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ABSTRACT

Intellectual legacies are part of historians' concerns, when they study the evolution of ideas. There are, however, no guidelines to help characterize the reception of intellectual legacies. This article provides preliminary tools to fill this gap, with a typology (faithful, formal, substantial legacies), and with two criteria to assess the conformity between the heir's and her inspirer's proposals. The objective is not to judge the legitimacy of this or that reception, but to facilitate its characterization, for a better understanding of the transmission of ideas. One case study from the history of economic thought, Nicholas Georgescu-Roegen's bioeconomics and its legacies, is provided to illustrate the operability of the toolbox.

1. Introduction

Historians of thought often study the transmission of theories, ideas, concepts, and methods from one author to another or from one generation of authors to another. Published materials are compared, archives are unearthed, biographical trajectories are scrutinized to uncover connections or indirect relations between thinkers. Historians can then identify “traditions” (e.g. Dockès, Frobert, Klotz, Potier, & Tiran, 2000), “schools of thought” (e.g. Shionoya, 2000; Thompson, 2017) or “movements” (e.g. Rutherford, 2011). Among such schools and so forth, intellectual legacy occupies an important place. In the history of thought, some books, articles and reviews explicitly refer to the “intellectual legacies” of Wroe Alderson (Fraedrich, 2007), Kenneth Arrow (Sandbu, 2017), Ronald Coase (Ricketts, 2014), Jules Dupuit (Ekelund & Hébert, 2012), John Harsanyi (Morini, 2001), Ivan Illich (Robert & Paquot, 2010), Karl Marx (Rapoport, 1968), Gordon Tullock (Rowley, 2012), Thorstein Veblen (Tilman, 1996) and so on. Obviously, each historian has a different understanding of what an intellectual legacy is, and it is very hard (almost impossible) to find a clear definition of what is at stake when the term is used.

The concept of intellectual legacy in the history of *economic* thought especially matters, as a well-known series of books entitled “Intellectual

Legacies in Modern Economics” (Edward Elgar Publishing) testifies. Yet this series does not provide any definition of intellectual legacy, which suggests that it is considered common knowledge.¹ To be sure, intellectual legacy can be intuitively defined as dealing with the transmission of ideas, theories, models, practices, graphs or other tools from a senior scholar, or a group of senior scholars, to a new generation of thinkers and practitioners. But could we go beyond this intuitive definition?

This article aims at providing some preliminary tools for a better understanding of what an intellectual legacy is, and how it is transmitted. It also aims at helping historians of thought characterize their interpretation of the reception of intellectual legacies. Is there a single form of intellectual legacy, or several? On which criteria can we build categories of legacies? Our objective is not to judge the legitimacy of this or that reception of an intellectual legacy. It is to provide a framework to better understand and characterize the transmission of ideas. Our proposals are a first attempt to clarify the historiographical debate on intellectual legacies. They do not pretend to address all questions related to the subject, but we hope they will be an invitation to colleagues to think in more detail about the subject.

This article is organized as follows. The section below introduces our guidelines about intellectual legacies. The next section then shows how these guidelines can be applied, with the example of Nicholas

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¹ Steven Medema (as the scientific editor of this series) told us that the use of the term “intellectual legacy” was a convenience, and did not result from a precise historiographical investigation.

Georgescu-Roegen's bioeconomics and its intellectual legacies. The last section concludes.

2. An inquiry into intellectual legacies

2.1. What is an intellectual legacy?

What is a *legacy* and what does the adjective *intellectual* mean? A legacy does not consist only in the transmission of some material inheritance, in a legal sense. As Hunter and Rowles (2005) have shown in their classic typology, a legacy can be “biological” or “material”, or it can be a “legacy of values”. As far as *intellectual* legacy is concerned, values are probably the category to observe, even if material items are not out of scope—books, papers and libraries are often where ideas are preserved. It seems, however, that Hunter and Rowles' “legacy of values” does not exactly correspond to what an intellectual legacy intuitively means. They insist on “personal, social and cultural” (Hunter and Rowles, 2005, p. 339) values (generosity, religion, honesty, etc.), rather than on ideas and theories.

In their edited book *Qu'est qu'un héritage? [What is a legacy?]*, Camilleri and Chandelier (2009) present, in the history of philosophy, different cases in which schools of thought were constituted, ideas circulated and legacies transmitted. In the chapter dedicated to republicanism, Miqueu (2009) investigates the issue of *intellectual* legacy. He makes the distinction between three types of transmission (Miqueu, 2009, p. 64): “patrimony” [*patrimoine*], “bequest” [*legs*], and “legacy” [*héritage*]. Patrimony constitutes what necessarily surrounds us—i.e. all the values, ideas, and views of the world that come from the past. Bequest is what a particular thinker (or a particular group of thinkers) transmits to and imposes on succeeding generations. It is easier to date a bequest than a patrimony, because there is an intellectual contribution (a book, a pamphlet, a speech, etc.) that can be pointed out. Finally, an intellectual legacy is defined as a set of *concepts* transmitted by a thinker (or a group of thinkers). Unlike a patrimony or a bequest, says Miqueu, a legacy can be refused, modified, or interpreted by the receiver. This interpretative dimension is a key feature of intellectual legacies: whatever the original thought of the inspirer, legacies are plural, disputable, and sometimes in competition, because all are the result of some interpretation of the original ideas.²

At this stage, an intellectual legacy may be defined as a series of concepts received by a new generation of thinkers who can use, modify, interpret or refuse them. Their inspirer can be anything between a single author and a whole school of thought.³ Such a definition fits well with a certain number of contributions. In his study of Alderson's intellectual legacy in economics and management, Fraedrich (2007) focuses on the concepts coined by Alderson (transvections, homeostasis, etc.), and their impact on marketing. Looking at the Coasean tradition, Ricketts (2014) insists on the concept of transaction cost. With respect to reception (interpretation, rejection, etc.), Rapoport (1968) emphasizes the various coexisting interpretations of Marx. And Rowley (2012) explains that Tullock's career was not homogenous, and that this variety offers multiple viewpoints on his contributions. In the presentation of Jacques Ellul's heirs, Rognon (2012) points out the interpretative enterprise of the new generations: most of the time, their thoughts are a combination of Ellul's ideas and other influences. Fraedrich (2007, p. 526) also reports such mixings in the Alderson case.

