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Modeling historical dynasties as emergent, dissipative mechanisms

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ABSTRACT

Societies strive to maximize their economic production in accordance with the Maximum Power Principle and its implications for entropy increase. Societies and firms achieve this maximization, in part, by striving for greater efficiency via increasing their economies of scale. However, the process of establishing the structures and institutions required for economies of scale may exhibit substantial barriers to reversibility. This paper traces processes of of dynastic growth using thermodynamic concepts and well as the thermodynamic implications of regimes facing intrinsic drops of overall efficiency and resource depletion. This paper applies this approach to modeling historical dynasties as emergent, dissipative mechanisms and shows how human history can, in part, be modeled as a progression of series of interacting dynastic dissipative mechanisms.

Keywords: history, world history, dynasties, Maximum Power Principle, entropy, dissipative mechanisms

1. INTRODUCTION AND CONTEXT

This paper provides a conceptual framework for analyzing history by utilizing the concepts from thermodynamics. It then applies this framework to macro-historical structures such as dynasties.

History is a grand field encompassing all the activities and artifacts of recorded humanity. Physics is also a grand field that ultimately constrains, and possibly drives, human activities and the formation of artifacts. Physics can go deeper than mere, empirical computations by using characterizations and principles that allow for a unified framework of analysis. This paper explores a few approaches to identify and apply unifying principles for some aspects of history.

During the approximately 5000 years of recorded human history, we see long-term trends such as the overall exponential increase in human population and advances in technology. While these are certainly important trends for humanity, temporary deviations from trends are even more interesting. These deviations might be the product of regularly occurring tendencies, processes and structures. We see such processes and structures repeatedly arising in world history. Dynasties and empires come and go. Rise-and-fall patterns are also seen in economics and business. We shall explore and investigate whether such deviations share commonalities in their formation and progression.

It has been observed that entropic potential results in the emergence of complex dissipative structures. [1,2,3] Where a thermodynamic potential exists, there is substantial evidence that systems tend to configure themselves to maximize their rate of entropy increase. [4] This tendency results in the emergence of structures that consume and dissipate entropic potentials. Atmospheric convection columns allow faster removal of thermal energy from the hot surface of the Earth into the coldness of space. Tornados and hurricanes are even more complex, faster mechanisms.

The further a system is removed from equilibrium, the more likely it is for complexity to form into mechanisms to consume potential.[5] For example, convective energy transport structures (cells of hot plasma) form in stars as their temperature gradient becomes steeper.[6]

If a complex structure can perform work, we can call it an *engine*. Steam engines in electric power plants are a type of engine called *heat engines*. A heat engine *consumes* thermal potential. It *produces* work that can be used to operate machine tools, pump water or generate electricity. Such work can be called production. Only a portion of the flow of thermal energy can be used to generate work. This proportion is the engine's *efficiency*, which is the percentage of consumption is transformed into production. Hence, a heat engine also produces waste heat and entropy.

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A heat engine by itself might not result in faster consumption of potential than a simple conductor. Yet what if the work from a heat engine is used to build additional heat engines? The result will be an exponential increase in the quantity (population) of heat engines. If each reproducing heat engine consumes potential, then there will be an exponential increase in the consumption of potential. Therefore, the emergence of reproducing heat engines is favored by the laws of thermodynamics.

The concept of an engine can be generalized to any mechanism that consumes potential and produces work. Bacteria consume high level energy and produce more bacteria, so they fit within this paradigm. Most living organisms do. Intelligent creatures can figure out additional means to consume thermodynamic potential, so intelligence is favored. The great organizations and technological developments of human civilization can consume potential even faster, through agriculture, trade, vast irrigation works, large coal mines, deep oil drilling and even the release of nuclear energy.

