Hodgson's (2015)

In treating all materials agnostically, with respect to their flow-fund status, Georgescu-Roegen provides a referent, with regard to which capital can be contextualized, to paraphrase Hodgson (2015). To better understand how this works, it may be helpful to return to Georgescu-Roegen's early institutional economics, where he discusses in great detail (Georgescu-Roegen, 1960, 1965a, 1965b, 1969) how a peasants' self-understanding of social-ecological place (Farrell and Thiel, 2013) is related to the organization and outcomes of their agricultural production practices. Recalling Simon's (1987) position on the institutionalised character of intuition in decision making and Vatn's (2009) conceptualisation of institutions-as-rationality-contexts, there is a clear relationship to be seen, between Georgescu-Roegen's (NGR71:Ch.1,S.5) initial discussion of what he called "economy of thought," where knowledge is parked, in traditions and customs, providing in that way, space for creativity and exploration, and the proposition that institutions not only constrain but also facilitate economic process (Bromley, 2006).

By adopting routines of thought that can be shared and referenced across space and time, i.e. by establishing protocols, customs and tradition, complex thoughts and ideas can be constructed (see also Clark, 1997; Clark, 2002) by parking some ideas outside the mind of the individual, these can be reflected upon, revised and ajusted. Presenting, on this point, a position quite similar to that of Cilliers (2005), Allen *et al*. (2001) and Funtowicz and Ravetz (1993), Georgescu-Roegen (NGR71) argues that reliance on axiomatic economy of thought, such as that employed in much of classical and nearly all neoclassical economics, runs up against its limits when applied to the formalisation of knowledge concerning novelty, since novelty can, by definition, not be logically anticipated. He proceeds to differentiate between three ways of understanding novelty, which he identifies as a task of utmost importance for economic analysis, since it is concerned with the realization of qualitative change in living systems:

> *rational phenomena of the first order*, the appearance of which can be explained through reference to established or plausible logical algorithms;
>
> *rationality of the second order*, where novelties "cannot be known unless they are actually observed first," and

rational phenomena of the third order, where, whereas "matter, at the physico-chemical level, is uniform…[m]ore often than not, this permanence is absent from the organic and superorganic [read social / institutional] domain… [He goes on to argue that] this peculiarity separates by a broad line the sciences of lifebearing structures from those of inert matter. …[T]o say that Matter has infinitely many

properties may not represent the whole truth and, hence, may be misleading. The whole truth is that Matter has infinitely many *potentiae* …" (NGR71:117 – *emphasis original*).

Linking this proposition to the question of purpose, in the subsequent chapter of his master work, he argues that "[r]ational phenomena of the third order, which abound in the organic [read organisms] and superorganic [read organizations] domain, … suggest that the same 'cause' may have various 'effects.' [Concluding that, of] course, it would be improper to attribute this variation to a random factor" (NGR71:184). He attributes it, instead, to historicity, which he argues is the general case of the "analytical regularities [i.e. rational phenomena of the second order] observed in nature. In fact, these regularities are nothing but a special, limiting instance of historical trend" (NGR71:184). That is to say, in lieu of treating the factors of economic production as given, as is the case in the Wicksteed production function, Georgescu-Roegen treats the factors of economic production as historico-cultural artefacts that reflect the different final causes toward which different economic processes, differently positioned in space/time are dedicated. This converts capital from a found object generating inevitable driving pressures on economic organization into an anthropogenic object that may serve a range of functions directed toward realization of one or another final economic purpose.

This is the heart of his critique of the limitations of an exclusively arithmomorphic approach to analysis of economic process (NGR71:100): that economic process is, ultimately, a biological process, through which human beings transform materials and relations into objects and activities which they themselves specify. This is not to somehow suggest that Maslow's (1943) hierarchy of needs is without meaning, nor to imply that seeking to secure sufficient food for a community, or indeed for humanity, is somehow a whimsical proposition. Indeed, we may imagine that to be one of the first and foremost purposes that a community would be inclined to specify. However, to meet basic needs is a minimum, one that we may presume could be met today, if there were sufficient will to do so, thanks to the exponential growth in productivity made possible by industrial capitalism (Keynes, 1963).

