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Institutionalizing a Pluralistic Alliance between Economics and Engineering

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Economics and engineering have often intertwined, through the sharing of mathematical modeling tools, analogies and the migration of concepts. These processes have contributed to bridging the epistemological gap between the two disciplines and above all they have fueled a contamination that has allowed the advancement of knowledge. However, this exchange has long entered a phase of diminishing returns and is now not sufficient to respond to the growing complexity that is required of science and its methodologies to interpret the real world, increasingly integrated in all its aspects and influenced by clusters of pervasive innovation and technological progress. This urges the establishment of a new "pluralistic alliance" between the different semi-autonomous branches of the two disciplines, to be realized on a scientific platform, understood as a socio-epistemic space that allows for the meeting between scholars aimed at achieving common or similar scientific goals. The article discusses how to institutionalize this platform and highlights the largely incipient state and difficulties that stand in the way of its legitimacy.

Keywords: *Economics-Engineering Nexus - Heterodoxy - Pluralism - Scientific Platform – Unification of Knowledge.*

Introduction

In their history, economics and engineering have often intertwined, with moments of remarkable closeness, as in the case of the contribution of French econo-engineers to the foundation of modern microeconomics in the nineteenth century, and more frequently, with moments of cross-fertilization, through the sharing of mathematical-modeling tools, analogies and the migration of concepts. However, there have been periods in which the two disciplines and professions appeared very distant from each other. In the 1930s, Hayek (1935, p. 8) noted with bitterness: «It is probably no exaggeration to say that to most people the engineer is the person who actually does things and the economist the odious individual who sits back in his armchair and explains why the well-meaning efforts of the former are frustrated». But in the same years the engineers also ended up in the dock. With reference to the United States, Bix (2020) explains how the Great Depression was accompanied by the widespread opinion that engineers were responsible for technological unemployment and its serious economic consequences. This prompted the Society for the Promotion of Engineering Education to review its rhetoric on «engineers as the embodiment of disciplined rationality, the problem-solvers who could straighten out the nation's crisis» and to urge a disciplinary review such that «[a] number of Depression-era schools experimented with curricula for teaching engineers more economics» (Bix, 2020, abstract).

Despite this warning, subsequent events have been contradictory. In fact, engineering schools have been aware since the end of the nineteenth century that economics is useful for the professional training of engineers. For example, in the United States, at the Massachusetts Institute of Technology (MIT), economic and business disciplines were present in a didactic concentrate that could be accessed by all degrees and, above all, by civil, mechanical, electrical and chemical engineering. But, when in 1900 the presidency of the Institute passed to the astronomer Henry Smith Pritchett, the latter took action to marginalize economic and social studies («it is not the study of Literature, nor of Economics, nor of History, nor of any other subject, that per se brings culture and a broad sympathy with men. Chemistry, Physics and Mechanics may be taught in such a way as to develop great humanistic interests as effectively as any of the so-called culture studies», in Adelstein, 1988, p. 316). There followed a period of harsh survival of the economic disciplines, which were resurrected only in 1940, when Paul Samuelson was called to MIT, to respond to the growing demand for economic training of engineers.

These historical notes serve to evoke the troubled and complex nexus between the two disciplines, which have become institutionalized, articulated and separated both scientifically and professionally, but which have never lost sight of each other (Duarte & Giraud, 2020). This intertwining is both cause and effect of the epistemological convergences (and divergences) between economics and engineering, which today constitute the foundations on which to build a new *pluralistic alliance*, in our opinion indispensable to face the current challenges of globalization and technological progress. Themes such as climate change, environmental sustainability, energy transition, artificial intelligence, transcend the scope of individual disciplines and highlight the difficulties that science, technology and related stakeholders (individuals, companies, governments, institutions) have to face.

The primary purpose of this paper is to discuss the need and conditions that can make a new engineering-economics alliance feasible. The remainder of the paper contains seven sections. The next section briefly stylizes the paradigms that describe the interactions between the two disciplines from the 20th century to the present. It then outlines the main epistemological convergences and divergences that have occurred along the resulting historical trajectories. This is followed by an analysis of their limitations and usefulness for improving our knowledge. Then, it is argued how the entanglement that has materialized is an insufficient response to the complexity posed by today's society. Because of this, the proposal for a new *pluralistic alliance* is put forward. The last section contains concluding remarks.

A Stylized representation for the Evolution of Economics-Engineering Relationships

The relationships between economics and engineering date back to the foundation of microeconomics. The historians of economic thought Ekelund and Hebert argue that microeconomics was developed first and foremost by engineers rather than economists, and that its origins were French rather than British (Ekelund & Hebert, 1999). The civil engineer Jules Dupuit is listed among the founders of the neoclassical economics and, above all, as the one who shaped the very essence of the Marshallian approach. Léon Walras and the Italian engineer Vilfredo Pareto were respectively fathers of general economic equilibrium and Pareto-optimality as condition for allocative efficiency.

It might seem like a story of engineers who changed their minds and moved on to economics. Walras's life and training offer arguments in this regard. Leon Walras enrolled at the Ecole des mines in Paris to pursue a career as a mining engineer, but soon left it to devote himself to literature and journalism. Two false starts, before being induced by his father Auguste Walras to engage in economics (Jolink, 2005). But these second thoughts are too numerous to be considered accidental. In addition to Pareto, other engineers arrived at the Lausanne School, of which Walras was the founder, such as the Italian Giovanni Battista Antonelli and the German Carl Wilhelm Friedrich Launhardt, as well as the Russian Eugene Slutsky and the Swede Karl Gustav Cassel, both of whom passed through engineering studies. Furthermore, the so-called *French Engineering Tradition* is perhaps the longest-running in the history of economic thought, including, over time, Maurice Allais (Nobel Prize for Economics in 1988), Gerard Debreu (Nobel Prize for Economics in 1983), Marcel Boiteax, Edmond Malinvaud and, more recently, Jean Tirole (Nobel Prize in Economics in 2014), all engineers or very close to engineering training.

A multiplicity of cultural paths starts from these origins. In Mariotti (2021) three paradigms are proposed to stylize the relations between economics and engineering during the twentieth century and up to the present day. A brief description is provided below.