Concepts are at the core of what is transmitted. But an intellectual

² Intellectual legacies can become even more complex to discover, when the original ideas are themselves plural, as in the Mertonian case of “simultaneous discoveries” (on the classical case on energy conservation, see Kuhn, 1959; on simultaneous discoveries in economics, see Niehans, 1995).

³ The existence of a manifesto facilitates the characterization of a school of thought. See the case of ordoliberalism (Böhm, Eucken, & Grossmann-Doerth, 1989; see Fèvre, 2017, pp. 210–19).

legacy can also be composed of methods, practices, models, graphs, or even epistemological frameworks and ontological views. Behnegar (1999) indicates that Leo Strauss' impact on political thought has not only been conceptual and theoretical, but also methodological, with an emphasis on philosophical backgrounds. In his short newspaper article about Arrow's intellectual legacy, Sandbu (2017) highlights the influential mathematical tools developed by Arrow in economic theory. Tilman (1996) shows that Veblen's perspective on economic issues was peculiar, embracing various concerns (political institutions, social relations); this perspective, in addition to other inspirations (e.g. German historicism, Weber, Commons), gave birth to a fertile paradigm throughout the 20th century (Hédoin, 2017; Rutherford, 2011).⁴

2.2. How can we detect intellectual legacies?

Since ideas, theories, concepts, tools, methods, epistemological frameworks and ontological views are subject to interpretation, intellectual legacies are necessarily multifaceted, and not always easy to identify. Sometimes, the supposed legacies are explicit because they are claimed, i.e. the receiver clearly refers (genuinely or not) to the inspirer, or to a theory, method or set of ideas considered as coming from this inspirer. Legacies are often claimed when there is a dispute between various legatees. Post-Keynesians, for instance, claim to be the true legatees of John Maynard Keynes. Legacies are also explicit when they are testamentary, i.e. the receiver agrees to be the executor of the inspirer. For example, Friedrich Engels was chosen by Marx for the perpetuation and development of his thought, and later Eduard Bernstein and August Bebel were designated by Engels (Riazanov, 1968).

These situations, however, do not cover all possibilities. Some legacies are less visible, for instance when they are hidden, i.e. a receiver uses ideas, theories, concepts, etc. from an inspirer without reference, or with an interpretation that makes the original ideas difficult to detect (e.g. Mikhail Tugan-Baranovsky drawing on the works of previous theoreticians of crises; see Allisson, 2015). Further, a scholar or group of scholars may be working in a tradition of which they are unaware, i.e. a receiver constructs theories resulting from a set of concerns, or made possible by the existence of specific tools or methods, unconsciously coming from some inspirer. Dupuit's development of utility theory figured unwittingly in the work of French engineers, who built upon Dupuit without knowing that their tools and concepts came from their predecessor (Ekelund & Hébert, 2012, p. 494).

When there is an explicit declaration of the filiation, the detection of supposed legacies is quite easy. On the contrary, when legacies are hidden or unknown to those who work in their tradition, their detection requires in-depth historiographical work, to find long-run filiations and connect authors or generations of authors. The reasons for these only implicit connections are also to be explored. For instance, it might be interesting to look at the psychological, sociological or strategic reasons to hide an intellectual legacy: from unintentional omission to the arrogant wish to appear as the inventor of an idea, through more conscious reflections regarding the readiness of the audience, up to the existence of a repressive context in which some legacies are—objectively or not—impossible to claim. Tugan-Baranovsky explains in the French edition of his book on crises, *Les crises industrielles en Angleterre*, that he was afraid of annoying readers with many scholarly references throughout the text (Tugan-Baranovsky, 1913, p. vi). This is clearly a different motivation from Soviet economists in the 1930s not referring to Tugan-Baranovsky, even if they were clearly his heirs: the 1930 Moscow

⁴ Most of the time, the receivers of intellectual legacies are scholars, thinkers or practitioners in particular fields. Some contributors, however, underline the circulation of ideas from one field to another, or the impact of some thinkers on non-academic spheres, such as public policy (Morini, 2001; Rapoport, 1968; Ricketts, 2014; Robert & Paquot, 2010), or vice-versa. Intellectual legacies are thus not limited to academics.

trials introduced a repressive context in which quoting an economist who engaged in what Lenin called “legal Marxism” and who was classified as a “liberal professor” by Lenin was no longer possible. The conditions under which writing takes place evolve, and what is nowadays considered as a will to hide a filiation was at another period only the fact that this filiation was so evident that it was unnecessary to spell it out.

On what materials can we base our detection and analysis of intellectual legacies? Textual analysis of published writings often provides a departure point: the published materials of the inspirer are compared with those of the potential legatee. In addition, the use of archival documents can also be supportive, in particular when letters, diaries or bibliographical memos help circumscribe the very nature of the relationship between two authors or groups of authors. It is for instance on the basis of archival research that the cross-influence between the British economist and philosopher Frank P. Ramsey and the American economist and mathematician Harold Hotelling can be clarified (Gaspar & Missemer, 2019). Other methods can also be useful, such as quantitative methods. Bibliometric analysis, network analysis, lexical analysis and prosopography (see Edwards, Giraud, & Schinckus, 2018 and the whole issue of the *Journal of Economic Methodology* that follows) may provide support for identifying filiations of ideas, and then intellectual legacies. Oral history—through interviews (Jullien, 2018)—can also be beneficial, to confirm filiations, or to uncover influences, by discussing with potential receivers of a particular set of ideas. When textual analysis does not provide a clear view of a filiation, interviews may be complementary. They can even be decisive when revealing influences otherwise unnoticeable. Witness seminars, consisting in gathering a community of scholars in a same place and observing their interactions with a minimum of mediation, can also be an oral method to confirm or detect the (hidden) role of some inspirer in the work of a whole group of researchers. Witness seminars have mainly been used in the history of science for examining the emergence or development of fields or sub-fields (e.g. Hilton, Arie, & Nicolson, 2010; Maas, 2018; Svorenčík & Maas, 2016). They would certainly be relevant as well for identifying the common inspirations of a scholarly community. These latter options (quantitative methods, oral history), as the former (textual analysis, archival research), do not, however, provide magic solutions to the indisputable identification of legacies. Just because a published text or an archival document shows, or an interviewee claims, parentage does not mean we should take it for granted. Similarly, raw results from quantitative methods are not informative by themselves; they must be analyzed and discussed. Interpretation and verification—in short, historical investigation—remain essential in the study of intellectual legacies.