The question at hand is not so much what the abstract formalized shape of the infinite possibilities for economic production is, as it is, which of the infinite *potentiae* will be realized. In considering this, Georgescu-Roegen brings back in the idea that economic process should be understood as a biological phenomenon, with reference to the concept of equifinality he continues the work of building into the flow-fund ontology purpose, motivation and "final cause, whether we consider the equifinality of the biological organisms or, especially, man and society running after their purposes" (NGR71: 187). In this way, he is able to link human intent together with the teleological constraints associated with achieving complex organization. Equifinality is the tendency of living organisms to achieve the same outcome through different routes of development. In the context of economic process, one can think, for example, of the great variety of automobiles produced around the world – all designed to serve the same purpose, there are a number of constraints that restrict the scope of *potentiae*. Bertalanffy illustrates the principle through reference to the intuitively obvious example of the way in which growth is regulated within organisms, producing humans in one size range, dogs in another and elephants in a third, because "the surface-volume ratio [of living system viability, in the face of gravity] is shifted in disfavour of surface with increasing size" (Bertalanffy, 1950:157-158). Blue whales are the largest animals on earth, one might say, because the constraints influencing how large an animal may grow (gravity, anabolism, catabolism) are differently *related* in the *context* of buoyance, so that the upper limit of this surface to volume ratio is increased, making it possible for whales to exceed the terrestrial ratio boundary. This is a consequence of the teleology of the blue whale, in that living blue whales are waterborne whales. While one can remove a blue whale from the water, it will not remain a *living* whale for long.

Continuing with the example, we can consider the counter example of a killer whale, which has a maximum size much smaller than that of the blue whale. This size can also be linked, using the principle of equifinality, to its teleology, in that a killer whale is an opportunistic hunter, which needs to be able to pursue a range of prey and therefore requires an elevated degree of agility in order to fulfil the purpose of staying alive. That agility requires that the metabolism and morphology of the killer whale be different from that of the blue whale, placing additional constraints on its potential maximum size. In order to move from reference to individual organisms, to social lifebearing organisms, comprised of multiple individuals, Georgescu-Roegen uses the example of ants, which have what he calls endosomatic social differentiation, manifest through the different body shapes serving different purposes within a colony (NGR71:348). The human social lifebearing organism of a village, or of any other superorganic bioeconomic community, can, following Georgescu-Roegen, be understood to have exosomatic social differentiation, manifest through the different roles and responsibilities assigned, and opportunities and constraints presented to, members serving different purposes, within an institutionally mediated society:

If a few marginal exceptions are ignored, man is the only living being that uses in his activity also 'organs' which are not part of his biological constitution. We economists call them capital equipment, but Lotka's [(1945)] term, exosomatic instruments, is more enlightening. …Exosomatic instruments enable man to obtain the same amount of low entropy with less expenditure of his own free energy than if he used only his endosomatic organs. (NGR71:307); …our exosomatic evolution has turned production into a social undertaking (NGR71:308); Like the social insects, man lives in society, produces socially and distributes the social product among his fellows. But, unlike the social insects, man is not born with an endosomatic code capable of regulating both his biological life and his social activity. And since he needs a code for guiding his complex social activity in a tolerable manner, man has had to produce it himself. This product is what we call tradition (NGR71:359).

Without wishing to propose that there is a simple one-to-one relationship between tradition and the teleology of equifinality discussed above, we may nonetheless say that, in much the same way that a killer whale is, teleogically speaking, an opportunistic waterborne mammalian hunter, tradition is, in human social community, teleological, in that it serves as a referent for what that community is. In elaborating his position on this matter, Georgescu-Roegen explicitly links it with the idea of institutions: "A biological process sees to it that the pool of genes is transmitted from one generation to another. Tradition does the same for what we call 'values' or, more appropriately, 'institutions,' i.e., the modes by which every man acts inside his own community" (NGR71:359). These modes, which are the social referent of what is appropriate, serve to determine, for example, which *potentiea* of elements will be realized in the society in question. Will it be considered appropriate that humans are treated as flows? Worked to the death and discarded, as if they were waste materials, as done in Auschwitz? Will it be considered appropriate that water flowing from high mountain glaciers and lakes is extracted at rates that do not exceed replenishment rates, in order to ensure that they continue to function as funds? Is it considered appropriate for capital to serve as a fund not only for processes of production but also for processes of speculation and accumulation?