(i) Economics *"for"* engineering. This paradigm gives title to a path according to which a set of concepts, methods and economic tools declined in a pragmatic way is taken at the service of technical engineering problem solving (Thuesen, 1950). The paradigm focuses on cost analysis, capital investment analysis, cost–benefit evaluation, but it simplifies or sometimes even neglects key concepts of microeconomics, such as market structure, competition, pricing. Hence an economics designed "for", or "adapted to". Its trajectory is mainly established at the educational level with courses often compulsory for engineering degrees and is consolidated after the war, when the ever growing demand for engineers trained in business management, and, conversely, for business economists with engineering skills urges the engineering schools to offer degrees with names combining the words engineering, management, technology, business in various ways. Among these, "engineering management" is the most widespread term, in accordance with a shared definition that reads: «engineering management is designing, operating, and continuously improving purposeful systems of people, machines, money, time, information, and energy by integrating engineering and management knowledge, techniques, and skills to achieve desired goals in technological enterprise through concern for the environment, quality, and ethics» (Omurtag, 1988). In this context, the economics *"for"* engineering finds its own space for international affirmation and diffusion, progressively enriching itself with its own research activities (Hartman, 2011).

(ii) Economics *"as"* engineering. The paradigm refers to how economics has adopted engineering epistemology for the design of markets, through common elements of language, methodology and organization of research. It is embodied in a generation of economists who, self-defining as "economic engineers", develop market models using tools such as optimal control and game theory (Cherrier & Saidi, 2020; Klein, 2020). In his essay *The economist as engineer*, Alvin Roth clarifies: « economists have lately been called upon not only to analyze markets, but to design them […] Designers cannot work only with the simple conceptual models used for theoretical insights into the general working of markets. Instead, market design calls for an engineering approach» (Roth, 2002 p. 1341). The economic engineer not only searches for the fundamental laws that regulate economic behavior, markets and organizations, but intervenes by *designing* new markets, forms of interaction and tools for achieving objectives of economic value. Thus a context emerges in which the accumulation of knowledge is shaped by the needs of society, and economic science is used to design and build systems that work, and not just to interpret existing ones. The works of David Kreps, Alvin Roth, Paul Milgrom and Robert Wilson (the last three being Nobel laureates in economics in 2012 and 2020) are the best expression of this approach. In parallel, to the extent that economists begin to imitate engineers in a practical rather than a conceptual way (Nik-Khah & Mirowski, 2019), there is an opportunity for engineers to take on the role of market designers. For example, Jenle & Pallesen (2017) show how electrical and computer engineers have seized this opportunity to enter the economic design of related industries. The paradigm therefore underlies an inversion of influence between the two disciplines, but which ultimately led to a limited integration and cross-fertilization in research.

(iii) Economics *"and"* engineering. The paradigm configures a scientific interaction between peers, respecting disciplinary singularities and different cultures, but in a context of mutual contamination, also thanks to the proximity between economists and engineers in the use of logical-mathematical and experimental techniques. Engineering benefits from a "genuine" and non-instrumental economic theory, thus being vaccinated with respect to the ideology of a technocratic management of the economy. Economics benefits from an intellectual and scientific environment that confronts it with the great problems posed by technology and innovation, which require both interpretations, solutions and regulatory responses that are often not reducible to the methodological specificities of the *"as"* paradigm. Emblematic of this scientific trajectory is, on the one hand, MIT, after the turning point brought about by the arrival of Paul Samuelson, with an expansion that attracts great economists to it and will forge others, up to boasting 22 Nobel laureates in economics attributed to teachers and alumni (the first to Samuelson in 1970); on the other hand, the renewed French school of economist engineers, of which Maurice Allais was the great promoter and Jean Tirole is today the most prominent exponent. Finally, a development close to the *"and"* paradigm took place in Russian Universities and Polytechnics[1]. The contribution that economists of Russian origin (including Alexander Chayanov, Nikolai Kondratiev, Eugen Slutsky and Nobel laureates Simon Kuznets, Wassily Leontief and Vladimir Kantorovich) have made to the economic thought has its roots in this first implementation of the economics-engineering nexus[2] (Saprykin, 2012).

These three paradigms have distinctive features, but their trajectories are intertwined in the succession of events and the recombination of their constituent elements have given rise to suggestive schools and individual profiles (Mariotti 2021). Understanding the underlying epistemology is crucial for reflecting on the future of relations between the two disciplines.

Epistemological Convergences and Divergences

The greater distance in epistemology, method and mentality between economics and engineering is claimed by those who raise the wall of contrast between the scientific and non-scientific nature of the two disciplines. For the most scholars, economics is a "social science", but Lazear (2000, p. 99) peremptorily states «[e]conomics is not only a social science, it is a genuine science. Like the physical sciences, economics uses a methodology that produces refutable implications and tests these implications using solid statistical techniques».

Engineering is a problem-oriented discipline that does not develop, but uses the fundamental scientific principles of natural sciences; engineers expand their knowledge through the practice and iterative nature of artifact design. The distinction made by the engineer philosopher Jon Alan Schmidt is very effective: «[s]cience is widely perceived as an especially systematic approach to *knowing*; engineering could be conceived as an especially systematic approach to *willing*» (Schmidt, 2013, p. 103; stress added). Scientists observe natural phenomena, propose hypotheses to explain them, and conduct experiments to test their theories. Although *will* is implicitly involved (the goal is to advance *objective knowledge*), the intellect is of prime importance. Engineers use heuristics to cause the best change with available resources in a little-known situation. Although the intellect is implicitly involved, *will* is of prime importance, the goal being a *subjective result*, for which knowledge serves as a necessary, but not sufficient, means.

However, the epistemological barriers vacillate when looking at the multiple dimensions of economics. John Neville Keynes (1890) gave it a tripartite definition, distinguishing between positive economics, normative economics and the art of economics. Positive economics is defined as «a body of systematised knowledge concerning *what is*»; the normative economy is understood as a « body of systematised knowledge relating to criteria of *what ought to be*, and therefore, concerned with the ideal as distinguished from the actual»; the art of economics is described as a « system of rules for the attainment of a given end», that is, it is not concerned with identifying goals, but with «*how to* achieve them» (Keynes, 1890, p. 34; stress added). Taking up this approach, Su and Colander (2021) discuss the fundamental distinction to be made between *economic science* and *applied economics*, the latter corresponding to the art of economics, according to which theories and methods are selected and applied to achieve a goal solved in the best way, given the resources available. In light of this, applied economists share the *will* of engineers, thus revealing an epistemological convergence, as Varian (2002) explicitly states: «[i]n these applications, economics looks more like engineering than it does pure science. Just as a civil engineer applies principles of physics and mechanics to design bridges, economists apply principles of economic analysis [….] to give advice about how to design new economic institutions».

