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It's All Connected, Man

A Review of César Hidalgo's Why Information Grows: The Evolution of Order, from Atoms to Economies (Allen Lane, 2015)

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The reason that “complex systems” research is able to be a somewhat coherent field of study is that there are quantifiable similarities in the patterns of organization and change that recur across spatial and temporal scales in many different systems of interest, from the physical to the physiological, from the atomic to the social. This fact is at once deeply profound and almost trivially banal. It is profound because learning about one system can help us to gain understanding of the behavior and organization of many others (Smaldino in press). For example, knowledge of the crystalline structure of spin glass can yield insight into the neural processes of memory retrieval (Hopfield 1982) and knowledge of the spread of diseases can yield insight into the diffusion of technologies (Bass 1969). The fact is banal because it cannot help us in any substantive manner until we also acquire deep knowledge of a particular system or systems. The major benefit of knowing *that* A is like B only comes when you know something *about* either A or B. Ideally, one knows something of both, so as to identify the limits of the analogy.

César Hidalgo's recent book, *Why Information Grows: The Evolution of Order, from Atoms to Economies* (2015, Allen Lane), quite clearly aims for the profound. The book attempts to illustrate the all-one nature of the universe through the unifying lens of information, which Hidalgo generally defines as physical structure. The intended scope of the book is enormous. In the prologue, we are told “This book is about the growth of information, and about the mechanisms that allow information to battle randomness and grow” (p. ix). This is elaborated in the Introduction: Hidalgo states that the book will be “an exploration of the mechanisms that contribute to the growth of information at all scales, from atoms to economies. ... The result will be a book about the history of our universe, centered not on the arrow of time but on the arrow of complexity” (p. xviii). This is an ambitious goal for a book whose main text runs only 179 pages, and one it largely fails to accomplish with any coherence.

The book's chapters are a series of rushed excursions that make up a frantic highlights tour of contemporary research on complex systems, with a focus on

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applications in the social sciences. Topics include the basics of information theory, computation, thermodynamics, management science, microeconomics, macroeconomics, and social networks. It is worth noting that the big leap from atoms to economies is accomplished by largely ignoring the levels of organization between the two. The writing is labored and leans heavily on rather trite observations, such as continually referring to all human-made products as “crystals of the imagination,” or observing that “hiring a musician by picking up a random person from the street is a bad idea because even though the information available in books can help us speed up the accumulation of knowledge and knowhow, knowledge and knowhow are not present in books” (p. 80).

In context, the latter quote is actually in service of an important idea that Hidalgo rightly calls attention to: the importance of tacit knowledge—that fingertip feel for things that is very difficult, if not impossible, to reduce to print or pictures (Polanyi 1966). There are profound things to be said about how the knowledge and knowhow needed for complex technologies and economic relationships forms and spreads in populations, and about the role of tacit knowledge therein. Hidalgo comes quite close to being profound here, but the discussion of tacit knowledge essentially ends where it began, and instead diverges to introduce one of the book’s presumptive theoretical innovations. This is the *personbyte*, defined as “the maximum knowledge and knowhow carrying capacity of a human” (p. 82). Knowledge and knowhow are their own special terms in the book, but basically just indicate what people know and what they know how to do. The idea of the personbyte is used to illustrate that the knowledge required for the production and trade of many goods cannot be held by any one individual (and therefore involve more than a personbyte of information). Instead, such goods require interconnected networks of many individuals, in which information is shared and labor is divided. This idea is an important one but hardly a new one; it dates back at least as far as Leonard Read’s pithy discussion of the legions required to make a simple pencil (Read 1958) and has been discussed by others since (Ridley 2010; Smaldino and Richerson 2013; Smaldino 2014). When first introduced, the personbyte seemed to me like it might be operationalized for some interesting analyses of technological complexity. Instead, it is used only as a rhetorical device, and a weak one at that. The simple insight that more information is captured by organizational networks than can be stored by a single individual seems rather minor to warrant the large number of mentions it receives in the book. A deeper exploration of the ways in which information in social networks arises, evolves, and shapes behavior across levels of organization might have been fascinating, but is largely absent.

The book's strongest chapters come late, in Part IV: The Complexity of the Economy. It is in this domain that Hidalgo is best equipped to write with confidence and originality, since he is able to draw on his own impressive research on economic networks in international trade (Hidalgo and Hausmann 2009; Hausmann and Hidalgo 2014). This work focuses on national portfolios of export goods and begins with the observation that the portfolios of nations' exports are not random, but entrenched in each nation's cultural traditions, natural resources, and pre-existing infrastructure. Industries will tend to cluster by virtue of shared workforce skills and technologies required to produce their associated products. So regions that grow cotton and produce textiles are more likely to also have thriving garment businesses, rather than, say, software companies or pineapple farms. Nations vary not only in what they export, but also in the diversity of products they export. Less common products are primarily produced in locations whose export portfolios are more diversified. In other words, unusual stuff tends to come from places that produce a *lot* of stuff. Conversely, nations whose exports are less diverse will tend to have more redundancy with other nations in what they export. That is, places that produce common stuff will compete with other places that also produce that same stuff, almost by definition.