2.3. The conformity of a legacy

To help characterize the relationship between a receiver and an inspirer, we propose to use two criteria to identify the conformity between two sets of proposals: *conformity-with-the-letter* and *conformity-with-the-spirit*. These criteria are borrowed from a long legal tradition opposing the *spirit of the law*, as a “general meaning or purpose of the law, as opposed its literal content” (Garner, 2009, p. 1531), and the *letter of the law*, as the “strictly literal meaning of the law, rather than the intention of policy behind it” (Garner, 2009, p. 988). Montesquieu (1748, p. 3) famously opposed the spirit and the letter in his work *Spirit of the Laws*, where he defines laws in a new manner: “Laws, taken in the broadest meaning, are the necessary relations deriving from the nature of things.”

Law is not an object, but a relation, and is a matter of interpretation. It is not always possible (or desirable) to apply the letter of the law as it stands, either because it contravenes the spirit of the law, or because a new context introduces a gap in the law that renders it inapplicable. Moreover, the spirit of the law is not always applicable, because the historical intentions of the legislators are not always known, nor is it

always easy to apply a law to a new situation. For all these reasons, interpretation of law is never only a positive description, and the distinction between the spirit of the law and the letter of the law is a necessary—albeit by no means sufficient—step towards a fair interpretation.⁵

In the context of intellectual legacies, the distinction between our two criteria—*conformity-with-the-letter* and *conformity-with-the-spirit*—aims to capture the same kind of complexity: the intentions of the inspirer are not always clear and often result from a historical reconstruction; and there is a dynamic dimension in the transmission of ideas. As in law, our two criteria aim to facilitate a fair interpretation of this transmission.

The first criterion—*conformity-with-the-letter*—is defined by the similarities in the use, by the heir, of the same expressions, notions, models, equations, graphs, etc. as the inspirer. Proximity in terms of methods, which translates into common tools, is also relevant here. This conformity can be important if the receiver draws on most of the inspirer’s works; or it might be modest, if the receiver hardly uses the same expressions, notions, models, equations, etc.

The second criterion—*conformity-with-the-spirit*—is defined by the similarities in the concerns, in the epistemological perspective or in the ontological views of the heir, compared to the inspirer’s. In other words, it is defined by the similarities in the meta-model in which the letter is embedded. Obviously, these dimensions are subject to interpretation. The objective, in this second case, is to search for comparisons beyond the wording and tools used by the authors.

Conformity-with-the-letter may imply *conformity-with-the-spirit*, because similarities in concepts, models and tools may imply similarities in concerns, interests, epistemological perspectives and ontological views. However, this is not always the case, because the meaning of the concepts and models can evolve from one author to another. For instance, Léon Walras and Vilfredo Pareto shared the same modeling framework (general equilibrium), but with radically different perspectives (ontological truth in Walras, first approximation of reality in Pareto; see Bridel & Mornati, 2009). *Conformity-with-the-letter* can therefore be guaranteed without much *conformity-with-the-spirit*. Conversely, *conformity-with-the-spirit* may sometimes appear in proposals formally different from the original reference. In this case, the receiver shares the inspirer’s intent, epistemological framework, ontological views, and general teachings, without the same closeness with regard to his precise concepts, tools and methods. This gap between the inspirer and the heir may lead to what Rognon calls (2012, p. 14) a “fruitful disloyalty” [*“infidélité fructueuse”*]: the receiver may develop the initial thought in insightful ways without strictly imitating the inspirer.

If a receiver’s proposal does not satisfy any of these criteria—*conformity-with-the-letter* or *conformity-with-the-spirit*—with respect to the inspirer’s set of ideas, we can thus conclude there is no intellectual legacy. If at least one criterion is fulfilled, then there is a legacy to be characterized.

2.4. A matrix for a typology of intellectual legacies

The two criteria mentioned above can help to characterize the relationship between a receiver’s proposals and initial teachings by an inspirer. Once a text or a corpus has been identified for comparison with an old set of ideas, one may wonder if the text or corpus satisfies the two criteria: Does it conform to the *letter* of the original set of ideas? Does it conform to the *spirit* of the original set of ideas? Answering yes or no to these two questions will help to define what sort of legacy the text or corpus entertains with the original ideas:

⁵ The historical intentions of the legislator are static, whereas the spirit of the law is understood as evolving through history. For more information on law as interpretation, see Perelman, 1970 and Dworkin, 1982.

		CONFORMITY-WITH-THE-SPIRIT	
		Yes	No
CONFORMITY-WITH-THE-LETTER	Yes	Faithful legacy	Formal legacy
	No	Substantial legacy	No legacy

Fig. 1. Matrix of intellectual legacies.

- If there is *conformity-with-the-letter* AND *conformity-with-the-spirit*, the legacy can be considered as *faithful*.
- If there is *conformity-with-the-letter* WITHOUT *conformity-with-the-spirit*, the legacy can be considered as *formal*.
- If there is *conformity-with-the-spirit* WITHOUT *conformity-with-the-letter*, the legacy can be considered as *substantial*.
- If there is no conformity on both criteria, there is *no legacy*.

To get a visual representation of this toolbox, we have constructed a matrix (Fig. 1), which classifies the different types of legacies. Each category just mentioned is represented in the matrix.

Obviously, this toolbox is theoretical, insofar as the conformity criteria are not always binary options in practical cases: a corpus may be in conformity with another corpus to some extent, but not fully. The classification will require choices by the historian, and there will certainly be room for interpretation and discussion. In our view, this is rather an asset than a flaw, as it can permit historians to have a common language to discuss their positions on the transmission of this or that set of ideas.