The second question concerns the "principles of economic analysis". Are the micro foundations of economics independent, or has their elaboration throughout history been influenced by advances in the other sciences? Without invoking principles of unity of science, it is universally recognized that the fundamental pillar of neoclassical economics and its core - the theory of general economic equilibrium - is given by the analogy with Newtonian mechanics (Mirowski, 1984). In this, Pareto and Walras were the vectors that allowed the migration of *nomadic concepts*, as defined by Stengers (1987) with regard to their transdisciplinary mobility mechanisms. Strands of heterodox economics have also resorted to analogies and nomadic concepts, borrowed from physics, eg. bioeconomics (Georgescu-Roegen, 1971), which anchors the economic process to the law of entropy, and econophysics as the intersection between economics and physics of complex systems (Mantegna & Stanley, 1999); as well as from biology, eg. evolutionary economics, which uses concepts such as novelty, variety, selection, adaptation and inheritance (Nelson & Winter, 1982).

The third question concerns the nexus between science and its fields of application. With regard to the natural

[1] *Saint Petersburg State University of Engineering and Economics was born at the beginning of the twentieth century.*

[2] *Unfortunately, the Russian school of engineering and economics was almost completely destroyed during Stalin's repressions in 1922–1937, when some economists were arrested and shot, and some (such as Leontief and Kuznets) emigrated. In the Stalin era, the and" paradigm was completely replaced by the "for/as" paradigms.*

sciences and engineering, reciprocal interactions are recognized in the relationship between *knowing* and *willing*. Thus Schmidt (2013, p. 107): «[a]ttentive experience, intelligent understanding, and reasonable judgment lead people to adopt beliefs about how the world was in the past and is now; considerate deliberation and responsible decision lead people to make choices about how the world will be in the future».

The collaboration between science and engineering rhymes with that between economic science and applied economics. After having established the boundaries between economics and applied economics, where the latter feeds on the theoretical conclusions of the former, as well as on the contributions of other non-economic sciences, so Su and Colander (2021, p. 300) argue: «[i]t follows that the conclusions reached by economics alone cannot provide policy prescription. Once the disciplines had separated, to reach a policy recommendation, a collaboration among disciplines became required».

These considerations lead to the conclusion that the divergences between the two disciplines are much less wide than those advanced by a narrative based on the tradition of *economics imperialism* (Maki 2009). With it, economists animated by a pronounced hubris claim to economics both a splendid isolation in its foundations, and a purpose and a method that expand in the direction of many other spheres of human behavior. Hirshleifer (1985, p. 53; stress added) notes: «[a]fter all, the ends that men and women seek include not just bread and butter but also reputation, adventure, sex, status, eternal salvation, the meaning of life, and a good night's sleep. According to this, the purpose of economics would not be limited to normal market phenomena: «[r]ational self-interested choice plays a role in many domains of life other than markets, for example in politics, warfare, mate selection, *engineering design*, and statistical decisions».

Contrastingly, the historical events of the relationship between economic theory and other disciplines (for a recent review, Bogenhold, 2021) suggest more articulated paths, along which, ironically enough, after having exported his vision of rationality to other social sciences, economics imported insights and knowledge from other disciplines (psychology, sociology, neuroscience, biology, anthropology, etc.), thus giving rise to a process that has been called "reverse imperialism" (Crespo, 2017).

In this context of albeit problematic convergence, the prejudices and barriers must be abandoned and instead leave room for a discussion both on the modalities and limits with which potential convergences have been implemented up to now, and on the prospects of their redefinition and re-orientation.

Usefulness and Limits of Economics-Engineering Relationships: Analogies and Nomadic Concepts

Analogies and nomadism of concepts are common in the circulation of knowledge between disciplines, as effective heuristics that allow for the construction of transdisciplinary bridges between one science and another (Stengers, 1987). The borrowing and transfer of concepts, theories and methods can generate new knowledge, to the extent that (i) they create cognitive tools that allow understanding a new and unknown situation in terms of a known situation, (ii) they open a constructive dialogue between science and imagination (Darbellay, 2012). Cases of "healthy contamination" are present in the history of science, fruitful when they reveal similarities in relationships, without postulating an identity or a reductive equivalence between the terms, fields or disciplines compared. Rightly, the use of analogy is contested by scientific orthodoxy when it is nothing more than comparisons that leave room for vagueness or mere puns in place of scientific proof. Analogies and concepts must therefore be exchanged between disciplines with rigor and without excess.

In the remainder of this section, for the sake of simplicity, we organize the discussion on the usefulness and limits of the scientific migration according to its directionality, i.e., from engineering to economics, and viceversa.

Migrations from Engineering to Economics

Engineering has played a role both as an inspirer of analogies and as a vector for transporting concepts from the natural sciences to economic science, having as a background the affinities in the *knowing-willing* epistemological interweaving that we have previously described.

Given its nature (economics ancillary to engineering), the *"for"* paradigm is not considered here. The starting point is the *"as"* paradigm, which expresses a *tout court* analogy between economist and engineer. Historically, many metaphors have been used to explain the peculiarities of the profession of economists (Johnson, 2020): they act as mechanics (Pigou), "dentists" (Keynes), engineers (Mankiw and Roth), "engineers, gardeners, technicians" (Colander and Freedman), doctors (Friedman), plumbers (Duflo). Generally, these metaphors have in common the desire to underline the applied implication of economics as a policy-oriented discipline, which requires vision, insight, technique, practical sense and not just scientific knowledge. To use the words of Mankiw (2006, 29–30): «God put [macro]economists on earth not to propose and test elegant theories, but to solve practical problems [….] The substantial disconnect between the science and engineering of [macro]economics should be a humbling fact for all of us working in the field».

Have these analog constructs been and are they useful? They evoke the role of the economist in the epistemological dimension of problem-solver and designer, but they do not go beyond a rhetorical reference to what is already recognized by the Keynes's tripartition.When the analogy is contextualized, we find specific areas (such as Stanford University) where the "economic engineers" have a personal history of cross-fertilization between economics, engineering and operations research, which has generated economic models for the design of auctions, electricity exchanges, financial exchanges, and other markets or market-like mechanisms. Here, engineering has served above all as a transport vector between mathematical and computational instrumentation and economics. Pioneers in this role include the electrical engineers and control theorists Arnold Tustin (1953), Michael Athans and Robert Pindyck (Athans *et al*., 1979) and computer engineers such as Jay Wright Forrester, father of system dynamics and author of the controversial *World dynamics* (Forrester, 1971), in which the complex interactions between the dynamics of the world economy, population and ecology were modeled, and their long-term sustainability discussed.