In order to trace to its conclusion, this link between the teleological character of the flow-fund distinction and the concept of economic *Anschauung*, we can return to the analytical argument presented above, regarding the special characteristics of *rational phenomena of the third order*, which Georgescu-Roegen treated as particular to lifebearing organisms and linked to teleology. In elaborating definitions for these three types of reason, he provides an illustration of how such rationality is, in economic process, dependent upon the social and cultural traditions that structure choices regarding how human economic practice is conducted: "in some human societies the bride is bought, in others she brings a dowry into the new family, and in still others there is no matrimonial transaction of any sort. Yet the elements of the next lower level, the biological humans that form by combination each of these societies, are the

same. From the same basis, therefore, a multiplicity of novel forms may spring up" (NGR71: 117). Here marriage can be understood as a *rational phenomenon of the third order* both because its realisation, in terms of it being executed through the buying of brides or homes or without any payment, has a degree of permanence across human societies, while how it is realised cannot be logically anticipated solely through reference to information gathered about a society. Put simply, the realisation happens within an historical and material context that has come into being over time, in the course of the evolution of a lifebearing organism, the community, going about being alive. Due to this, its coming into being cannot be explained solely through reference to logic. *Why* marriage is done the way it is done is a matter of tradition, while *that* it is done, and that it is usually expected to be done in some particular way, are matters of the human inclination toward tradition.

Decisions regarding how an economic process is configured, are, in this respect, not only shaped by intent, but also by historicity, context and reflection. For example, a given object may be an input flow element in one process and a fund element in another. If there are, in a society, advocated pursing the realization of each of these two processes, then we can expect there to be conflict between them, because their respective economic *Anschauungen* delimit competing flow-fund element configurations (Silva-Macher and Farrell, 2014). One could make a similar argument with respect to the decision as to whether to invest a supply of capital on the stock market, with a bank or in a productive enterprise: each option can be associated with a distinct economic *Anschauung*, in which the original capital is classified, respectively, as either a fund or flow element. By contrast, if an object or material is an output flow element of one process and a fund of another, we can speak of a dependency relationship between the two processes and of a potential contribution by the former toward maintaining the productive capacity of the latter. This is not the same as capitalization, but it has a similar effect, of making production possible: producing, as it were, productive capacity (Farrell, 2020; Scheidel and Farrell, 2015).

Georgescu-Roegen specifically addresses this special character of elements that make production possible (i.e. forms of capital), through elaboration of the concept process funds (NGR71:239-240). A process fund, is a flow that maintains its function throughout the duration of the process under consideration, as does any other fund. However, where ordinary funds are simply used, process funds are both produced and consumed during the economic process. They are what is typically referred to as goods-in-process (NGR71:239). We can understand these as intermediate flows, which neither leave nor enter the process, because their production is an intermediate step to allow the realization of the productive process under consideration. The parallels to capital investment are obvious.

Remaining with the example of a fruit tree, for the grower, sap, bark and leaves can be understood as process funds that must be produced and maintained throughout the growing season, in order to generate the output flow of fruit. For the carpenter, the orchard, which produces trees, is a process fund that must be maintained, in order to guarantee a steady flow of wood, to be made into tables. At the level of an economy, fruit farming can, in this example, be understood as a □Sector, which produces productive capacity in the form of funds, in this case orchards, and on that basis facilitates, much as we typically imagine does capital, production, in this case, of wood tables (NGR71:239-240 and 274-275; Scheidel and Farrell, 2015:231).

Through the introduction of these four new analytical categories of flows, funds, process funds and the □Sector, Georgescu-Roegen develops an ontology suitable for representing, in concrete terms, how decisions regarding the allocation and distribution of available resources, across an economic process, is related to both the intentional perspectives of those involved realizing the processes in question and to the maintenance of the productive capacity of these processes, in both economic and biological terms. The combination of these two features facilitates formalised analysis of the relationships

between qualitative changes in economic and in ecological processes, bringing a whole new meaning to the term natural capital – instead of dragging biological phenomenon into the logic frame of neoclassical economic mathematics, it provides a set of analytical categories that can be applied in precisely the same way, in order to represent the contribution of machinery, money or mangroves toward the maintenance of productive capacity in an ecological economy.

Looking to the future: more accumulation? or living well together?

Returning one last time to the ontology of flow-fund theory, the incorporation of final cause, purpose, intent, at the structural level, makes it possible to formulate a constructive critique of the neoliberal paradigm, one that continues to provide a place within its conceptualization of economic process for exchange, commodities, and capital, all three of which have proven to be remarkably useful elements and none of which seem likely vanish from human society in the immediate future.