3. A case study: Georgescu-Roegen's bioeconomics

The Romanian-American economist Nicholas Georgescu-Roegen (1906–1994) framed his bioeconomic paradigm in the 1960s, 1970s and 1980s to study economic processes in relation to the natural environment. His set of ideas, labeled *bioeconomics*, constitutes a particularly good example to study intellectual legacies, and to apply our toolbox, because many discussions and treatments of the relationship between nature and economic activity within and outside economics are today likely to be inherited from Georgescu-Roegen. Georgescu-Roegen refused to build a school of thought around him (Ayres, 1997, p. 285; Maneschi & Zamagni, 1997, p. 705; Missemmer, 2013; Röpke, 2004, pp. 310–11), which also makes the examination of his legacies a true historiographical challenge. His innovations were diverse and multidimensional, offering opportunities for the appearance of many close or far legatees.

3.1. Bioeconomics

In the 1960s–1970s, Georgescu-Roegen began dedicating his entire agenda to the criticism of the mechanistic bias of conventional, neo-classical economic theories, depicted as only interested in quantity, forces (e.g. supply and demand) and equilibrium. He promoted instead a close relationship between economics, classical thermodynamics and evolutionary biology (Georgescu-Roegen, 1966; 1971; 1976). Georgescu-Roegen's proposal can be interpreted as the constitution of a new paradigm (Dragan & Demetrescu, 1986; Grinevald, 1992; Giampietro & Pastore, 1999; Missemmer, 2013; 2017b), because it mixes a specific ontological view of economic processes, resulting in a new epistemological perspective, new methods, concepts and tools, and the promotion of particular practical measures.

The ontological consideration of economic processes as physically and biologically embedded leads to an epistemological framework in which the challenge is not to replace one scientific ideal (mechanical physics) by others (thermodynamics and evolutionary biology). The

objective rather consists in observing that social and economic phenomena do not occur in a mere mechanistic environment, but in an environment also imbued with qualitative changes, uncertainty and limited energy and resources.⁶ Thermodynamic and biological laws can therefore help us understand the true nature of economic processes. In Georgescu-Roegen's perspective, anchoring economics in thermodynamics and biology is not an epistemological *choice*, but a necessity coming from his ontological perspective.

The entropy law, which indicates that in an isolated system all the energy used is irreversibly damaged, becomes the key concept of economic processes, since most production activities rest upon the exploitation of a limited stock of fossil fuels—in this energy regime, the economy marginally benefits from the external energy source constituted by the sun.

From biology, Georgescu-Roegen (1978) imports the distinction between endosomatic and exosomatic instruments, consolidated by Alfred Lotka from the 1920s onwards (see Bobulescu, 2015; Grinevald, 1990). Because humans prolonged their biological evolution with the production of tools and devices (*i.e.* economic goods), which are no longer endosomatic attributes (*i.e.* arms, hands), but exosomatic instruments (*i.e.* external limbs), economic processes are ontologically related to biological evolution. This means that the qualitative and stochastic nature of evolutionary processes plays a role in economics—quantitative and deterministic theories become insufficient.

To take into account ecological boundaries and the qualitative evolution of energy and organisms, Georgescu-Roegen (1971) calls for an abandonment of production functions in economic theory, in favor of a new analytical tool: the fund-flow model. By distinguishing funds, which are the agents of production, and flows, which are the objects of production that can be either inputs (raw materials, intermediate goods) or outputs (products, waste), he represents production as a combination of qualitatively-defined factors, inside specific temporal and spatial boundaries. Natural constraints and qualitative changes are then intended to be taken into account (Georgescu-Roegen, 1979; see Couix, 2020).

On technical progress, with the enunciation of a fourth law of thermodynamics on material dissipation, Georgescu-Roegen warns about the chimerical characteristic of technical solutions, leading to the massive overuse of metals and fossil materials.⁷ To avoid the ecological trap, Georgescu-Roegen (1975; 1978) proposes a series of political and practical measures: anti-militarism, R&D in solar energy, development of organic agriculture, public policies against planned obsolescence, sufficiency in consumption. The key to ecological salvation is to be found in a future technological and behavioral qualitative breakdown, in which renewables will be the only source of energy, and in which “the enjoyment of life” (Georgescu-Roegen, 1975, p. 353) will become again the true objective of economic activities.

Today's intellectual landscape in environmental economic thought is divided into what can be called *conventional environmental economics*, mainly based on the internalization of externalities through the use of neoclassical tools (utility and production functions, inter-temporal optimization, general-equilibrium models),⁸ and a *pluralist ecological economics*, which promotes a view of economic activities embedded in social and natural dynamics.⁹ This second trend has been categorized in several sub-currents according to various criteria: Petit (1997) identified

⁶ On the criticisms addressed to the mechanistic bias of neoclassical economics, see Mirowski, 1989.

⁷ This fourth law has been criticized for lacking reliable foundations in physics (Cleveland & Ruth, 1997).

⁸ The expression ‘standard environmental economics’ is sometimes alternatively used to define this category of theories, models and ideas.

⁹ On the historical roots of ecological economics, and the debates over pluralism, see Martínez-Alier, 1987; Turner, 1997; Spash, 1999; Pearce, 2002; Röpke, 2004; 2005; Franco, 2018; 2020a; 2020b.

a London School of ecological economics, distinguished from a more radical trend; Spash & Ryan (2012) and Spash (2013) coined a typology now regularly used, by differentiating between “new resource economists”, close to conventional economists, “environmental pragmatists”, using contested tools for operational purposes, and “social ecological economists”, supposedly more in line with the original spirit of the field, anchoring the reflection in political deliberation. Some extensions from Spash’s typology have been proposed (e.g. Douai & Plumecocq, 2017).

Discussing the accuracy of these typologies is out of the scope of this paper. On the basis of these various options, and taking into account (i) the *conventional environmental economics* trend, we propose to delineate six other categories of economists involved in environmental and ecological issues and potentially inspired by Georgescu-Roegen: (ii) the *pragmatists*, who do not hesitate to use mainstream tools (monetary valuation, utility function) to provide sustainability principles in an embedded framework; (iii) the *utopians*, who imagine what an ecologically sustainable future would look like; (iv) the *biophysical radicals*, who insist on strong sustainability and planetary boundaries to foresee an ecological transition; (v) the *thermo-economists*, who try to hybridize thermodynamic and economic representations of production processes as much as possible; (vi) the *socio-political radicals* who draw on the power relationships and potential conflicts in resource management; and (vii) the *degrowth partisans*, who insist on the ecological boundaries of economic activities, promoting a reduction of the size of the economic realm inside the social and natural systems to achieve a durable level of production.