2. LIMITS AND DECREASING EFFICIENCY

There will always be factors that limit the growth in a system. A regime that experiences exponential growth will eventually begin to experience such limiting factors. Work on system dynamics such as the Club of Rome's *Limits to Growth* [7] involves attempts to better understand these limiting factors. Such factors restrain growth and sometimes stop it altogether. Limiting factors usually exist due to a shortage of some essential resource or an excess of some "negative" resource. Turning to biotechnology, an examination of reproducing cells shows that the chief limiting factors are typically a nutrient limitation or an accumulation of a toxic metabolite.[8]

If there is a nonrenewable, built-up potential, such as oil, coal or gold, then generally, the intrinsic efficiency at which each additional unit of consumption is transformed into production decreases. This is expected: we go for the low hanging fruit first, then the slightly higher fruit, and only go for the hard-to-reach fruit at the top of the tree last. There are two chief types of efficiency: intrinsic efficiency and overall efficiency. Intrinsic efficiency is limited by the Second Law of Thermodynamics prohibition on entropy decreasing in an isolated system. Overall efficiency cannot exceed intrinsic efficiency, but it can be much lower. Technical improvements and economies of scale can help improve overall efficiency.

Overall efficiency functions can be in several forms, depending on the circumstances involved. For example, for a nonrenewable resource, the efficiency function may decay linearly or exponentially. There are ways of determining the overall efficiency function from actual data or known constraints.

3. THE RISE AND FALL OF A BUBBLE

We have seen how the emergence of reproducing dissipative structures can lead to exponential growth. We have also seen how intrinsic efficiency decreases as a nonrenewable resource is consumed. Hence, we now have the conceptual means to understand the lifecycle of a bubble. From this point on, a ***bubble*** will refer to *a rise-then-fall progression due to the emergence of reproducing, dissipative structures operating upon a limited, nonrenewable resource*.

1. A thermodynamic potential accumulates.
2. A reproducing, dissipative mechanism has emerged to consume the potential.
3. The mechanism reproduces exponentially. Consumption increases exponentially.
4. Growth continues, but intrinsic efficiency decreases.
5. Eventually either all the potential gets consumed, or the efficiency of exploiting it falls below the ability of the mechanism to maintain itself.
6. The progression of the bubble ends.

Since exponential growth is involved, but the transformation of consumption into production must be discounted by efficiency, this approach to bubble modeling is called *efficiency-discounted exponential growth (EDEG)*.

A bubble can involve physical or social resources. However, it is easier to begin analyzing physical resource bubbles, since there is often more available data and the examples are fairly straightforward. EDEG analysis has been performed by the author upon regional petroleum and metals mining. [9,10] However, this paper shall focus on applications to human history.

4. EMERGENCE AND PROGRESSION OF A SINGLE DYNASTY

We will now express historical dynasties as emergent dissipative structures, and generate power progression models of dynasties from fundamental principles. In this discussion, the term *dynasty* is used broadly to refer to a continuous ruling group; it could be a related family but not necessarily so. In contrast, the term *society* will refer to a large group of related people, typically of a single or similar group of ethnicities, such as the Han people in China or the Frankish people in France. Dynasties exist within a society, but can conquer other societies as well. For example, the society of Russian people produced a series of dynasties, and those dynasties sometimes conquered other societies.

Dynasties as Bubbles. Both physical and social built-up potential can drive the formation of dynasties. Within the context of a civilization progressing over centuries, it is often possible to degrade built-up potential even more quickly with high-level, governing social structures for a society. Hence, dynasties form to accelerate consumption of such potential. Hypothetically, dynasties should result in more rapid degradation of energy than does a more static society.

Each dynasty has a lifecycle. A dynasty is born, matures, endures awhile, then ends. A new dynasty will not necessarily follow an old one, or might not immediately appear. Yet generally, dynasties continue to form, one after another, so long as there exists built-up potential that cannot be more quickly consumed by other means. The dynastic lifecycle can be described as a march towards equilibrium in terms of nonrenewable resources, and towards dynamic equilibrium in terms of on-going flows such as sunlight and rainfall.

