Structural Change in Big Economic History

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Abstract: Structural change is an important process that is much studied in economic history. Early studies include industrialization and the stadial theories of human activities. Biologists have adopted "economic" concepts of competition, cooperation and innovation to study the history of life in a broader sense. Extending the study of structural change over an even longer time frame is likely to require the adoption of new analytical frameworks. One possible approach is the computational-information-entropy-complexity framework. This could lead to a novel perspective that places economic history within a broader Big Economic History.

Keywords: Structural change, complexity

1. Introduction

Economists have long observed that the structure of economies undergoes distinct change over long periods. These long-term structural changes are characterised by how production, distribution and consumption activities are transformed over time, often driven by technological innovations. Such changes have been analysed in two ways. First, human society has evolved from hunter-gatherer to agrarian and finally to industrial economies. Second, a more recent approach has been to study economic transformation from agriculture to industry and services. These approaches have primarily focused on human economic activities and are, as such and by design, very much human-centred.

However, human existence is only a small portion of the broader canvas of big history that stretches back to the Big Bang, an event dating back to some 13.8 billion years ago (see **Table 1). Figure 1** provides a visual image of the differences in the time scale of various components of big history.

In studying economic activities across a longer time scale that includes pre-human existence (one that covers other species), it is necessary to frame economic history in a different way. Such a framework is built upon the idea that economics is a method that can be universally applied to study how living beings come into existence, interacts, survive, reproduce and evolve over time. This approach is not really novel because it has long been articulated by biologists (studying animal behaviour) and ecologists e.g. Noe et al (2001) and Vermeij (2004).

Table 1: Big History Timeline

Time	Event
13.7 billion years ago	Big Bang – Origin of Universe
4.5 billion years ago	Formation of the solar system, Earth, Sun
4 billion years ago	Emergence of Life on Earth
750 million years ago	Emergence of Animals (multicellular eukaryotes)
450-440 million years ago	Ordovician–Silurian extinction events
375-360 million years ago	Late Devonian extinction
252 million years ago	Permian–Triassic extinction event
201 million years ago	Triassic–Jurassic extinction event
85 million years ago	Divergence of apes from other mammals
5 - 7 million years ago	Emergence of first human ancestors
10,000 - 13.000 years ago	Domestication of plants and animals
12,000 years ago	Emergence of agriculture
1730-1840	Industrial revolution

Source: Christian (2011)

If the study of structural change is extended further back all the way to the Big Bang, it must necessarily use an entirely different approach built upon different metrics/ variables that are more fundamental such as energy and information. One possible approach is to use complexity theory to explain the whole period of Big History.

The goal of this essay is to reflect on all of the above issues. It begins in section 2 by surveying and synthesizing the existing literature on structural change in human-centred economics. It then extends it to include a broader framework of analysis that covers all living matter in Section 3. An attempt to sketch an even broader framework that covers the entire history of the universe is undertaken in Section 4. Section 5 concludes.