However, instead of treating the investment of capital for maximum return as a *fait accompli*, somehow inherent in the character of the factor, flow-fund theory invites one to ask, what end is served by the mobilization of a given amount of a capital fund in the form of an input flow, directed to facilitate the realization of one or another productive process (Farrell and Löw Beer, 2019). Flow-fund theory is specifically designed to provide a more appropriate representation of the characteristics and dynamics of economic process, conceptualised as an combination of activities undertaken by thermodynamically open, life-bearing organisms and organizations, which achieve stability by processing materials and energy throughputs coming from, and eventually released back into their environments, under conditions where teleology matters (Prigogine, 1997; Schrödinger, 1948[1944]).

“All lifebearing structures work toward a purpose - to maintain their entropy intact… No form of cause that may fit other phenomena could do for the sciences of life. The final cause – that is, purpose – is not only in its right place in these sciences but it also constitutes an indispensable and extremely useful tool of analysis” (NGR71:194).

When capital is viewed as an element – which might be an input flow, an output flow, a fund or a process fund – this opens up the way we can think about its role in production and liberates us from the idea, intrinsic to neoliberal arguments, that capital accumulation is the only engine upon which we can rely to keep the contemporary global economy afloat. Making explicit the place of purpose in determining the configuration and composition of economic processes, provides space to reflect upon whether the general purpose of economic production should be the accumulation of monetary wealth, the flourishing of life, or perhaps something else altogether: to consciously adopt a future oriented, creative posture: characterized by an economic *Anschauung* that is actively chosen, not passively received. Perhaps the overarching purpose of economic process should today be to halt, reverse, redirect and replace current globalized dynamics that are quite literally destroying the biological substrates of the planet earth, ranging from still rampant carbon based fuel use, to the making invisible of material exploitation and ecological destruction, through the digitalized, globalized consumer experience (Klein, 1999; Luxemburg, 1951[1913]). What is clear, is that flow-fund theory provides a coherent, rigorous and structure means to determine whether or not the economy actually being practiced consists of processes compatible with that, or indeed some other given purpose.

References:

Allen, T.F.H., Tainter, J.A., Pires, J.C., Hoekstra, T.W., 2001. Dragnet Ecology—"Just the Facts, Ma'am": The Privilege of Science in a Postmodern WorldScience of intrinsic quality needs narratives with explicit values—not just facts—particularly as it faces multiple-level complexity in advising on environmental policy, such as planning for energy futures. BioScience 51, 475-485.

Bertalanffy, L.v., 1950. An Outline of General System Theory. British Journal for the Philosophy of Science 1, 139-164.

Boulding, K.E., 1955 [1941]. Economic Analysis (3rd edn.). Harper (as cited by Georgescu-Roegen, 1999[1971]), New York.

Bromley, D.W., 2006. Sufficient Reason: Volitional Pragmatism and the Meaning of Economic Institutions. Princeton University Press, Princeton.

Cilliers, P., 2003. Do Modest Positions Have To Be Weak? A View From Complexity, Complexity, Ethics & Creativity, LSE.

Cilliers, P., 2005. Complexity, Deconstruction and Relativism. Theory, Culture & Society 22, 255-267.

Crutzen, P.J., Stoermer, E.F., 2000. The Anthropocene. IGBP [International Geosphere-Biosphere Programme] Newsletter 41.

Dewey, J., 1958 [1929]. Experience and Nature (Dover Edition). Dover Publications Inc., New York.

Faber, M., Manstetten, R., Proops, J., 1995. On the conceptual foundations of ecological economics: a teleological approach. Ecological Economics 12, 41–54.

Farrell, K.N., 2020. Mejorar la Vida Ecológica, Mejora la Vida Económica, in: Rincón-Ruiz, A., Arias-Arévalo, P., Clavijo-Romero, M. (Eds.), Hacia una valoración Incluyente y plural de la Biodiversidad y los Servicios Ecosistémicos Visiones, avances y retos en América Latina. Universidad Nacional de Colombia, Bogotá, CO, pp. 57-74.

Farrell, K.N., Löw Beer, D., 2019. Producing the ecological economy. Ecological Economics 165, 106391.

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, 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, 166-179.