However, in the works of the Nobel laureates Roth, Milgrom and Wilson on market matching mechanisms it is not easy to see contaminations with engineering, especially if we consider the pragmatism of the latter. Varian (2002), in commenting on the Nobel Prize attributed to Roth, warns about the pitfalls of transforming economists into design engineers: theoretical and computational models are important for elaborating projects, but must be tested through experiments, since factors that are not included in the models could be critical in practice. In civil engineering these could be wind and snow; in economics it could be psychological biases and social norms. He cites the California electricity market as a "notorious example" of a failed economic engineering project and concludes: «[t]hese examples should be sobering lessons to economic engineers. An understanding and appreciation of existing institutions, good theory, good computational modeling and well-designed experiments are critical ingredients to a successful design», a warning that calls into question the dangerous tendency towards reductionism inherent in the migration of analogies.

Coming now to the *"and"* paradigm, the migration from engineering to economics has taken place under the broader umbrella of the so-called heterodox economics. The latter primarily includes evolutionary economics and behavioral economics, which in a more incisive and penetrating way have begun to question the mainstream, as well as a multitude of disciplinary niches inspired by other sciences, such as neuroeconomics, ecological economics, feminist economics. Specifically, some areas are locus of conceptual migrations of which engineering has been the source or vector: bioeconomics, econophysics, quantum economics, agent-based and system thinking-based economics of complexity. To these are added *ad hoc* modeling where, from time to time, analogies are proposed between economic processes and others of an engineering nature, e.g., those relating to the fields of gravitational and electromagnetic forces (see the recent work of the civil engineer Blockley, 2022).

These approaches have not dented, or have done so minimally, the fundamentals of the economic mainstream, for some main reasons. First of all, the intrinsic conceptual limits. In this regard, some recent reviews are worth. Regarding econophysics, Yee (2021, p. 1) observes that, of the two methodological programs that characterize it («to export mathematical methods used in physics» and «to export mechanisms in physics into economics»), «physics transfer is often justified at the level of mathematical transfer but unjustified at the level of mechanistic transfer». Regarding bioeconomics, Vivien *et al*. (2019) describe its fragmentation and also the terminological controversies.

Secondly, a self-marginalization shared with the other niches of heterodoxy. Assuming that a pluralist attitude, as heterodox economists often invoke, implies talking to each other, Dobusch & Kapeller (2012), through the analysis of reciprocal citations flows, find that heterodox economics, when compared *en bloc* with traditional economics, is very pluralistic, while mainstream economics is essentially closed, i.e., not open to alternative theoretical approaches. However, if we focus on individual niches, it results that heterodox economists are confronted much more with orthodox economists than with heterodox economists from other niches, thus avoiding consciously discussing and integrating each other's theoretical propositions and empirical results. The diversity of methods and analogies contribute to a "pluralism of disinterest".

The evolutionary economist and historian of economic thought Geoffrey Hodgson has placed on the agenda the issue of which strategy can give unity and institutional legitimation to heterodox economics, referring back to the thought of Michael Polanyi on the need for the institutionalization of sciences to «impose a framework of discipline and at the same time encourage rebellion against it» (Hodgson, 2019; 2021). However, until now the state of the art has not changed (Ambrosino *et al*., 2021) and the economic mainstream continues to live in its ivory tower, confirming the severe judgment expressed by Robert Skidelsky, author of the award-winning biography of John Maynard Keynes: «no branch of human inquiry has cut itself off from the whole—and from the other social sciences—more than economics […] Economists claim to make precise what is vague, and are convinced that economics is superior to all other disciplines […] Today's professional economists […] have studied almost nothing but economics. They don't even read the classics of their own discipline. Economic history comes, if at all, from data sets. Philosophy, which could teach them about the limits of the economic method, is a closed book» (Skidelsky, 2016, p. 1–3).

Migrations from Economics to Engineering

If the source or vector of engineering today has very little chance of contributing to the advancement of economic theory through more or less detailed analogies and the transfer of concepts, even in the opposite direction the criticalities are evident, if we leave the didactic field - dominated in history by the *"for"* paradigm - to enter that of scientific research.

In relations with the natural sciences, the contribution of economics is rare and when it occurs it is based on mathematical analogies, i.e. the migration of models born in this discipline and fungible in others (e.g., physics; see Jovanovic & Le Gall, 2021). The relationship with engineering is very different. Here the conceptual migrations have been significant.

Under the umbrella of all three *"for/as/and"* paradigms, the penetration of economics has occurred in areas where systemic complexity and the relevance of technologies require the search for a synthesis between the aggregate approach of the economist, which looks at technology as a black box (provided "by God and the engineers", as in the famous saying of Joan Robinson) and the disaggregated modeling of the engineer who is required to match the economic values associated with more aggregate market variables. Past and present examples can be found in network industries: the foundation of energy economics in the late nineteenth century, coinciding with the intervention of many states in the production and distribution of energy (Evans & Hunt, 2011), the foundation of transport economics in the 1960s (Dupont-Kieffer *et al.*, 2021), the emergence of the digital network economy, with its inextricable intertwining of the properties of ICT technologies and some essential economic concepts, such as complementarity, compatibility, standards, externalities and switching costs (Shy, 2001).

Furthermore, a renewed relationship has been established with the emergence on an international scale of engineering sub-disciplines dedicated to production and project management, which culminate in the synthesis represented by *engineering management* first and then by *management engineering* (see Mariotti 2021)[3]. In this area, engineering has an important history also as a source of knowledge and techniques (think of the engineers Henry Fayol and Frederick Taylor, father of scientific management). In this context, economics "*for*" engineering found the natural environment for its diffusion (Hernandez, 2017).