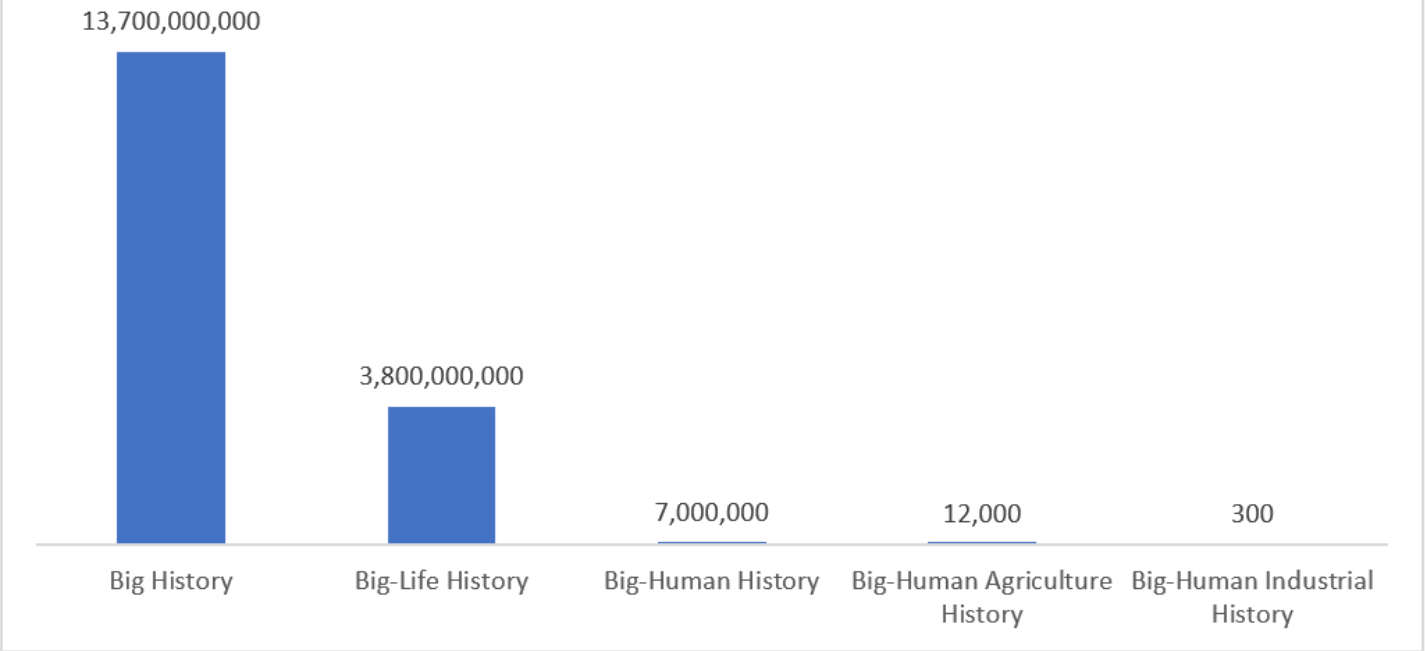
2. Structural Change in Economic History (Past 300 Years)

A common interpretation of the term 'economic structure' is the relative importance of different types of economic activities (or sectors) in an economy. Structural change or structural transformation refers to the reallocation of economic activity across three broad sectors of the economy, namely, primary (agriculture and mining), secondary (manufacturing and construction), and tertiary (services). A standard characterisation of structural change is to frame it in terms of changes in the relative importance of these sectors (Herrendorf et al., 2014).[1]

The study of economic structure and structural change at the sectoral level is not a recent endeavour. An early precursor was Quesnay's Tableau Économique (first published in 1758), which depicted the economy as comprising three classes, namely, the proprietary class (landlord), productive class (farmer and farm labourer) and sterile class (artisan and foreign merchant). The more 'modern' studies of economic structure and structural change date from the 1930s following the Great Depression. The early pioneering works focused on the development of data collection methods and tools such as national accounts (Simon Kuznets, Colin Clark, and Richard Stone) and input-output analysis (Wassily Leontief).

In the economics literature, the study of structural change usually focuses on two major phases of transformation

Figure 1: Scale of Big History (Years)



Source: Author

(**Figure 2**). In the industrialisation phase, there is a shift in the relative importance of economic activities (in terms of output and employment) from agriculture to manufacturing (Syrquin, 1988). Economic historians use the term "Industrial Revolution" to describe the industrial transformation beginning in Britain from the mid-18th century to the mid-19th century (Allen, 2017). Industrial revolution has been posited as a key factor in the "great divergence" between Europe and the rest of the world.
The next phase of structural change which has been labelled "deindustrialization" occurs when developed economies began experiencing a reduction in the manufacturing share of economic activity. This is often accompanied by an increase in the share of services in economic activity.