Farrell, K.N., Thiel, A., 2013. Nudging Evolution? Ecology and Society 18, art47.

Foucault, M., 1984. What is Enlightment?, in: Rabinow, P. (Ed.), The Foucault Reader: An Introduction to Foucault's Thought. Penguin, London, pp. 32 - 50.

Funtowicz, S.O., Ravetz, J.R., 1991. A New Scientific Methodology for Global Environmental Issues, in: Costanza, R. (Ed.), Ecological Economics: The Science and Management of Sustainability. Columbia University Press, New York, pp. 137-152.

Funtowicz, S.O., Ravetz, J.R., 1993. Science for the Post-Normal Age. Futures 25, 739-755.

Funtowicz, S.O., Ravetz, J.R., 1994a. Emergent complex systems. Futures 26, 568-582.

Funtowicz, S.O., Ravetz, J.R., 1994b. The worth of a songbird: ecological economics as a post-normal science. Ecological Economics 10, 197-207.

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. Pergamon Press, Oxford, pp. 103-145.

Georgescu-Roegen, N., 1965a. The Institutional Aspects of Peasant Communities, in: Georgescu-Roegen, N. (Ed.), Energy and Economic Myths: institutional and analytical economic essays. Pergamon Press, Oxford, pp. 199-231.

Georgescu-Roegen, N., 1965b. 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. Pergamon Press, Oxford, pp. 71-102.

Georgescu-Roegen, N., 1969. The Economics of Production, in: Georgescu-Roegen, N. (Ed.), Energy and Economic Myths: institutional and analytical economic essays. Pergamon Press, Oxford, pp. 61-69.

Georgescu-Roegen, N., 1990. Production process and dynamic economics, in: Baranzini, M., Scazzieri, R. (Eds.), The economic theory of structure and change. Cambridge University Press, Cambridge, pp. 198–226.

Giampietro, M., Mayumi, K., 1997. A dynamic model of socioeconomic systems based on hierarchy theory and its application to sustainability. Structural Change and Economic Dynamics 8, 453-469.

Giampietro, M., Mayumi, K., 2000a. Societal Metabolism Part 1 of 2: Introduction of the Analytical Tool in Theory, Examples, and Validation of Basic Assumptions. Population and Environment 22, 97-254.

Giampietro, M., Mayumi, K., 2000b. Societal Metabolism Part 2 of 2: Specific Applications to Case Studies. Population and Environment 22, 257-352.

Haraway, D., 2015. Anthropocene, Capitalocene, Plantationocene, Chthulucene: Making Kin. Environmental Humanities 6, 159-165.

Hodgson, G.M., 2015. Conceptualizing Capitalism: Institutions, Evolution, Future. Chicago University Press, Chicago.

Holling, C.S., Meffe, G.K., 1996. Command and Control and the Pathology of Natural Resource Management. Conservation Biology 10, 328-337.

Kant, I., 1990 [1787]. The Critique of Pure Reason, in: Adler, M.J. (Ed.), Great Books of the Western World. Vol. 39, Kant. Encyclopædia Britannica, Inc., London.

Keynes, J.M., 1963. Economic Possibilities for our Grandchildren (1930), Essays in Persuasion. W. W. Norton & Company, New York, pp. 358-373.

Klein, N., 1999. No Logo: Taking Aim at the Brand Bullies. Knopf Canada, Toronto.

Latour, B., 2013. An Inquiry into Modes of Existence: An Anthropology of the Moderns. Harvard University Press, Cambridge, MA.

Light, A., 2002. Contemporary Environmental Ethics From Metaethics to Public Philosophy. Metaphilosophy 33, 426-449.

Lotka, A.J., 1945. The Law of Evolution as a Maximal Principle. Human Biology 17, 167-194.

Luxemburg, R., 1951[1913]. The Accumulation of Capital (Translated by Agnes Schwarzschild). Routledge and Kegan Paul, London.

Marcuse, H., 1978. Protosozialismus und Spätkapitalismus - Versuch einere revolutionstheoretischen Synthese von Bahros Anzatz, in: Claussen, D. (Ed.), Spuren der Befreiung - Herbert Marcuse. Luchterhand [reprinted from the original in Kritik, Zeitschift für sozialistische Diskussion, 19 / later published as (1980) "Protosocialism and Late Capitalism: Toward a Theoretical Synthesis Based on Bahro's Analysis." International Journal of Politics 10(2/3) Rudolf Bahro: Critical Responses:25-48], Darmstadt und Neuwind, pp. 89-116.