However, the migration of scientific ideas and theories appears severely bumpy. First, being predominantly within the *"for"* paradigm, engineering has captured, with a pragmatism that shuns the coherence of conceptual constructs and the framework that holds them together, single techniques, modeling, evaluation tools for use them in problem-setting and problem-solving. In this sense, engineering research is eclectic, open to multiple disciplinary contributions (e.g., sociology, psychology, medicine, etc.), with respect to which it assumes an instrumental and *ad hoc* vision. Mutual disciplinary legitimation is therefore difficult. Secondly, engineering research in the social field has often been polluted by a constructivist orientation, according to which it would seem possible to design and build a society *de-novo* as one plans the construction of a bridge. Hayek already criticized the "engineering mindset", according to which the engineer «has been trained in objective possibilities, irrespective of the particular conditions of time and place, in the knowledge of those properties of things which remain the same everywhere and at all times and which they possess irrespective of a particular human situation» (Hayek, 1952, p. 169). Of course, the existence of a variety of engineers with their hands in the social process pie is not in question (a reference to Taylor would suffice). However, constructivism often remains in the imprinting of academics engaged in management, environmental and energy engineering, despite a renewed epistemological interpretation of engineering that adds the social dimension to those of the application of exact sciences, design and the art of getting things done (Figueiredo, 2008).

Finally, engineering research has a closer relationship with business and management studies than with economics. Relatedly, engineer's mindset worsens the inherent intricacy that already exists between economics and management. To discuss this in an agile way, we refer to a recent testimony by Bart Nooteboom (2021). He tells of a failure when in the nineties he was appointed scientific director of a research institute in a Dutch university with the specific task of integrating the studies of economics and business. Nooteboom attributes the failure to fundamental divergences in basic assumptions and perspectives of scientific investigation between the economic mainstream and management, mainly concerning: (i) the *outcome* orientation, i.e., constructing models that maximize utility or efficiency *versus* the *process* orientation in designing and managing firms' activities; (ii) the assumption of perfect rationality *versus* bounded rationality of the agents; (iii) the different value given to mathematical models as proof of being scientific; (iv) the use of statistics in the calculation of risk *versus* an approach to uncertainty (with no probability distribution). Nooteboom (2021, p. 6) concludes: «[i]n retrospect, in view of these fundamental differences, it is not surprising that economics and business could not be integrated. They reside in different worlds, different perspectives, with different cultures». In the case of business and management engineering, the "mutual rejection" referred to by Nooteboom is amplified by pragmatism and constructivism, often declined together.

In conclusion, the intricacy of the cross-relations between economics and engineering contrasts with the prospect of greater epistemological convergence, as described in the previous section. The risk is to miss the appointment with some crucial challenges that the world is presenting to us today.

The Challenge of Change and Complexity

It is not rhetorical to say that humanity is faced with ever more radical changes that involve increasing complexity. However, we must agree on the meaning to be attributed to this last noun. Here the complexity is not referred to an evolutionary property of nature, but to the way in which human society interprets it, in order to improve its living conditions. The complexity therefore refers to the models of science. Herbert Simon (1967, p. 7) argues: «[t]he primordial acts of science are to observe phenomena, to seek patterns (redundancy) in them, and to redescribe them in terms of the discovered patterns, thereby removing redundancy. The simplicity that is sought and found beautiful is the simplicity of parsimony, which rests, in turn, on the exploitation of redundancy. We do not seek the absolutely simplest law but the law that is simplest in relation to the range of phenomena it explains, that is most parsimonious».

In this interpretation, what is meant by *increasing complexity* is that in order to model contemporary reality more redundancy is needed and that, contextually, the more parsimonious scientific laws that describe economic and social phenomena are less parsimonious than in the past. This implies a shift in the way of thinking. In economics, a shift from neat mathematical, precision-oriented, closed-loop, linear, equilibrium supply-demand way of thinking that has characterized neoclassical economics, to a mindset that appreciates uncertainties, open and nested systems, and nonlinear relations with multiple dynamic disequilibria. The change of mentality invests the canonical assumptions of neoclassical economic models, i.e., homogeneous agents (representative agent), olympic rationality (without computational limits) and perfect information. As one of the

[3] *Note that the inversion from engineering management to management engineering is not a simple semantic juxtaposition, as it underlines the transition from a predominantly technical-centered view to a systemic one, in which the analytical methods used in engineering look at the economic, behavioral and social dimensions of organizations and their environment.*

first economists of complex systems argues: «neoclassical theory involves incredibly smart people in unbelievably simple situations», while the real-world entails «believably simple people cope with incredibly complex situations» (Leijonhufvud, 1993, p. 2).

More redundant and less parsimonious models also imply a *greater variety* in the set of variables to be included and in the relationships between them, which calls into question a closer integration between disciplines. Our thesis is that analogical mechanisms and conceptual nomadism are not sufficient to satisfy the new demand for complexity. It is necessary to scale from disciplinary and multidisciplinary approaches towards interdisciplinarity and transdisciplinary synthesis, in which «information, data, theories, and methodologies from multiple disciplinary viewpoints are brought into the process and are combined in order to create something new that is irreducible to the disciplinary components that were initially brought to bear» (Leavy, 2011, p. 31; for further deepening, Mariotti 2021, p. 022).

It is easy to find areas in which the call for interdisciplinarity/transdisciplinarity is pressing. First, climate change and the ecological crisis where accounting for heterogeneity, interactions and disequilibrium dynamics provides a complementary and novel perspective to the one of standard equilibrium models (Balint *et al*., 2017). Ecological economics strives to implement a trans-disciplinary link between economics and ecology, extended to other disciplines (engineering, sociology), as exemplified in Max-Neef (2005). Second, systems thinking acquires credibility and value also in the debate among policy makers on how to deal with planetary emergencies related to the environment, the economy and socio-political systems (Hynes *et al*., 2020).

In Mariotti (2021; 2022) the shortcomings of the current economics-engineering links are discussed with reference to artificial intelligence (AI). Observing the broader social implications of AI, scholars have proposed opposing views on the transformation of (or overcoming) capitalism. Some have emphasized the authoritarian potential of AI, and the dangers to the freedom of individuals due to the concentration of data and knowledge in the hands of a few economic organizations and/or institutions (e.g., Dyer-Witheford *et al*., 2019; Srnicek, 2017; Zuboff, 2019). According to other scholars, AI will pave the way for a society of abundance and almost zero marginal costs of reproduction, in many respects beyond capitalism (e.g., Bastani, 2019; Mason, 2015; Morozov, 2019).