The process of structural change is complex, involving many dimensions such as demand, technology, employment, factor accumulation, migration, location, demography, income distribution and the environment. The theories and empirics of structural change have focused on a number of drivers (Van Neuss, 2019). From a domestic demand perspective, a rise in per capita real income is accompanied by a decline in the share of food in final demand and an increase in producer goods, machinery and social overhead (Chenery and Syrquin, 1986). Not only is there an increase in the production of manufactured goods with greater income elasticity, but a higher proportion of these goods are intermediate goods – which leads to greater intersectoral interactions and dependencies. Sectoral change is also driven by changes in the prices of manufactured goods relative to agricultural goods – which is brought about by

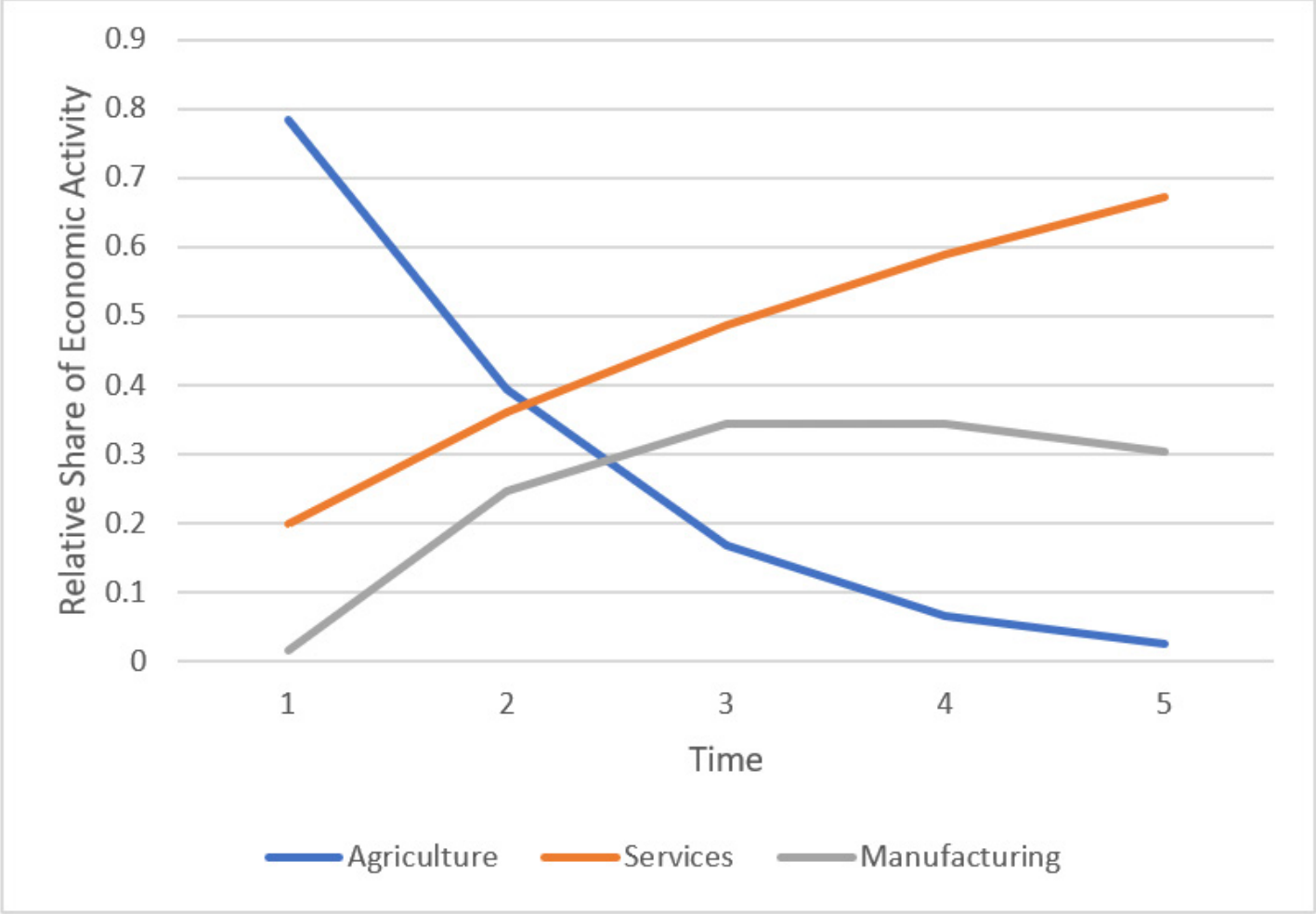


Fig. 2. Figure 2: Phases of Structural Change.
Source: Author

differences in productivity growth.