Probably some authors’ works would not perfectly fit into this nomenclature, and we do not claim to cover all possibilities. Our intention is not to propose a complete and incontestable classification of environmental economic thought—this would be a research project in itself and it is not the purpose of this contribution. We invite the reader, therefore, to take this nomenclature as it is, being aware of its imperfections. Our objective is simply to have the opportunity to test the historiographical tools described above, on a sufficiently detailed classification to help us illuminate the variety of intellectual legacies. We mainly used the method of textual analysis of published materials to identify and analyze bioeconomics and its legacies. This does not preclude the value of the other methods mentioned in Section 2.2, which would be complementary.

In the next subsections, we review each trend to characterize its reception of Georgescu-Roegen’s legacy, and finally we situate all trends on a matrix, for a visual representation of the legacies of bioeconomics.

3.2. Conventional environmental economics

In conventional environmental economics, most environmental issues are considered as coming from market failures or imperfect information leading to externalities and potential degradations of the future conditions of production. Resources, materials, climate, etc. are observed through what they are able to provide to human beings in order to satisfy needs. The concepts and tools of conventional environmental economics are close to the core of neoclassical economics, mobilizing production and utility functions, discount rates to draw intertemporal optimization pathways, and private property rights to encourage the management of resources and the preservation of natural spaces. On the resource side, the long tradition of conventional environmental economics fully started with Harold Hotelling’s 1931 model on exhaustible resources (Kula, 1998; Missemer, 2017a).¹⁰ Then it was developed in the 1960s and 1970s, with the incorporation of resource depletion in growth theories (e.g. Solow, 1974b). In the early 21st century, resource economics is the continuation of this tradition (e.g.

¹⁰ To know more about Hotelling’s 1931 contribution in the history of economic thought, see Darnell, 1990; Franco et al., 2019; Ferreira da Cunha & Missemer, 2020.

Chakravorty, Magné, and Moreaux, 2006; Anderson, Kellogg, and Salant, 2018 for extractive models; D’Autume & Schubert, 2008 for optimal growth pathways). On the pollution side, conventional environmental economics corresponds to the Coasean tradition (Coase, 1960), which insists on the role of property rights to deal with externalities. The development of emission trading schemes, from Dales (1968) to contemporary refinements, is part of this tradition for massive pollution (see Berta, 2006).¹¹

How did conventional environmental economics receive Georgescu-Roegen’s contributions? In its contemporary form, does it take into account parts of these teachings? When Georgescu-Roegen published his first major book in 1966, Paul Samuelson, who was inside mainstream economics, wrote the Preface. He praised Georgescu-Roegen for his uncommon skills and talents (Samuelson, 1966, pp. vii–ix). But he was not really interested in bioeconomics, even if he had respect and friendship for Georgescu-Roegen (Samuelson, 1999). In the early and mid-1970s, several conventional economists recognized that thermodynamics, and more broadly natural constraints, could play a role in economics, as soon as energy becomes a key issue in production processes (Nordhaus, 1973; Solow, 1974b; see Pottier, 2014). Soon, however, their attention to these matters vanished.

The best characterization of the impact of bioeconomics on conventional environmental economics is probably found in what Robert Solow famously wrote in 1997 about Georgescu-Roegen in a special issue of *Ecological Economics*. Challenged by Herman Daly (1997), who defended Georgescu-Roegen’s proposals, Solow clearly showed his skepticism about the so-called need of the entropy law to understand economic processes:

No doubt everything is subject to the entropy law, but this is of no immediate practical importance for modeling what is, after all, a brief instant of time in a small corner of the universe. (Solow, 1997, p. 268)

Solow’s stance is not necessarily representative of all conventional environmental economics. But it is relevant because Solow was, and still is, an important reference in growth and resource economics (Solow, 2009). As emphasized by Couix (2019), this 1997 episode shows the fundamental ontological, epistemological and methodological difference between the standard approach and Georgescu-Roegen’s perspective.

Conventional environmental economics is more in opposition to bioeconomics than in its inheritance. The foundations of Georgescu-Roegen’s paradigm (in particular thermodynamics) are rejected, and contested analytical tools (as the neoclassical production function) are still used. The concepts, tools and methods of bioeconomics are not mobilized. The concerns are not the same, nor is the time horizon. In other words, conventional environmental economics fails both in terms of *conformity-with-the-text* and in terms of *conformity-with-the-spirit*. On the matrix (Fig. 2), it does not appear as a legacy of bioeconomics.

3.3. The pragmatists

The category of pragmatists joins what Petit (1997) called the London School of ecological economics, gathering scholars from London (e.g. David Pearce) and other places involved in a hybrid version of ecological economics, mixing strong ecological goals with the usual economic tools coming from the neoclassical apparatus. These scholars do not challenge the core of most economic theories: the optimum, discount rates, factor substitution and monetary valuation are retained. But, as Pearce and Turner (1990) indicate, the natural laws are no longer

¹¹ For local pollution, norms and cost-effectiveness analysis are often preferred because they are more operative in the design of public policies. To know more about the history of conventional environmental economics, see also Pearce, 2002; Banzhaf, 2017; 2019.

ignored; they are included in economic reasoning:

Underlying some sustainability thinking is an increased recognition that knowledge accumulated in the natural sciences ought to be applied to economic processes. For instance, the scale and rate of throughput (matter and energy) passing through the economic system is subject to an entropy constraint. Intervention is required because the market by itself is unable to reflect accurately this constraint. Modern economics lacks what we call an *existence theorem*: a guarantee that any economic optimum is associated with a stable ecological equilibrium [...]. The Pareto optimality of allocation, for example, is independent of whether or not the scale of physical throughput is ecologically sustainable. (Pearce & Turner, 1990, pp. 23–24)

Other contributors, centered around Robert Costanza, also promote a combination of ecological constraints with classic economic tools, yet refuse to ignore natural dynamics inside economics.¹² This is why they argue for a distinction between substitutable and irreplaceable resources,¹³ and for a global understanding of the economic value of these resources (and natural spaces):