This literature must be taken with a grain of salt. Futurism is an unsuccessful effort if it does not take into account that reality can take a multitude of different paths, depending on the past and present action of humanity. However, it is evocative of the uncertainty and also of the irreversibility of the social processes enabled by technology. It is imperative that scholars seek to link technological predictions with social and economic change, as the transformative applications and social impacts of AI are expected in the near and intermediate future. What matters most here is that AI requires a complex modeling approach and the ability to jointly design the new markets and algorithms that such markets will populate, as well as the reverse engineering ability to understand the behavioral rules nested in such algorithms (Makridakis, 2017). The AI scientist Virginia Dignum (2019, p. 18; stress added) states «[a]ll technological change has traditionally been accompanied by fundamental societal changes. We are now at the brink of yet another one. It is up to us to make this a change for the better, for all of humankind and for the environment. *This challenge is too large and too important to be left to engineers alone*. All fields of knowledge from humanities and social science to art and design are needed to better build, understand and use AI».

Paraphrasing Leijonhufvud, we are faced with the need for models of "incredibly smart machines in incredibly complex situations". Many engineers and computer scientists are fascinated by this perspective. David Parkes and Michael Wellman put it this way on the pages of *Science*: «The field of AI strives to build rational agents capable of perceiving the world around them and taking actions to advance specified goals. Put in another way, AI researchers aim to construct a synthetic *homo economicus*, the mythical perfectly rational agent of neoclassical economics. We review progress toward creating this new species of machine, *machina economicus*» (Parkes & Wellman, 2015, p. 267). A program of "engineers as neoclassical economists", to which the heterodox Daneke (2020) contrasts the need for an economics centered on *homo complexicus*. He denounces that a selective and ideologically use of AI, which does not fully embrace the implications of AI for the study of economics as a complex dynamic system, could lead to a reinvigoration of neoclassical economic theory. In particular, he points out how mainstream economists could exploit the strong impenetrability of the *machina economica* to reinforce the illusion that their approach is inspired by a logic free from subjectivity, as in pure science. In this they would be helped by engineering schools that produce intelligent but uncurious IT, management and financial engineers, to be hired in companies, banks, knowledge-intensive services and public administration as super-true believers in *machina economica* flattened on the economic mainstream.

In the same journal, faced with phenomena such as algorithmic collusion between learning machines, economists Calvano *et al.* (2020, p. 1042) offer a different approach from the aforementioned engineering colleagues, underlining the need for a «broad research program that requires the combined efforts of economists, computer scientists, and legal scholars», to generate, also through simulations and laboratory experiments, a knowledge capable of offering valid solutions for the regulation of markets aimed at social welfare. What is needed is not futurism, but studies that integrate the technical characteristics of AI with the analysis of the social, economic, industrial and institutional context in which they are used.

This example highlights the opportunities, but also the threats of an economics-engineering integration if reductionist approaches are followed. The need for closer collaboration arises spontaneously from the facts and their interpretation, but the scientific paths that will follow depend on the strategies adopted by the various disciplinary fields to institutionalize these relationships.

A Pluralistic Alliance between Economics and Engineering

The main conclusion from the previous section is that the interpretation of current reality involves the overcoming of the three *"for/as/and"* paradigms, as they are insufficient for advancing knowledge in the field of complexity. We claim that a new "pluralistic alliance" between the two disciplines is needed, named in Mariotti (2021) *alliance à la Prigogine*, with reference to the "nouvelle alliance" between natural sciences and social sciences evoked by the Nobel Prize for Chemistry to re-establish the "ancient alliance" of man with nature and to promote a unitary knowledge based on plurality, diversity and multiple perspectives (Prigogine & Stengers, 1984).

The pluralistic alliance means that each discipline, with equal dignity, independence and mutual respect, accepts to be crossed and transformed by the other, in a context of coexistence and the continuous emergence of new theoretical and practical approaches. An alliance between peers that leverages on epistemological affinities and a shared platform to allow them to talk to each other, in this no longer hindered by forms of disciplinary imperialism of the respective mainstreams.

The institutionalization of this alliance can take advantage of some factual foundations, well described by Peter Swann, according to whom economics should and is in fact following the example of many other disciplines, which moved from monolithism to a federation of semi-autonomous sub-disciplines. Swann (2019, Ch. 12) notes that important disciplines are recognized as federations: medicine, physics, chemistry, biology, neuroscience, psychology, computer science, materials science, and engineering. Even economics today manifests a substantial fragmentation and semi-autonomy of the various branches (labor economics, public economics, experimental economics, behavioral economics, microeconomic theory, applied microeconomics, econometrics, industrial economics, innovation economics, financial economics, etc.). Swann (2021) argues that semi-autonomy is the prerequisite for a dialogue between sub-disciplines and the creation of stable alliances, able to escape the imposition of dominant models. For example, the history of biochemistry tells us that it had no chance of survival as a non-autonomous domain of biology, nor as a non-autonomous domain of chemistry. The only hope of survival hinged on achieving a high degree of autonomy, which meant that the new hybrid had its own criteria for success and could not be destroyed by performance deemed poor when measured by the prevailing, but inappropriate, success criteria. Swann sees the economics of innovation in Europe as a semi-autonomous hybrid discipline based on the work of scholars with backgrounds in different disciplines, but whose main interest is innovation, and who are willing to engage in a transdisciplinary work.

The federation of semi-autonomous sub-disciplines of economics and engineering provides the most suitable environment in which the alliance can materialize, on the basis of relationships already established over time. However, the crux of our argument consists in *how* to institutionalize the alliance, given that it is not a discipline, but an epistemic space shared by scholars aimed at achieving common or similar scientific goals, thanks to a background broad enough to embrace pluralistic theories and practices. Institutionalizing means building up and incentivizing a sufficient consensus within the scientific communities on the alliance, based on full recognition to and acceptance of the permanent tension existing between orthodoxy (backed by authority) and diversity within and across disciplines. A lack of institutionalization means that the conditions for the autonomous reproduction of scholars engaged in the economics-engineering alliance do not exist. The latter becomes at most a non-essential second skin to researchers that inscribe in this label, not to be mentioned or mentioned in second, third, or fourth place in their CVs and self-presentations (Li Vigni, 2021b).

All this calls into question the need for an *institutionalization strategy*. Hodgson (2019; 2021) argues that institutionalizing a school of thought involves understanding the mechanisms of power in science and academia, and must rely on (i) a *raison d'etre*, (ii) positioning in the orthodoxy versus heterodoxy scientific debate; (iii) achieving legitimacy by carving out a space inside highly-ranked departments, highly-ranked degree programs, publicly and privately funded large-scale research programs, high-profile journals. In the following, we apply these criteria to the context we are dealing with.