For many countries, especially smaller countries with a relatively lower endowment of natural resources, the rise in the trade of manufactured goods is another characteristic of industrialisation (Syrquin, 1988; Syrquin and Chenery, 1989). Recent empirical work has also emphasised the importance of country-specific technological factors (Eberhardt and Teal, 2012).

3. A Human-Centric Not-So-Big Economic History (Past 0.3 million years)

In the spirit of big history, the coverage of economic history is expanded further back – before industrial revolution – to essentially include the entire history of human existence. This is not entirely new to economic historians (Cameron and Neal, 2003 and White, 2018).

The split between the ancestors of humans and chimpanzees took place earlier, around 4-6 million years ago.[2] Humans, of the genus Homo, emerged around 2.5 million years ago (Belwood, 2022). The transformation brought about by the domestication of plants and animals took place around 10,000 to 13,000 years ago. Thus, for much of human existence, before the emergence of agriculture, humans lived as hunters and gatherers.

How have scholars theorized these different economic structures? These different economic structures have been the subject of analysis and theorizing as far back as the early 18th century. Theories of the different phases of dominant economic structures are known as "stadial theories" and "theories of four stages" (Schorr, 2018). Such theories influenced Adam Smith (1723-1790) who argued, notably in the *Wealth of Nations* and the *Lectures on Jurisprudence*, that there are four stages of structural change for societies, namely hunters (hunter-gatherer), shepherds (nomadic), agriculture, and commerce (industrial).[3] These stages are characterised by differences in production, consumption as well as stock and capital accumulation (**Table 2**). In earlier stages such as hunters and shepherds, labour is the main production input, and that production takes place with zero or minimal division of labour. Structural change in terms of transition from one stage to another is driven by population growth. Division of labour is more extensive in agriculture and reaches an advanced state in the commerce stage. It is the key driver of the transition from the agriculture stage to the commerce stage. This change is made possible with more extensive market exchanges and capital accumulation. Institutional dimensions such as property rights also become more important with the progression from the hunters stage to the commerce stage (Okun, 2017).

Another early and influential contribution on the study of long-term structural change comes from Thomas Robert Malthus (1766-1834). In Malthus's theory of population

Table 2: Adam Smith's Four Stages of Development

	Hunters	**Shepherds**	**Agriculture**	**Commerce**
Activity	Hunting and gathering	Pastorial, animal domestication	Agricultural	Manufacturing and services
Production Inputs	Labour	Labour	Labour, Land	Labour, Land, Capital
Division of Labour	Low number of occupations; High number of tasks per worker	Low number of occupations; High number of tasks per worker	Moderate number of occupations; moderate number of task per worker	High number of occupations; One task per worker
Extent of Market Exchange	Rare	Limited	Extensive	Extensive
Stock Accumulation	Zero	Moderate	High	High
Capital Accumulation	Zero	Zero	Moderate	Advanced
Drivers of stage transition	Population growth	Population growth	Population growth	Division of labour

Source: Author's compilation based on Okun (2017)

any increase in the standard of living (income per capita) would bring about higher population growth that would eventually reduce the standard of living in the absence of (further) technological changes. Scholars have used the term "Malthusian Trap" to characterize the stagnation of economies in the period from 10,000 BC to the 18th century (dawn of the Industrial Revolution).[4] More contemporary works by Oded Galor and his collaborators have led to a "Unified Growth Theory" that explains the long-term structural change in terms of three regimes, namely, Malthusian, Post-Malthusian and Modern Growth (Galor and Weil, 1999, 2000 and Galor, 2011).

In the Malthusian Trap literature, the focus on income per capita or standard of living divides the entire human epoch into essentially two major phases, namely, a long period of Malthusian Trap characterised by economic stagnation and a shorter Post-Malthusian which began with the Industrial Revolution (**Table 3**). From a structural change perspective, the literature on the Malthusian Trap does not deny the existence of the four different stages discussed by Smith. This point is emphasized by Lloyd (2020). In a manner similar to Smith, Malthus discussed the existence four states – (i) savage or hunter state, (ii) shepherd state, (iii) state of mixed pasture and tillage, and (iv) commerce. The three early stages are embedded in the Malthusian Trap whilst the fourth "commerce" is post-Malthusian.