To achieve sustainability, we must incorporate ecosystem goods and services into our economic accounting. The first step is to determine values for them comparable to those of economic goods and services. In determining values, we must also consider how much of our ecological life support systems we can afford to lose. To what extent can we substitute manufactured for natural capital, and how much of our natural capital is irreplaceable [...]? (Costanza et al., 1991, p. 9)

In comparison with Georgescu-Roegen's bioeconomics, there are similarities insofar as entropy is considered, the irreplaceability of some resources is taken into account, and economic optimality is related to the stability of the ecological realm. The pragmatist view of ecological economics has some *conformity-with-the-letter* of bioeconomics, even if some tools rejected by Georgescu-Roegen (e.g. the production function) are peripherally still used by the pragmatists (Pearce & Turner, 1990, p. 254). With regard to *conformity-with-the-spirit*, the connection between economics and the natural sciences is an important common feature between Georgescu-Roegen and the pragmatists. But the latter do not seem to fully incorporate economics into the natural sciences; they simply connect the two fields of research. And they do not intend to completely abandon the neoclassical apparatus. They opt for a more global perspective on economic activities, but without totally adopting Georgescu-Roegen's ambitions and concerns. There is thus no clear *conformity-with-the-spirit* of bioeconomics. On the matrix (Fig. 2), the pragmatist approach appears as a formal legacy.

3.4. The utopians

The utopian trend in ecological economics gathers scholars who depict future sustainable worlds without necessarily explaining the path to follow from today's situation to the new era. Their crucial contribution is to show that such sustainable worlds are not chimerical but could exist, thanks to new regulations, new social behaviors and new technologies. Among the utopians are several post-growth theorists, such as Tim Jackson (2009), Kate Raworth (2017) and Peter Victor (2019). A common thread in this literature is to describe the future of humankind with much detail, with concrete contrasts to the present time. So writes Jackson about the future of agriculture and manufacturing:

[...] manufacturing, construction, food and agriculture, and more conventional service-based activities such as retail, communication and financial intermediation, will still be important. Critically though, these sectors will look rather different from the way they do right now. Manufacturing will need to pay more attention to durability and reparability. [...] Agriculture will have to pay more attention to the integrity of land and the welfare of livestock. (Jackson, 2009, p. 197)

The framework for the design of these future worlds is a strong embeddedness of economic activities into social and ecological dynamics. This is particularly visible in Raworth's doughnut representation of a sustainable society: the internal border of the doughnut marks the lower-limit for the satisfaction of human basic needs, while the external border marks the upper-limit for "planetary boundaries" (Rockström et al., 2009). As a result, economic activities are conditioned both by social requirements and ecological limits.

The utopians often make some reference to Georgescu-Roegen's initial contributions (e.g. Raworth, 2017, p. 215). They do not strongly claim to be his inheritors, but they consider there is a filiation. The assessment of the proximity between bioeconomics and the utopians' work is insightful, because utopians do not use the same wording as Georgescu-Roegen to analyze economic activity. They scarcely talk about entropy, bioeconomics, irreversibility and so on, preferring terms such as "prosperity without growth" (Jackson, 2009), post-growth, planetary boundaries, etc., which indicates an unclear *conformity-with-the-letter*. Yet, as Georgescu-Roegen with his bioeconomic program for ecological salvation, they describe a possible future for the humankind, which suggests a rather important *conformity-with-the-spirit*. On the matrix (Fig. 2), the utopian trend appears as a substantial legacy.

3.5. The biophysical radicals

While the pragmatists make use of conventional tools, and while the utopians are focused on the upcoming new world, the biophysical radicals are interested both in a profound reconfiguration of the relationship between economic activities and the natural environment, and in the transition mechanisms needed to reach a sustainable world. Representatives of this trend include, for instance, Cutler J. Cleveland, Kozo Mayumi and Herman Daly.¹⁴ As early as in the 1980s, some of them sketched the necessity to build new theoretical models to report on the energy dependency of economic activity, including thermodynamic issues (Cleveland et al., 1984). The idea behind the emergence of *biophysical* models was to assume "that capital and labor are intermediate inputs produced ultimately from the only primary factor of production: low entropy energy and matter" (Cleveland, 1991, p. 289). In other words, the ambition was not to make corrections to classic models, but to replace them with new frameworks, moving towards a paradigmatic shift.

Georgescu-Roegen constitutes a reference-point for the biophysical radicals, as one of the main 20th-century economists who draw attention to energy issues and ecological limits. As a former student of Georgescu-Roegen, Mayumi (2001) worked on extending the flow-fund model, applying it also to new case studies, such as the electricity sector (Farrell & Mayumi, 2009).

As mentioned, one characteristic of this trend is to dedicate time to the transition mechanisms needed to reach a sustainable world. Cleveland et al. (1984) wrote about the use of the 'Energy Return On Investment' (EROI) indicator, instead of economic returns, to concretely assess the efficiency of energy extraction. Daly (1991) proposed a steady-state economy to adapt current sociotechnical constraints to environmental requirements. This is partly in line with

¹² We shall note that Costanza, as other members of the ecological economics movement, found inspiration in many other authors than Georgescu-Roegen, in particular Howard T. Odum (Røpke, 2004).

¹³ This refers to the debates about the characteristics of natural capital. For a historical discussion of these disputes, see Missemmer, 2018.

¹⁴ Once again, the label placed on a particular author is subjective. Perhaps even these authors would not recognize themselves in this or that category.

Georgescu-Roegen's set of practical measures for achieving ecological salvation.

All in all, in terms of *conformity-with-the-letter*, the biophysical radicals use the same wording (entropy, thermodynamic limits) as Georgescu-Roegen, and consistently try to get rid of contested tools such as the neoclassical production function, or growth models. In terms of *conformity-with-the-spirit*, despite some divergence (in particular on Daly's steady-state), the general idea to merge ecological and economic processes, and the ambitious line of research, makes it logical to consider the biophysical trend as close to bioeconomics. On the matrix (Fig. 2), this trend appears as a faithful legatee.