In the previous sections we have argued that the *raison d'être* of the economics-engineering alliance lies in the scientific need for a complex and non-parsimonious modeling in terms of laws, number and variety of the variables involved, where among the triggers, new technologies and tangible and intangible engineering artifacts play a fundamental role. Alliance between semi-autonomous sub-disciplines and not a "new applied science", as the different components of the two federations have irreducible distinctive characteristics, but also many contacts in terms of one or more areas, such as fields of investigation, shared studies of phenomena in the real world, conceptual approaches, similar contiguities with other disciplines, analytical techniques and experiments. In this sense, the alliance must guarantee the spontaneous aggregation of scholars, that is, govern the tension between consensus and pluralism without imposing dominant visions on what the spaces for interdisciplinary collaboration must be. This style of governance has to do with the academic mechanisms by which the different scientific communities select and promote the careers of researchers in order to reproduce themselves. The institutionalized communities of investigators in quite a few countries had been built on academic corporatism and authority. This cultural set-up must be reformed, to introduce career incentives certainly inspired by scientifically rigorous scrutinizing and guidance, but also by critical dialogue, tolerance of diversity and patient long-term investments in new knowledge. It should be recognized that modern science has become a highly diversified social system in which there are many differences both between disciplines and between them and research fields with different degrees of disciplinarity and transdisciplinarity, as regard as the ways in which the output of research work is published and disseminated. Research quality is complex and multidimensional and its evaluation involves finding the right balance between metrics and peer judgment, and an accordingly diversified set of indicators and benchmarks in order to produce adequate information, i.e. not forced to single disciplinary silos.

As for the orthodoxy-heterodoxy debate, if being heterodox in economics means criticizing max U (utility maximization) as predictable motivation of human behavior and moving away from the mainstream "holy trilogy" assumptions of rationality, selfishness and equilibrium, surely the alliance is on the ground of heterodoxy. However, Colander *et al*. (2004) argue that even orthodoxy is changing from max U towards a mainstream pluralism (Davis 2006), while Hodgson (2019, p. Ch 3) contrasts that «the rumours about Max U's death are exaggerated». Therefore, the alliance must be positioned in a more specific way. I find as the best starting point the text by Hodgson (1994) on the different ways in which the precursors of evolutionary economics - Marx, Marshall, Veblen, and Schumpeter - related to the idea of evolution and the several meanings they attributed to "evolutionary", variously borrowed from biology and Darwinist evolutionism.

These distinguished scholars shared some key concepts and approaches. First, they contrasted the focus on equilibrium in neoclassical economics, examining the irreversible historical processes of change and the succession of social phases of extreme instability; in this way, they recognized the analogical limitations of Newtonian physics and mechanical reasoning and turned to economic biology or economic dynamics.

Second, they promoted a transdisciplinary approach to economics. Alfred Marshall is widely believed to be the first to address the issue of integrating physics and biology into economics to represent the economic world. Cassata & Marchionatti (2011, p. 134) investigate his transdisciplinary research program, concluding that «the theoretical part of Marshall's work – essentially contained in Book IV of the Principles – is a successful attempt to integrate physics and biology simultaneously into economics, doing so within a framework which yields understanding of a complex world. [….] Marshall developed a powerful intellectual model: the evolutionary machine [….] The style of exposition used was, of course, not formal [….] The mathematics of that time, based on linearity and systems of differential equations, was inadequate for the representation of complex systems. Marshall was entirely aware of this shortcoming and consequently used mathematics only in the first approximation of his analysis». Later, Joseph Schumpeter engaged as a theorist of science with the idea of a universal social science in which the interplay of different disciplines comes up like an orchestra whose different branches have different functions but even the smallest contribute to the success of the common enterprise. His transdisciplinary way of thinking emerges in some of his academic writings. Especially, his «substantial preface of the *History of Economic Analysis* reads as a manual on how to refer to different academic branches and how to integrate them into a coherent universal social science». Schumpeter's study on mainstream economics «leads him to argue offensively for an institutional approach to integrating economics with different social sciences and avoiding the formulation of divisional order or ranking [….] Recent discussion on the need for transdisciplinary thought can learn a lot from Schumpeter» (Bogenhold, 2014, p. 207).

Finally, they shared attention to technical progress, engineering culture and innovation: Marx's discussion of machinery and technological change remains unprecedented among economists; as already mentioned, the Marshallian approach is indebted to the French econo-engineers; Veblen, whose use of evolutionary thinking from biology was broader than that of the other predecessors, showed surprising sympathy for engineering technocracy, predicting that engineers would form the basis for a well-run economy (Stabile, 1986); Schumpeter is universally regarded as the father of modern innovation economics.

These pioneering approaches have instigated the creation of a fertile field of heterodoxy in which the economics-engineering alliance can have its roots. It has allowed the growth of important disciplinary branches, including Herbert Simon's behavioral economics, Nelson and Winter's evolutionary economics, neo-Schumpeterian economics (Hanusch & Pyka, 2007), complexity economics (Arthur, 2021) and related computational economics (Tesfatsion & Judd, 2006). *The raison d'être* of engineering in this field no longer resides in the contribution of mathematical tools and analytical modeling, which indeed often see applied economists excel, but rather in their intimate knowledge of technological platforms and infrastructures, and of innovation clusters such as AI, biotechnologies, mechatronics, in their propensity to systems thinking as an integrator in social design, in their orientation to experiments and hypothesis testing (Garcia-Diaz, 2021). The prerequisite is an engineering scholar well educated in the history of economic thought, so that nothing is conceded to pragmatism, the technocratic idea and the reductionist shortcuts of formally elegant modeling. As Paul Samuelson argued, regarding the choice of a non-heavily mathematical textbook for his MIT students: «the engineers were very good at routine math, but they would not have seen the forest for the trees [….] I wanted them to see the great principles involved» (quoted in Bix, 2020, 54).

Coming to the third pillar of institutionalizing, i.e. building up consensus, a parallel can be made with the domain traditionally referred as "science of complexity". Li Vigni (2021a; 2022b) examines the failed legitimization strategy of this domain of study that aims at modeling natural and social "complex systems", despite of the 1970s-1980s promissory ambitions and enthusiastic claims on revolutionizing all of knowledge and even private and public actors who had learned to master them. The failure to realize a well-established and autonomous research and educational field, capable of reproducing itself through professional institutions, is explained by the fact that the complexity *sciences* (nb, plural) are «a "conglomerate" more than a stable, unique, and coherent entity. They indeed configure as a socio-epistemic space whose unity is loose enough to embrace variable and pluralistic theories and practices, with the aim of providing a temporary refuge or a perennial home to scientists who may be hard to classify» (Li Vigni, 2021b, p. 369). Drawing from sociology of science (Bourdieu, 2004), Li Vigni (2021a) defines the complexity domain as a *scientific platform*, i.e., a meeting point between different specialties, which, on the basis of a flexible common ground, pursue together shared or parallel socio-epistemic objectives. Other "studies" for which classical terms like "discipline and specialty" are inadequate due to the heterogeneity of theories and practices, can be defined as platforms: e.g., cognitive sciences, Earth system sciences, sustainability sciences, nanotechnologies.