How did the transition from Malthusian Trap to Post-Malthusian occur? Galor and Weil (1999, 2000) and Galor (2011) provide explanations for the transition from one regime to another in the following manner:

- **Malthusian → Post-Malthusian**
  Population growth leads to larger population that, over time, induces higher technological change which, in turn, leads to higher income growth. This spurs further higher population growth. Per capita income continues to rise as output growth is higher than population growth. The rise in income per capita leads to an increase in fertility and a decline in mortality. As a result, both population and per capita income increase.
- **Post-Malthusian → Modern Growth**
  The increases in income growth and lower mortality provide incentives for reduction of fertility and investment in human capital. This leads to lower population growth. Greater human capital leads to higher technological change. As a result, population size (as well as average family size) decreases (demographic transition) and income per capita continue to increase.

The inter-dependence and transition between the different stages (path dependence) is also highlighted by Clark (2007) who argued that a precondition for the transition to productive capitalism is the existence of long periods of settled agrarian societies with strongly disciplined workers.

Another influential theory of long-term structural transition was articulated by Karl Marx (1818-1883) who also attempted to provide a historical analysis involving five stages (see Elster, 1986). The five stages do not correspond exactly to the stages of earlier stadial theories of the eighteenth century.

This is because the focus of Marx's theory is on the generation and distribution of value generated by labour and capital. In the first stage, economic activity comprises production for immediate consumption, resulting in no exchange or reinvestment. This could correspond to the most primitive version of the hunter and gatherer stage. Further comparisons break down. There is some surplus and exchange emerge in Marx's second stage. Trades become more established in the third stage following the generation of greater surplus (production for surplus). The

Table 3: Malthus and Regime Change

	Malthusian	Post-Malthusian	Modern Growth
Income Per Capita Growth	Constant	Slow	Steady
Relationship between income per capita and population growth rate	Positive	Positive	Negative
Technological Change	Slow	Slow	Steady

Source: Galor and Weil (1993)

fourth stage and the fifth stage are characterised by the emergence of the internal market and money, respectively. In the fifth stage, production is driven by the pressure to generate surplus. Pastoral and agrarian societies seem to have some features of Marx's second and third stage, and possibly even the fourth stage (internal market). Both agrarian and capitalist societies are likely to use money, hence, are part of the fifth stage. The notion of subsistence (which appears in the stadial and Malthusian theories) also appear on Marx's analysis – wages in capitalist systems are driven to subsistence levels. Conflict over distribution of surplus value produced is a key feature of Marx's theory. Conflicts such as wars are featured in Malthusian theory differently – as positive checks on population growth.

More recent works such as North *et al* (2009) also emphasized the institutional mitigation of conflict or violence in human history through social orders. The authors argue that human history is characterised by three types of social orders, namely, foraging order, limited access order and open access order. Limited access order (also known as natural state) is characterised by social organizations based on personal relationships. In open access order, social organizations become increasingly accessible to individuals who met a minimal set of impersonal criteria. The three social orders differ in terms of the governance of societies and the importance of individual identities in social interactions. As we move from foraging order to limited access order and finally, open access order, personal relationships become less important in economic interactions. Placing the four stages discussed earlier within these three categories is not a straightforward exercise. The hunter-gatherer is foraging order and the pastoral and agrarian could be limited access order. The commerce/industrial stage is an open access order where impersonal markets thrive. The social order framework provides another dimension to analysing structural change – one embedded in institutions and conflict.

The theorizing of human-centric economic history is inexhaustible and not likely to converge to a single explanation. The above review of stadial theories provide some flavour of how economists have attempted to make sense of structural change within the long duration of human existence. Existing theories clearly do not spend enough time on the hunter-gatherer societies in the structural change story. Perhaps this is due to the focus on history driven by written records. The challenge is even greater if the time coverage is expanded further to include the emergence of all forms of life. This is explored next.