Given that economic bargaining power is intimately connected with exclusivity, we should expect that nations whose export portfolios are more diversified will have higher income levels. Hidalgo shows this, but also goes a step further. With his collaborator Ricardo Hausmann, Hidalgo has measured the relative diversity of a nation's exports using novel metrics that control for the relative ubiquity of those exports (Hidalgo and Hausmann 2009). In the book, Hidalgo refers to this diversity as a nation's "economic complexity." By exploring a large dataset of nations, he has confirmed that a country's economic complexity (diversity) is predictive of its GDP. More interesting, however, is that *mismatches* between GDP and the regression on economic complexity are also predictive. Looking at changes in GDP over a twenty-year period, it is shown that a nation's deviation from the regression prediction was itself predictive of that nation's future economic growth. In other words, countries whose networks of industry produce more diverse exports than expected for their GDP are due for a rapid increase in income, while those whose GDP is greater than expected are due for slowed or even negative income growth.

The research discussed here is exciting, original work that integrates ideas from network science, complexity physics, and "data science" to make meaningful macroeconomic predictions. This work might also lead to more general insights about the evolution of technologies and industries, as well as cultural evolution more broadly. Pragmatically, Hidalgo and Hausmann have developed an

interactive online database (Hausmann and Hidalgo 2014) that I can imagine being quite useful for testing theories of cliodynamics and cultural evolution.

Despite these important insights in economics, the book is disappointing overall, due in part to its attempt to cover too much ground. In his rather rambling author's note at the end of the book, Hidalgo reveals that he was initially commissioned to write a book focused entirely on economic growth, economic complexity, and development. However, during the early stages of writing, the author decided that economic growth was a "shallow topic":

I learned that economic growth was nothing more than an epiphenomenon of a larger, more universal, and more relevant phenomenon. This is not the growth that captures headlines and political agendas, but the growth that makes possible the existence of life and society—even if we ignore it. This is the growth of physical order, or information. Soon I had to accept that information was what it was all about. (p. 184)

This is a pity. Hidalgo could likely have written a detailed (and possibly profound) book on economic complexity, perhaps with a small section or sections devoted to broader interpretations relevant to other fields. Instead, he has written a shallow (and at times banal) book that attempts to cover absolutely everything, with only a small section devoted to exploring his area of expertise in any depth. Hidalgo comes across a very smart person who is widely read and thinks deeply. The problem with his book is not a lack of good ideas, but appears instead to be a lack of sufficient time and focus to let those ideas coalesce into a coherent picture. The book feels hurried, slapdash. Ironically, considering the grand view described in the book's introduction, the view of human existence presented is myopic. Interactions are almost exclusively economic ones. Differences are largely discussed only in terms of those existing between nations, not between or even within more nuanced communities. Production is limited to exported goods, while services and locally accessed goods are generally ignored. The social, ecological, and personal consequences of the globalization for which Hidalgo enthusiastically cheerleads are largely absent from the discussion, which is disappointing. Considering Hidalgo's interests in the interconnectedness of systems across time-scales and levels of organization, it is also a shame that he does not touch on the ecological impact of globalization, which is accelerating habitat loss for many species (and which might also be regarded as a loss of information) and exacerbating climate change. Such changes will also, presumably, affect the economy.

Lastly, it was disappointing to find few references to scholarly work on cultural evolution, particularly the evolution of technology, because several of the

themes discussed by Hidalgo could be enriched by their integration. I have already mentioned that one of the book's major theoretical points is that larger social networks are required for more complex technologies. The idea that networked humans can perform computations that no individual can do alone is certainly one toward which I am sympathetic (Smaldino and Richerson 2013; Smaldino 2014). In the field of cultural evolution, this point has been richly developed through the application of theoretical models (Henrich 2004; Powell et al. 2009; Baldini 2015), analysis of cross-cultural data sets (Kline and Boyd 2010), and behavioral experiments (Derex et al. 2013; Derex and Boyd 2015; Kempe and Mesoudi 2014; Muthukrishna et al. 2013). This literature has also identified limitations to the theory of network size and technological complexity, which are unexamined in Hidalgo's book. For example, sparsely connected networks may be critical to finding quality solutions to complex technological problems, because higher levels of clustering can cause a network to become stuck on local optima (Lazer and Friedman 2007; Derex and Boyd 2016). Thus, the sheer size of a network may be a poor measure of the information that it can contain or grow. Relatedly, despite the book's title, there was little discussion of the temporal dynamics of how human social networks (including networked economies) actually *grow*, nor how they rise, fall, and compete. A cultural evolutionary mindset may have helped in this regard.

In sum, Hidalgo is doing interesting work on economic complexity, but his book writes a check that it cannot cash.

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