A common scientific platform is exactly what has to be legitimated as foundation of the economics-engineering alliance. In affirming this, we are aware of the contradiction between institutional consolidation, favored by the delimitation of disciplinary boundaries, and the transdisciplinarity of the platform. But the caution of Russell et al. (2008) applies: attempts to institutionalize transdisciplinarity in a single silo may actually inhibit flexibility and openness, while diminishing prospects for creativity, interconnection, complexity, and systems thinking.

Surely, the platform includes branches of heterodox economics, so that the consolidation of the latter can benefit the alliance. At this regard, in a recent review of two main published books on heterodox economics (D'Ippoliti, 2020; Jo *et al.,* 2018), Eichacker (2022, abstract) summarizes the strategy suggested by the authors: «a two-track approach in attaining relevance: some practitioners of heterodox economics should focus on targeting their work for broader audiences, whether in policy or conventional journals, while others should explore newer ideas in heterodox, pluralist, and interdisciplinary journals to expand the boundaries of possibility». In light of this it would be quite interesting to question whether an alliance with engineering can be a way for heterodoxy to build consensus, while eschewing disciplinary gatekeeping on the part of the relatively hostile mainstream economics.

But what about the chance that the engineering faculties could be the main locus of the alliance? To investigate the question, we focus on the departments and degrees that combine management and engineering, so as to be home to the largest number of economic scholars and courses, as compare to other degrees, such as environmental, energy, ICT, and mechanical engineering, where nonetheless economics is somehow present. These initiatives had some international success and spread quickly in the second half of the twentieth century[4]; Most international prominent examples were offered by Columbia University, Istanbul Technical University, Lehigh University, Politecnico di Milano, University of Waterloo, among others. In these contexts, economic courses (macroeconomics, micro-economics, industrial economics, innovation economics, international economics) joined management and engineering courses in the training of graduates, according to approaches variously sensitive to typical engineering issues, such as technology, business organization, production systems. Contextually, scientific research integrating the same topics has been promoted.

Unfortunately, the current picture is far from comforting. There is no evidence that organic alliances have been established between scholars of the two disciplines, nor that, where vaguely delineated, they have constituted the way to acquire authoritative consensus in the academic communities, especially in the economic field. Many obstacles stand in the way. A strong disciplinary hubris, especially on the part of economists thinking they are superior beings, even more so if mainstream-oriented. The prevailing business-orientation and pragmatism of engineering scholars, which amplify the epistemological divergences between economics and management. In many countries, academic corporatism in selecting the "best" and setting career incentives. Research programs, which have the potential to bridge people and to engage relevant stakeholders, generally appear to pursue incremental and disciplinary focused goals. Similar to fads, inter/transdisciplinary labels experiment with cycles of funding that do not give them research continuity. In particular, public and private funds are not sufficiently allocated to programs open to variety, creativity, and participation of cooperative networks of scholars and practitioners, so as to accept the inefficient redundancies inevitably implied in large-scale and long-term social and scientific experiments, i.e., patient funding that looks at generating new radical economics-engineering trans-disciplinary knowledge is rare (Mariotti, 2021). Finally, international scientific journals that conjugate economics and engineering are predominantly inspired by the old paradigm of economics *"for"*engineering or are practitioner-oriented and therefore rated low in quality research. In this sense, revisions of the editorial line of existing journals and new high-profile editorial initiatives are needed to offer a credible outlet to talented scholars engaged in the pluralistic alliance.

Ultimately, to be optimist, the alliance has a social existence only in some institutes, journals, conferences, and very few, anecdotal, and heterogeneous master's degrees, and PhDs. Too little for its institutionalization. It can be hoped that the demand for a new interpretation of complexity that comes so urgently from the reality of social phenomena will finally unleash a Kuhnian "scientific revolution" within disciplinary mainstreams. But it must be admitted that economic science is still far from achieving what should be one of its priority objectives, i.e., it is not yet sufficiently integrated with the other social sciences (see Bogenhold, 2021; Cedrini & Dagnes, 2022). Given this, a meeting between economic and engineering minds could also lead to techno-constructivist visions, such as those feared by Hayek and which transpire in the field of AI. Therefore, a collective effort by those who believe in this pluralistic perspective is strongly required to give solidity and legitimacy to the scientific platform in which the economics-engineering alliance can take root.

Conclusion

In this article, the secular evolution of the economics-engineering nexus is stylized through three *"for/as/and"* paradigms. It is documented how this evolution underlies mechanisms of knowledge exchange mainly based on analogies and nomadic concepts in which the two disciplines have variously played the role of source, destination, and transport vector. These processes have contributed to bridging the epistemological gulf between the two disciplines and above all they have fueled a cross-

[4] *Engineering management took off in the 1960s–1970s. At the beginning of the 1980s, there were about a hundred Engineering management programs in the world, 86 of which in the United States. A decade later, the number doubled: 204 courses, of which 32 bachelor of science, 132 master of science and 38 PhD courses, with an extra-US incidence rising from 14 to 35 % (Mariotti, 2021).*

fertilization that has allowed the advancement of knowledge. However, this intertwining has long entered a phase of diminishing returns and is now not sufficient to respond to the growing complexity that is required of science and its methodologies to interpret the real world, increasingly integrated in all its aspects and affected by clusters of pervasive innovation and technological progress.

With this in mind, the article urges the establishment of a new *pluralistic alliance* between different semi-autonomous branches of the two disciplines, to be realized on a scientific platform, understood as a socio-epistemic space that allows for the meeting between scholars aimed at achieving common or similar scientific goals. Consistently with this, the article discusses how to institutionalize this platform and highlights the largely incipient state and the difficulties that stand in the way of its legitimacy. While the past of the economics-engineering nexus is written in ink, its future is written in pencil: the evolution of the alliance is by no means a deterministic process, but open to alternative trajectories depending on how far the institutional context will be aware of and support the new pluralistic impulses of the two disciplines.

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