4. Big Life Economic History (Past 4 billion years)

Life in the form of a simple microbe, protocell, first emerged on earth some 4 billion years ago. This microbe is the sole shared ancestor of all life forms on earth (with the exception of possibly, virus). Over time, new life forms emerged. Two billion years after protocells emerged, simple microbes evolved into complex cells with nucleus. Mitochrondia, which powers multi-cellular cells, emerged two billion years ago. Chloroplast appeared about 1.5 billion years ago, paving the way for the emergence of plants about one billion years ago.

The earliest ancestor of animals first came into existence some 750 million years ago. Animals subsequently evolved in different complex life forms – fish (600 MYA), insects (480 MYA), mammals (310 MYA), dinosaurs (230 MYA) and primates (56 MYA).

Economists generally do not study the emergence and evolution of life on earth. If the study of economic history is to be extended before human existence, a new framework of analysis is needed. In a human-centric economic history, *Homo Sapiens* is the central economic agent and this economic agent is assumed to be remain relatively unchanged over time biologically (but perhaps not culturally). If the relevant time span is expanded to cover all life since their beginning, the focus of analysis is shifted to cover the different types of life forms.

Returning to the issue of structural change, what exactly is being transformed over time in Big History? In the human-centric approach, the focus is on different type of economic activities. Across the different life forms, it is perhaps more meaningful to frame "economic activities" in terms of how living organisms carry on activities that sustain life in terms of both survival and reproduction. This is not entirely novel, as biologists have modelled non-human animal behaviour in terms of optimization strategies – which is a key feature of economics (Noe et al, 2001). Others have focused on demand-side explanations based on individual-level strategic pursuits (Snooks, 2008).

Economists too have acknowledged the kinship between economics and biology from this perspective (Hirshleifer 1985 and Hodgson 1993). This kinship is premised on shared emphasis on competition, cooperation,

specialization, innovation (random mutation), and evolution (Hirschleifer, 1985). Biologists such as Vermeij (2004) have also proposed an economic history of nature based on these perspectives on the role of competition and cooperation in nature.

How should the history of structural change be analyzed from a natural economy perspective? First, the time dimension, over which changes take place, can be very long indeed especially when evolution through natural selection is the driver of change. Within the process of evolution, competition and cooperation take place at both intra and inter species levels. Structural changes occur when there are changes in the ways in which living organisms compete and cooperate in nature. This would include major transitions associated with the emergence of new species.

Within this interpretation, evolution can be seen as a process of structural change. This process is subject to random shocks in terms of mutation and genetic drift. The latter could be driven by climate change and extinction-level events, for example, caused by large asteroids. The mass extinction of dinosaurs 66 million years ago is an example of the latter.

The above discussions lead to the question of whether there is a meaningful way to distinctively classify the different phases/stages of life history on earth. The emergence of new species leads to large-scale changes in the nature of competition and cooperation within ecosystems. One possible way to examine this is in terms of how evolution affects the structure of food web (Eklöf et al, 2012). Each key event, which is related to the emergence of new animals or the extinction of animals, could be considered to be a key phase of structural change. An even more fundamental transformation could be the emergence of genetic materials as a key hardware for evolution. But these may not necessarily be the most important stages for at least two reasons.[5] First, multicellular organisms only emerged 600 million years ago – a mere 15 percent of the entire timespan of life on earth. Second, as the emergence and evolution of life forms are sequential, the earliest ancestors are important.

Finally, much of the literature on the emergence and evolution of life points to complexity of biological systems (Zimmer, 2013). What is a complex system? Mitchell (2009, p.13) defines a complex system as "a system in which large networks of components with no central control and simple rules of operation give rise to complex collective behaviour, sophisticated information processing, and adaptation via learning or evolution". An important concept in complexity theory is emergence defined as the formation of global patterns that arise from local interactions.

One appeal of complexity theory is its usefulness in studying an extensive range of phenomena from biology to economics. For example, in biology, scholars have examined whether evolution increases the complexity of life forms. This topic remains much-debated and contentious. In economics, complexity theory is used to model various economic phenomena such as cities, traffic and business cycles (Hildalgo, 2021). Aside from scope, the wide range of application of complexity theory provides a framework to analyse structural change over a very long range of time. The notion and modelling of structural change could take on a different meaning within the complexity theory perspective.