Marshall, A., 1920[1890]. Principles of Economics, 8 ed. Macmillan and Co, London.

Maslow, A.H., 1943. A theory of human motivation. Psychological Review 50, 370–396.

Mayumi, K., 1995. Nicholas Georgescu-Roegen (1906-1994): An admirable epistemologist. Structural Change and Economic Dynamics 6, 261-265.

Mayumi, K., 2001. The Origins of Ecological Economics: the bioeconomics of Georgescu-Roegen Routledge, London.

Mayumi, K., 2017. Thermodynamics: relevance, implications, misuse and ways forward, in: Spash, C. (Ed.), Routledge Handbook of Ecological Economics: Nature and Society. Routledge, London, pp. 89-98.

Mayumi, K., Giampietro, M., 2006. The epistemological challenge of self-modifying systems: Governance and sustainability in the post-normal science era. Ecological Economics 57, 382-399.

Mayumi, K., Giampietro, M., Gowdy, J., 1999. Georgescu-Roegen/Daly versus Solow/Stiglitz Revisited. Ecological Economics 27, 115-117.

Milliken, D., Holton, K., 2020. Tech giants and tax havens targeted by historic G7 deal, Reuters Business. REuters, London.

Mirowski, P., Plehwe, D., 2009. The Road from Mont Pèlerin: The Making of the Neoliberal Thought Collective. Harvard University Press, Boston.

Moreau, V., Sahakian, M., van Griethuysen, P., Vuille, F., 2017. Coming Full Circle: Why Social and Institutional Dimensions Matter for the Circular Economy. Journal of Industrial Ecology 21, 497-506.

Pikkety, T., 2014. Capital in the Twenty-First Century [Le capital au XXI siècle]. Harvard University Press, Boston.

Popper, K., 1968[1959]. The Logic of Scientific Discovery. Harper & Row Publishers, New York.

Prigogine, I., 1997. The End of the Certainty - Time, Chaos, and the New Laws of the Nature. Free Press, New York.

Prigogine, I., Stengers, I., 1984. Order out of Chaos: man's new dialogue with nature. Heinemann, London.

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, 230-240.

Silva-Macher, J.C., 2016. A Metabolic Profile of Peru: An Application of Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM) to the Mining Sector's Exosomatic Energy Flows. Journal of Industrial Ecology 20, 1072-1082.

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, 1-22.

Simon, H.A., 1987. Making Management Decisions: The Role of Intuition and Emotion. The Academy of Management Executive (1987-1989) 1, 57-64.

Steffen, W., Rockström, J., Richardson, K., Lenton, T.M., Folke, C., Liverman, D., Summerhayes, C.P., Barnosky, A.D., Cornell, S.E., Crucifix, M., Donges, J.F., Fetzer, I., Lade, S.J., Scheffer, M., Winkelmann, R., Schellnhuber, H.J., 2018. Trajectories of the Earth System in the Anthropocene. Proceedings of the National Academy of Sciences 115, 8252.

Veblen, T., 1934. Essays in Our Changing Order. The Viking Press, New York.

Veblen, T., 1964. Imperial Germany and the Industrial Revolution. Augustus M. Kelley, New York.

Walker, B., Holling, C.S., 2013. Probing the boundaries of resilience science in practice, in: Farrell, K.N., van den Hove, S., Luzzati, T. (Eds.), Beyond Reductionism: a passion for interdisciplinarity. Routledge, London.

Waters, C.N., Zalasiewicz, J., Summerhayes, C., Barnosky, A.D., Poirier, C., Gałuszka, A., Cearreta, A., Edgeworth, M., Ellis, E.C., Ellis, M., Jeandel, C., Leinfelder, R., McNeill, J.R., Richter, D.d., Steffen, W., Syvitski,

J., Vidas, D., Wagreich, M., Williams, M., Zhisheng, A., Grinevald, J., Odada, E., Oreskes, N., Wolfe, A.P., 2016. The Anthropocene is functionally and stratigraphically distinct from the Holocene. Science 351.

Zalasiewicz, J., Williams, M., Haywood, A., Ellis, M., 2011. The Anthropocene: a new epoch of geological time? Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences 369, 835-841.

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