3.6. The thermo-economists

In the 1970s, following the oil crisis and the new insights on ecological constraints coming from system modeling (Meadows, Meadows, Randers, & Behrens, 1972), research programs emerged to measure the role of energy in economic processes, in particular in aggregate growth.¹⁵ As mentioned, conventional economists proposed their own response to the new concerns, through updates of Solow's growth model (Solow, 1974a; Stiglitz, 1974a; 1974b). Other economists and physicists developed alternative proposals, more anchored in thermodynamic constraints (e.g. Ayres & Nair, 1984; Kümmel, 1982; 1989). This movement led to the constitution of what Couix (2019) calls a "thermodynamic approach to production and growth".

These thermo-economists, whose research agenda is still being developed (e.g. Ayres, 2001; Ayres & Warr, 2005; 2010; Keen, Ayres, and Standish, 2019; Kümmel, Ayres, and Lindenberger, 2010; Kümmel, Lindenberger, and Weiser, 2015; Lindenberger et al., 2017), are characterized by a deep awareness of the role of the entropy law in economic processes, in particular at the aggregate level. Their main objective is to provide a formal representation of production, taking into account energy as a specific factor of production. Doing so, they do not refuse to use aggregate production functions, in the conventional sense, but they add strict constraints and modeling specificities to warrant the embeddedness of economic processes within thermodynamics (e.g. Kümmel et al., 2010). As clearly emphasized by Steve Keen, Robert Ayres and Russell Standish:

The purpose [...] is to provide an aggregate production function—that is, a function relating a single measure of output (Q) to single inputs of Labour (L), Capital (K) and Energy (E)—in which energy plays an *essential* role, and to follow through the consequences of this function at the level of aggregate inputs and outputs. (Keen, Ayres, and Standish, 2019, p. 40)

In terms of intellectual legacies, thermo-economists have a puzzling relationship with Georgescu-Roegen's bioeconomics. Firstly, some of the scholars involved in this movement already worked on the role played by natural constraints in economics before Georgescu-Roegen published his major works on the subject (e.g. Ayres & Kneese, 1969). This suggests that the inspirations of the thermodynamic approach are manifold, and not limited to bioeconomics. Yet Georgescu-Roegen occupies a special place in this corpus, as he is regularly claimed as a strong inspirer. So write Robert Ayres and Benjamin Warr:

Both casual observation and physical intuition have convinced many investigators since Georgescu-Roegen first expounded on the subject, that production in the real world cannot be understood without taking into account the role of materials and energy [...]. (Ayres & Warr, 2005, p. 182)

¹⁵ We can find early experiences of research in this direction even before the 1970s–1980s, for instance at the Brookings Institution in Washington D.C. in the late 1920s (Missemmer & Nadaud, 2020).

The filiation between the research agenda of thermo-economists and Georgescu-Roegen's proposals seems particularly strong in terms of ontological and epistemological perspectives: both emphasize the role of energy and natural constraints in defining economic processes; both are critical towards the theories and models of conventional economics. The *conformity-with-the-spirit* of bioeconomics therefore is strong.

The concepts that are used are also close. However, there is a major contrast between bioeconomics and thermo-economics as to how to model economic processes, especially at the aggregate level. As mentioned, Georgescu-Roegen was very critical towards the use of aggregate production functions; he did not think they could accurately represent economic activities. Production functions are at the heart of the thermo-economists' concerns; they devote time and energy to improving the equations, and to empirical testing of the proposals (see Couix, 2019). This central contrast between bioeconomics and thermo-economics leads us to conclude that, in terms of *conformity-with-the-letter*, the legacy is limited. Consequently, thermo-economists are to be considered, in this sense, as substantial legatees of Georgescu-Roegen (Fig. 2).

3.7. The socio-political radicals

The socio-political radicals refuse to use tools and methods coming from neoclassical economics. They particularly insist on the social and political dimensions of sustainability, through the observation of deliberation, sometimes of conflicts, in natural resource management. Joan Martinez-Alier (2002) and Clive Spash (2012) are two representatives of this trend. What is at stake is an extensive reconstruction of economics: uncertainty, empirical validation, and interdisciplinarity are key concepts and methods to construct a new paradigm. In contrast to the pragmatists, the socio-political radicals do not make monetary valuations of environmental features, because they insist on the idiosyncratic value of nature. What is at stake is to acknowledge the incommensurability of nature, which does not mean that no comparison or assessment is possible to make a decision, but that multi-criteria evaluation is needed, beyond what the narrow economic rationale establishes (Martinez-Alier, Munda, and O'Neill, 1998). One of the important characteristics of the socio-political radicals is a focus not only on Northern countries, but also on Southern countries, to observe and analyze ecological inequalities and power relationships between individuals and organizations. Researchers working on the commodification of the natural environment can sometimes participate in these debates (for a review, see Smessaert, Missemmer, and Levrel, 2020).

The common points between the radicals' approach and bioeconomics can be found in the combination of epistemological foundations, analytical proposals and practical measures. We also find a common emphasis on potential social conflicts arising from the competition for natural resources, as suggested by Georgescu-Roegen (1983, p. 145). The *conformity-with-the-spirit* of bioeconomics is quite important, even if Georgescu-Roegen's initial purpose was to influence his fellow economists, and not necessarily to step out of economics and reach a more social and political audience. In terms of *conformity-with-the-letter*, the radicals use terms such as entropy and irreversibility. Their wording seems close to the initial bioeconomic paradigm. On the matrix (Fig. 2), the socio-political radicals thus appear as faithful legatees.

3.8. Degrowth

Degrowth movements emerged and developed in the 2000s, in particular in France and Spain. They participated in the construction of new political, ethical and economic thinking, with the objective of ridding society of excessive consumption and environmental damages. There are several degrowth trends, with many representatives such as Paul Ariès, Mauro Bonaiuti, Giorgos Kallis, Serge Latouche, Anitra Nelson, etc. who insist on different priorities (Weiss & Cattaneo, 2017).