We can consider large, independent, robust dynasties to be bubbles. A new dynasty within a society encounters a built-up potential of physical and social resources (e.g. goodwill), albeit of limited magnitude. The society governed by the dynasty fills the role of a collection of heat engines, producing both work and entropy. Prosperity expands exponentially, increasing the consumption of potential exponentially. Eventually, it becomes increasingly difficult for the dynasty to rely upon its store of physical and social resources, decreasing its efficiency. As efficiency decreases, the dynasty will experience social crises and will eventually stop functioning.

Considerations for Modeling Dynasties. It is simpler to model a sufficiently large, robust, independent dynasty than one that existed merely at the whim of its neighbors, for there are less significant dependencies, and thus it can be approximated as a substantially isolated system. We will examine Russia's Romanov dynasty as an example. Widely accepted start and end dates are 1613 and 1917.[11] Peter the Great and Catherine the Great were the two important rulers of the Romanov dynasty, and the Russian Empire gained much of its most valuable territory by the end of Catherine's reign in 1796. The Romanov dynasty was big, robust and essentially independent. It fought wars, but generally was not under serious threat of extinction. Even Napoleon could not conquer Russia. This Romanov dynasty was reasonably long-lived, rather than just a quick, "flash-in-the-pan" empire.

By developing a fundamental approach to modeling the rise and fall of dynasties, it is possible to accept or reject models (within a range of uncertainty) based upon both qualitative historical evidence and quantitative historical data. We shall discuss generating models of the rise and fall of power of dynasties versus time and how a single dynasty can be modeled using the efficiency-discounted exponential growth (EDEG) approach.[12] Such an EDEG model of a dynasty can be called a power progression. The models shown should be considered mere first approximations rather than definitive assertions of fact. They are a beginning point of further explorations.

Historical dynasties are consumers of energy and producers of power, so models in terms of such quantities are inherently fundamental in that they can be derived directly from the laws of physics and expressed in physical quantities. Such models are not theories of everything, but rather describe certain aspects of broad macro-historical phenomena rather than the intricate workings of the interactions of individual people.

The term energy is meant in the physical sense here. There are several possible proxies of the physical energy of a dynasty, such as population governed or grain production. Each of these is translatable into physical units of energy. For example, the quantity of people multiplied by the mean Calorie diet per person will result in units of energy. These figures can be estimated for most dynasties over their lifespans, albeit with differing degrees of uncertainty. The proportion of that energy that rulers of a dynasty effectively have at their disposal is beyond the scope of this paper, but should be considered for improved accuracy.

Power is a physical term. It refers to energy expended per unit of time. Yet it also has meaning within social and political contexts, and will be discussed in both senses. Absolute power would generally be presented in physical units of power such as Watts. However, it is possible to express any type of power in terms of proportions, such as the ratio of power at a dynasty's peak to its start date. Such a ratio can apply to physical, political or even military power. Possibly, the EDEG approach can be utilized to model other types of power, such as political power. In fact, the EDEG approach provides a framework to explore the question of how political and physical power are related.

Exponential Growth of Dynasties. A new dynasty will tend to experience exponential growth. A chief characteristic of exponential growth is that growth feeds even more growth, resulting in an increasing rate of growth. Increases in population and power can become explosive. Nevertheless, the growth rate in early stages tends to be relatively flat, while the growth rate later tends to be relatively steep. The transition between "flat" and "steep" can be surprisingly sudden and disruptive.[21]

It will be assumed that dynasties will strive to grow exponentially. (This paper does not attempt to prove this assertion, but rather it is a rebuttable presumption). If so, this certainly explains the rise of a dynasty. Sources of growth can include increased agricultural productivity, geographic expansion, and trade expansion. The growth rate function can be constrained by the data and an understanding of the growth mechanisms involved.

Limiting Factors and Decreasing Efficiency. Another source of limiting factors is the increasing cost-per-unit to extract certain resources. Malthus [13] pointed out limiting factors in the growth of agricultural production. Societies attempt to use large-scale social and technical structures to shore up efficiency, but these structures create additional challenges.

A dynasty will typically consume both nonrenewable *and* renewable resources. Yet it is the consumption of one or more critical nonrenewable resources that determines the growth and decline characteristics of the regime. Production in a dynasty is ultimately dependent upon nonrenewable physical and social resources (otherwise dynasties would not typically end). Dynasties inevitably do end, which is typically preceded by a decline in power.