5. Is A Truly Big Economic History Possible? (13.8 billion years)

The literature on Big History covers the entire existence of the universe, starting from the Big Bang which took place some 13.8 billion years ago. The time period with lifeforms on earth (4 billion years) accounts for only 29 percent of the time period since the Big Bang. Any attempt at constructing an economic history that covers pre-life-on-earth time period is very challenging. To set up the context for discussions on this topic, it is perhaps useful to review what is known about Big Bang and the history since this event (up until the emergence of life). The analysis of the pre-life period since the Big Bang is entirely in the domain of physics. Based on the narrative provided by Kinney (2022) and Christian (2004), the very short and early period immediately after Big Bang, which amounted to less than 3 seconds, is characterised by the emergence and transformations of the basic building blocks of the universe (**Table 4**). This is brought about by changes in the operations of different fundamental laws of nature (physics) – strong force, electromagnetic force and gravity. As the universe cooled, density declined and space inflated. Clearly, this portion of big history involves several phases of structural change (using the term in the widest sense) that ultimately led to the large-scale structure of the universe as it is observed by us today.

At this point, it is difficult to see how economic

Table 4: Key Events After Big Bang

Time after Big Bang	Significant Events
$t = 10^{-43}$ seconds	**"Planck Era"** • Universe is smaller than the "Planck length" - the smallest length that has any physical meaning • Physics unknown
$t = 10^{-34}$ seconds	**Grand Unified Theory/Symmetry Breaking / Energy Scale of Inflation** • Phase transition takes place where strong nuclear force is separated from the weak and electromagnetic forces • Creation of asymmetry between matter and antimatter
10^{-34} sec $< t < 10^{-12}$ sec	**Unknown** • Inflation - universe expands faster than the speed of light and cools to near absolute zero
10^{-12} sec $< t < 10^{16}$ seconds	**Higgs Instability / Electroweak Phase Transition** • Higgs boson becomes unstable around $t = 10^{-12}$ sec • Universe is a dense primordial soup comprising free quarks, leptons, force carriers (gluons, W and Z bosons and photons) and antimatter counterparts • Formation of dark matter
$t = 10^{-6}$	**Quark/Hadron Phase** • Free quarks and gluons condense into protons and neutrons
t = 1 seconds	**Primordial Nucleosynthesis** • Proton and neutrons condense into atomic nuclei • Neutrinos decouple from thermal equilibrium • Electrons and positron annihilate into photons
t = 60,000 years	**End of Radiation** • Dark matter decoupled from cosmic plasma and collapse into bound structures
t = 300,000 years	**Recombination** • Nuclei and free electrons condensed into neutral hydrogen and helium gas • Universe becomes electrically neutral
t = 1 billion years	**End of Dark Ages** • Emergence of first stars and galaxies
t = 6 billion years	**Onset of Cosmic Acceleration** • Dark energy causes expansion of universe

Source: Author's compilation based on Kinney (2022) and Christian (2004)

history can be related to the Big Bang and the subsequent transformation of the universe up to a point before the emergence of life. This difficulty arises from the lack of a useful framework within more conventional economic history that could be extended to analyses of wider time frame. Interactions between various types of forces occur but not in the sense of "competition" and "cooperation" that underpins economic analysis.

New notions and concepts that traverse a wider time frame are needed. Four interrelated concepts come to mind – computation, information, entropy and complexity (Mitchell, 2009). Lloyd (2006) provides a narrative of the history of the universe since Big Bang from a computational (information processing) perspective. Big Bang is a maximum entropy event with zero information (entropy and information are two opposite sides of the same coin). As the universe cools downs and expands, entropy decreases, and the amount of information (processing) increases. The subsequent emergence and evolution of life can also be couched in terms of increasing complexity (information) over time (see Davies and Gregersen, 2010; Lineweaver, 2013; Walker et al, 2017).

