A review of César Hildago's *Why information grows*

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In *Why Information Grows*, the complexity researcher César Hildago provides a compelling account of the growth of information in the universe [1]. Drawing on wide-ranging theories of statistical mechanics, the field of economic sociology, the theory of social capital, and the emerging science of complexity economics, Hildago argues information can grow in the universe whose law seems to favor the growth of entropy because of the following three conditions: out-of-equilibrium systems, solids, and the computational abilities of matters. These conditions are the foundation for the emergence of the ultimate computer, human economy, which can be viewed as a distributed computing networks that seek to generate embodiment of information (“*crystals of imagination*” (p.50)) that satisfy human needs and desires.

First, the Nobel-winning work of Ilya Prigogine, according to Hildago, shows us information can emerge naturally in the steady states of non-equilibrium systems. The example used in the book to illustrate this property is a whirlpool that forms when a bathtub is open. Whirlpool is an information-rich state because it is a configuration of water molecules that do not appear by themselves in still water.

However, this natural emergence of information cannot support the rise of complex information. For complex information to arise, Hildago argues solid objects are essential. Solids allow information to endure, thus being able to be recombined to continue to grow. Here, Hildago invokes the argument of Erwin Schrödinger in his 1944 book, *What is life?*, that solids such as DNA can store information, while DNA's aperiodic nature is essential for information to be embodied [2]. The long- and short-range correlation of DNA, similar to the long- and short-range correlation of language enable the packing of a large amount of information. Finally, the ability of matter to compute is the final physical condition for the growth of information to continue to grow in the universe.

After explaining the growth of information in the language of physics, Hildago seeks to provide an explanation for the growth of information in human societies. Hildago provides us with a wide range of unconventional conceptual tools to think about the growth of information in the economies, which depends on the ability of human networks to embody information in products. First, Hildago invites us to think of products as crystals of imagination and their most important property concerning the growth of information is their ability to augment human capacity to beget more information. Hildago argues the emphasis on the products' ability to augment human capacities allow us to move away from the traditional conception of the economy as a system of

resources management, or the wealth of a nation, or a network of financial transactions. Rather, the author urges us to consider the interpretation of the economy as an amplifier of knowledge and knowhow, or “a *knowledge and knowhow amplification engine*: a complex sociotechnical system able to produce physical packages containing the information needed to augment the humans who participate in it.”

Second, as the economy is understood as an engine of knowledge and knowhow amplification, Hildago argues the next step to understand how information grows in an economy is to quantize knowledge and knowhow, thus he postulates a concept called *personbyte*, which is defined as “the maximum knowledge and knowhow carrying capacity of a human.” *Personbyte* is a conceptual tool and it is fundamental, argues Hildago, because it underlies the importance of network of peoples in producing complex products. It implies any product that is bigger than a *personbyte* will require more than one person to produce. And it explains the fact that a productive structure such as a factory cannot take over the whole world as the personbyte limit also implies the collective constraints on the accumulation of a large amount of knowledge and knowhow in networks of people. To produce a complex product, such as an electric car, it is necessary to break a large amount of knowledge into smaller volumes and distribute it to individuals. The success of this process depends on the ability of each individual to accumulate knowledge and knowhow as well as the ability of these individuals to coordinate to embody such knowledge and knowhow in their networks.

Both the individual learning process and the coordinating process are costly. For each individual, learning is social and experiential, which takes time and energy. While for a group of humans, coordinating depends on a multitude of factors: trust, quality of social and political institutions, etc. Here, Hildago invokes the theory of social capital, the empirical work by Mark Granovetter on how people getting jobs [3], Francis Fukuyama’s thesis that the ability for a society to form large networks reflects its level of trust to demonstrate the economy is embedded in our social and professional networks [4]. Rather than purely responding to the market incentives, as ultraorthodox economic theories posit, people’s economic behaviors are influenced by factors that are hard to quantify such as trust, quality of social institutions [5], ingenuity [6], or culture [7-12]. These cultural and political factors help determine human networks’ size, adaptability, and composition, which then determine the ability of such networks to accumulate knowledge and knowhow.

Finally, Hildago invites us to consider the global disparities in ability to produce complex products via a theoretical construct of “*economic complexity*,” which is defined as “the knowhow and knowledge accumulated at the collective level, which gives rise to the diversity and sophistication of economic activities.” To measure economic complexity, Hildago and Hausmann use export data on industries and products, then characterize these products by their ubiquity (i.e., the number of countries that export them) and their diversity (i.e., the counts of the number of different products exported by an economy). These metrics combine help identify whether some products are low in ubiquity because they are rare (such as uranium) or they are complex (such as X-ray machines). Consequently, the metrics of economic complexity help identify whether two economies that export the same number of products are equally complex. The mathematics behind

the use of these types of information to construct economic complexity is presented in a 2009 PNAS paper [12] and the 2021 Nature Review Physics paper [13].

Hidalgo shows in these papers that economic complexity can predict changes in GDP over a long period of time. This new metrics can tell us which countries are underperforming or overperforming given its level of economic complexity. Eventually, a country's GDP will settle to its level of economic complexity. This method combines the new sciences of information, complexity, and networks with export data to preserve the information about the intensity of knowledge and knowhow in an economy better than traditional ways of calculating human capital by average years of schoolings or physical capital by aggregating all the market prices, argues Hidalgo.

Overall, *Why information grows* is a concise and very accessible book about the growth of information in the universe as well as in human society. More importantly, it invites a new generation of social scientists to look at the economy in a novel way. Whether this new paradigm will stand the test of time will depend on the willingness of the new generation of scientists to move beyond traditional disciplinary boundaries, adopt new methodological tools such as network analysis and complexity equations, and apply these tools on high quality datasets to the most stringent standard of academic rigor [14-19].

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