The definitions of degrowth are therefore large in number, and are not limited to the reduction of aggregate production, as measured for instance by the GDP. Van den Bergh (2011) highlights some basic meanings:

The first interpretation of degrowth is striving for negative GDP growth or a reduction in GDP (Gross Domestic Product). This is the most logical interpretation and useful one in the sense that it is likely to be understood as such by most economists, politicians and the general public. [...] The second interpretation of degrowth means striving for a reduction in the amount of consumption, however measured. [...] Implicit in most writings on degrowth as a strategy to relieve environmental pressure is the idea of physical degrowth [...]. This can be defined as a reduction of the physical size of the economy, notably in terms of resource use and polluting emission. (van den Bergh, 2011, pp. 882–84)

Even if they do not reduce themselves to GDP adjustments, most of the definitions of degrowth are related to the size of the economic realm, in comparison with the social, political and environmental realms: this size should be reduced, in favor of new ways of defining well-being (social relations, ethical values, etc.). In terms of practical measures, degrowth programs are ambitious, since they imply radical changes in production and consumption behaviors (Parrique, 2019). Sufficiency becomes the key concept of economic thinking.

With respect to intellectual filiations, degrowth is usually considered as an obvious legacy of bioeconomics (Bayon, Flipo, and Schneider, 2012; Bobulescu, 2013; Bürgenmeier, 2008; Levallois, 2010). This is mostly due to the fact that degrowth defenders often claim to be heirs of Georgescu-Roegen (Bonaiuti, 2011; 2012; Grinevald, 2008; Latouche, 2011).¹⁶ Moreover, many concepts (entropy, ecological constraints, irreversibility) are common to degrowth and bioeconomics.

With respect to *conformity-with-the-letter* of bioeconomics, degrowth advocates use concepts (entropy, sufficiency) and methods (interdisciplinarity, dialectic reasoning) initially promoted by Georgescu-Roegen. With regard to *conformity-with-the-spirit*, at a glance there is some closeness between bioeconomics and degrowth: both are radical projects, and both consist of theoretical proposals and practical measures. Yet this intuition needs to be qualified, because there is an important paradigmatic, ontological difference between bioeconomics and degrowth. As promoters of the reduction of the size of the economic realm, some degrowth defenders opt for a quantitative view of ecological constraints and economic activities. Georgescu-Roegen’s stance was different, deeply anchored in a qualitative view, in which development was more important than growth, evolution more than reproduction (Georgescu-Roegen, 1976; see Missemmer, 2017b). In this sense, the *conformity-with-the-spirit* of bioeconomics can be judged as modest. This is subject to interpretation, and obviously, this does not challenge the right of degrowth defenders to claim a filiation with Georgescu-Roegen. Our toolbox simply helps characterizing this filiation, and questioning the usual unequivocal link made between the two. On the matrix (Fig. 2), following our own reading, degrowth appears as a formal legacy.

3.9. The matrix of bioeconomics’ legacies

Fig. 2 shows the distribution of bioeconomics’ legacies according to our classification criteria. It appears that today’s approaches entertain diversified relationships with Georgescu-Roegen’s pioneering perspective. One may note that corpuses can be similarly characterized for various reasons: the pragmatist approach to ecological economics and degrowth are both *formal legacies* of bioeconomics, but for much

		CONFORMITY-WITH-THE-SPIRIT	
		Yes	No
CONFORMITY-WITH-THE-LETTER	Yes	<p><u>Faithful legacy:</u></p> <p>Biophysical radicals</p> <p>Socio-political radicals</p>	<p><u>Formal legacy:</u></p> <p>Pragmatists</p> <p>Degrowth partisans</p>
	No	<p><u>Substantial legacy:</u></p> <p>Utopians</p> <p>Thermo-economists</p>	<p><u>No legacy:</u></p> <p>Conventional environmental economics</p>

Fig. 2. Matrix of bioeconomics’ legacies.

different reasons. Being part of the same category does not mean either that the comparability between corpuses is easy: the proximity of utopians is not of the same kind as the proximity of thermo-economists with Georgescu-Roegen; placing them in the same box does not necessarily mean that they are close to each other.

There is certainly room for improving this nomenclature, to draw sub-categories and to discuss the relevance of placing this or that trend in specific boxes. As mentioned, authors listed above might challenge their labels, and other historians of thought might have placed a different judgment on the conformity of this or that legacy—which would be rather interesting for the historiographical discussion. In any case, Georgescu-Roegen’s bioeconomics and its legacies provide an illuminating case study illustrating how our toolbox can be used in the history of thought.

4. Conclusion

This article explored the notion of intellectual legacy, by going beyond an intuitive definition, and by providing some historiographical guidelines for well-informed uses in the history of thought. To reach this goal, we proposed two criteria to characterize the reception of ideas: *conformity-with-the-letter* and *conformity-with-the-spirit*. These two criteria enabled us to propose a synthetic matrix to distinguish three types of intellectual legacies: *faithful*, *formal* and *substantial* legacies.

Our approach constitutes only a first step toward a better understanding of intellectual legacies, and beyond that, of the transmission of ideas. There is some subjectivity in the classification, as soon as the conformity between corpuses is subject to interpretation. Further research could also improve the characterization of legacies within the same category, since, for instance, two corpuses can be considered as legacies of the same kind for very different reasons. In its current state, our toolbox therefore allows us to characterize a legacy in comparison to its source of inspiration, but not directly legacies between them.

Our own field of expertise led us to focus on examples mainly pertaining to the history of economic thought—Georgescu-Roegen’s bioeconomics is part of this field. Applications in other domains of intellectual history and of the history of science would probably offer complementary insights, with potential amendments to our toolbox. We do think, however, that the historiographical tools presented above are sufficiently generic not to be limited to the history of economic thought.

Intellectual legacies are part of a classic lexicon used by historians and researchers in science studies in many fields. A legacy is a multi-dimensional notion, with unstable bases. Our toolbox is not the ultimate solution for all the issues surrounding the transmission of ideas, concepts, methods and tools. But it may help clarify the debates, and help scholars share a common language to discuss their interpretations of the middle and long run evolution of thought.

CRedit authorship contribution statement

François Allisson: Conceptualization, Methodology, Writing - original draft, preparation. **Antoine Missemmer:** Conceptualization, Methodology, Writing - original draft.

¹⁶ In the French-speaking literature, the publication of a collection of some of Georgescu-Roegen’s texts in a book entitled *La Décroissance* contributed to this association with degrowth (Missemmer, 2017b).

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