The next step is to use the same computational-information-entropy-complexity approach to frame structural change in the human-centric (economic) history. Scholars such as Hildalgo (2015, 2021), Hildalgo et al (2007) and Haussman et al (2013) have already attempted to re-cast economics in terms of complexity. Haussman et al (2013, p.18) describes complex economies as "those that can weave vast quantities of relevant knowledge together, across large networks of people, to generate a diverse mix of knowledge-intensive products". The authors go on to construct an index to measure product complexity that is based two notions – diversity (in product space) and ubiquity (in country space). Theoretically, it might be possible to construct a human-centric economic history based on structural change that is measured in terms of product complexity.

One aspect of complexity that is worth examining is the increase in the interactions, linkages and interdependence between individuals, groups and societies across time and space. Globalisation is a manifestation of this phenomenon which has a prominent place in both history (McNeill and McNeill, 2003) and economic history (Allen, 2011 and White, 2018). Technological change is a key driver of globalization which has many dimensions such as social, economic, cultural and political. Sachs (2020) has proposed the classification of the history of human-centered globalization into seven ages (see **Table 5**). Re-framing these seven ages in terms of complexity theory

Globalization Age	Approx. Dates	Primary Energy	Information Media	Agriculture	Industry
Paleolithic	70,000-10,000 BCE	Human, ocean currents	Language, petroglyphs	Hunting, gathering	Stone tools
Neolithic	10,000-3,000 BCE	Oxen	Hieroglyphs	Crops, animal husbandry	Bronze, copper
Equestrian	3,000-1,000 BCE	Horse	Early writing system, stela	Plow	Iron, wheel cart
Classical	1,000 BCE – 1,500 CE	Windmill, waterwheel	Alphabet, book	Large-scale grain trade	Engineering, infrastructure
Ocean	1500 – 1800	Ocean, wind	Printing press	Global trade of crops	Ocean navigation
Industrial	1800 – 2000	Fossil fuels hydroelectric	Telegraph, telephone, broadcasting	Chemical fertilizers	Stem engine, textile, steel
Digital	2000 -	Solar, wind	Internet, artificial intelligence	Precision agriculture	Digital nerworks

Table 5: Sachs's (2020) Nine Ages of Globalization Source: Table 1.1, p.6 in Sachs (2021)

entails paying attention to the transformations in terms of changes in information and information processing which is also linked to energy production and utilisation. Each of these changes are covered by existing studies separately, for example, information (code) by Auerswald (2017) and energy by Smil (2017, 2021). The various branches of the relevant literature needs to be synthesized into a more holistic and open framework based on the computational-information-entropy-complexity approach.

6. Conclusions

The essay began with a modest attempt at reviewing the various notions and theories of structural change in economics and economic history. In contrast, the current notion of big history is one that covers a much broader time dimension – the entire existence of the universe. This goes further back than what economists have traditionally covered. Biologists have adopted "economic" concepts of competition, cooperation and innovation to study the history of life in a broader sense.

As we attempt to go back further in time, the frameworks of analyses need to be changed to accommodate a broader range of phenomena. An underpinning assumption underlying such an endeavour is that it is possible to have a universal approach to big history. In such an approach, the existing interpretation of economic history need to be entirely re-framed. The computational-information-complexity approach is one plausible way to do this. This could lead to a novel perspective that places economic history within a broader Big Economic History.[6]

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Endnotes

1 Economic historians often study structural changes at a more disaggregated level such as within sectors, industries, firms and households.

2 Source: https://www.science.org/content/article/generation-gaps-suggest-ancient-human-ape-split#:~:text=For%20the%20past%2045%20years,to%209%20million%20years%20ago.

3 Reid (1989) attempts to reconstruct Adam Smith's four stages of history in a deterministic growth trajectory. However, the coherence of Smith's work on the four stages is called into question by Paganelli (2002).

4 There are disagreements amongst economic historians about the great divergence and the Malthusian trap. For example, there is empirical evidence supporting "little divergence" in which the economic gravity shifted away from Asia and Southern Europe towards northern Europe between 1300 and 1800. The author thanks one of the anonymous reviewer for pointing this out.

5 It might also be useful to think about the difference between self-replication and self-reproduction.

6 However, it is possible that approach may not necessarily appeal to economic historians who would argue that economic history does not have anything useful to say about life before humanity and that the computational-information-complexity approach could be focusing more on new (e.g. mathematical) methods. The author thanks an anonymous reviewer for this point.