As the dynasty progresses, nonrenewable resources will be consumed, and efficiency will decrease. There will still be production until the end, but there will be a lower return on investment, so to speak. Physical causes of decay can include overuse of agricultural land leading to nutrient depletion, the build-up of toxins in the environment, and the depletion of old growth forests. Social causes can include running low on social goodwill, the increased dependency on expensive, monopolistic centralized institutions and structures, and the resulting decreased accountability of aristocratic "deadwood". All such may have nonrenewable aspects. Exponential decline in an EDEG situation can happen more quickly than exponential growth.

5. SERIES OF DYNASTIES

A society can be modeled as a series of dynasties or EDEG bubbles. Each bubble would typically represent a dynasty for a traditional historic monarchy. Robust, traditional, monarchical, agricultural-based regimes have historically tended to endure for roughly 300 years. This is an empirical observation and not based upon theory. Not all regimes last for about 300 years. Yet the 300-year pattern has appeared frequently in history from France to China to West Africa. We will focus on dynasties that endure for about that time.

A common error would be to assume that the series of EDEG curves represents a periodic function. It's not. Dynasties might not follow immediately one after another. Not all dynasties last the same amount of time. Or there could be some overlap between older and newer regimes.

Dynasties in major historical civilizations are typically easy to identify. In a sense, dynasties are what fill the pages of historical textbooks. A series of power progression models of Russian dynasties is plotted. Although the plots are each set to a maximum power of one, actual power would vary among dynasties.

There are two main approaches to generating a series of dynasties. One approach is to generate a model for each dynasty separately, and then combine the simulation results for a combined period. A second, more insightful approach is to model potential as an ongoing flow versus a resisting tendency, so that a series of logjams and bubbles are created. This allows for some resource replenishment. The challenge is to do so with as few parameters as possible. While the second approach has been tested, only the first approach is used in this paper.

The power progressions shown were normalized. However, one dynasty in a series might be more powerful than another. There are several ways to express changing power. For example, later dynasties might have more power than preceding ones due to greater population or energy technologies (animals, windmills, agricultural improvements). However, the relative power of a series of dynasties compared to nearby dynasties could vary as well. A society may face differing levels of competition from neighbors.

6. INTERACTING DYNASTIES

A EDEG function can be a robust entity, but it can still be affected by simultaneous or co-existing dynasties or even overwhelmed. Potentials can exist between dynasties (generalized as *regimes* here), such as in the case where one regime has a persistent trade surplus with a co-existing regime.

Only something out of a science fiction movie could have eliminated either the Roman Empire or the Chinese Tang dynasty at their heights. The power profiles for the very largest human regimes in history will be largely independent of each other. Many smaller regimes are still powerful enough to be fairly robust. However, regimes of small states are highly affected by their neighbors. Likewise, new or dying regimes of larger states lie along portions of their power progressions that are not as robust as middle portions. Such vulnerable regimes may have power profiles that are abruptly terminated rather than gradually terminated. The remaining critical resource of the regime must either be considered to have been discarded, or must be consolidated into the power progression of a conquering regime.

Regimes often interact with each other. Therefore, one regime can impact another. This interaction can become quite complicated, especially for smaller regimes. However, the largest, most durable regimes often provide more available data and tend to be somewhat less affected by other regimes, so that the effects are more discernable.

7. DISCUSSION AND FUTURE DIRECTIONS

This discussion of the EDEG approach is more of a barebones beginning than a complete end. It raises more questions than it answers, but it enables a broad framework to answer these questions. This framework acts as a unifying skeleton to link the humanistic elements of history with the quantitative constraints of the physical universe.

The power of such a framework should not be underestimated. It is possible to gather quantitative data (or quantify qualitative evidence), perform statistical analysis and accept or reject hypotheses.

For a more detailed analysis, see: Ciotola, "Navigating the Currents of History", *World History Connected*, (v. 15 no. 1, Feb. 2018)

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