

Review Essay: Gaining Understanding with Recent Inter-generational and Developmental Models

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Abstract

The evolution of technology has facilitated improved lifestyles with better health, substitution of energy instead of human power, and better comforts such as temperature control and sanitation. However, there are real and potential problems to the entire population including those in the third world and future generations. These problems include diminished resources such as water, metals, soil, and inexpensive fossil fuels along with pollution of both local environments and changes in global environments.

Recently models and empirical correlations have been explored which help to understand the relationship between the environment, unequal development, and future generations. Specifically, these models include the Human and Nature Dynamics (HANDY) model, the Wonderland Scenario generator, an agrarian society model, and a systems dynamics model of transition to sustainability.

This paper investigates the assumptions and potential implications for the environmental and economic development of future generations. This study includes comparing the models with historical civilizations including different modes of potential civilization collapse. The current trends can be placed in the context of inter-generational ethical models such as an extension of John Rawls' "Veil of Ignorance". Understanding can be gleaned from this exploration to inform debate and discussion on the topics, such as the role of technology and governments under uncertainty. While the models are currently too simplistic to be used in decision-making, they can be useful educational tools in exploring potential relationships and scenarios.

Introduction

Environmental problems have contributed to the decline of many historical civilizations through resource pollution and depletion [1]. We currently are in an interesting phase of history where technology has enabled an increasing number of people to lead satisfying lives without the fear of want. However, this technology has also led us along a precarious path with increasing demands on our limited resources through both quick population growth and diffusion of a technologically dependent life-style. A previous paradigm assumed that technology would continue to facilitate solutions through greater efficiency, energy extraction, material substitution, and more effective organizational structures. However, these solutions led to unintended consequences such as stimulating higher demand, facilitating rogue applications, or accentuating unstable feedback mechanisms. Various techniques and tools have been suggested to assist in addressing environmental issues. This paper reviews difficulties in the decision process when considering inter-generational environmental justice. Phases of the decision process include context awareness, problem identification, option identification, criteria establishment, and option assessment and selection, followed by implementation, monitoring, and revision.

Historical perspective is gained by exploring cases of civilizations that did not adequately address environmental and social issues. The impact of environmental degradation has been an important factor in the decline of civilizations, such as the Easter Islanders, Romans, Mayans, and Mesopotamians [1, 2], often these civilizations overextended their abilities to sustain their particular systems as they grew more complex. It is unclear whether the current increasing pace of current technological change will overwhelm social responses aimed at handling the unintended consequences of technological change [3]. In the past century, a large set of environmental problems has been dealt with at a variety of levels (local, national, international), with a dynamic combination of political and technological techniques [4]. The technology-related environmental problems range from sanitary conditions in urban areas in the early 20th century, to national-level air and water problems in the 1970s, to the recent interest in international environmental treaties. While the amount of time elapsing between these periods of action seems to be decreasing, the duration required for their resolution has increased. Many 21st century issues

involve all scales, from individual decisions (e.g., purchases and habits) to global consequences, such as potential global climate change, sustainable production, and ecosystem stability.

Approach

Modeling various scenarios is an important activity in gaining understanding of the current situation and potential impacts of various alternative actions. A top-level modeling approach includes empirically determined aggregate behaviors that reflect robustness, resiliency, and efficiency. Historical trends in trade, energy, environment, consumption, and population can form the basis for modeling future scenarios. Models might then project these trends to offer insights into potential global development scenarios.

The role of technology in the future is often debated [5]. Some see it as a way to increase efficiency, others see it leading to increased resource demand. A major question of inter-generational justice is whether the gap caused by advanced technology of one group will continue to dominate the developing group. One model assumes that higher technology results in higher rates of progress leading ever increasing inequality. A contrasting model is that the leading countries are slowed in their growth rate due to the difficulty in discovering new improved technologies. Then the developing countries can adapt and adopt the existing technologies to increase their growth rate and therefore reduce the economic gap. A major example of this has been the economic growth of China and India in recent years. For the most of the time since the industrial revolution the gap between developed and developing countries grew. However, recently this gap has shown signs of slowing and reversing [6]. This seems to suggest that the technology diffusion to other parts of the world is happening faster than technology discovery within the developed world.

Wonderland Model

The Wonderland model [7] was developed in 1994 and extended later to include two population groups – North and South. Population, natural capital, pollution, and economic growth were considered. The economic and demographic models are relatively simple logistic transitions in growth rates

(economic, birth, and death) as functions of the remaining natural capital and economic productivity. The environment is modeled with 4 variables- the pollution flow rate, the remaining fraction of natural capital, the cost of pollution impacts, and the fraction of the economic production that becomes pollution. The natural capital is depleted by the pollution flow. An important assumption is that the fraction of the economic productivity that becomes pollution is reduced over time by a constant factor (related to the technological progress in efficiency).

Policy levers were included in the Wonderland model. A simple lever is the pollution tax that improves technology in reducing the pollution fraction but also reduces net economic output. Depending on this policy setting, the scenarios ranged from Dream (continual economic growth with smooth transition to a stable population), Escape (erratic economic output and population eventually leading to a stable population), and Horror (where the environment is degraded to a point that is irreversible leading to a collapse in the economy and population). With the extension to a world model which includes the two (North and South) populations, more lever options became available, such as the diffusion of pollution-reducing technology from the North to the South. This extended Wonderland model was then used in new techniques to determine the long-range effects of the policy levers under different scenarios. The goal was not to optimize the result but rather to determine a range of parameters such that the system would be somewhat stable, reducing the potential regret.

Handy Model

The Human and Nature Dynamics (HANDY) model [8] was published in 2014. The model is set up in a similar way to a traditional predator-prey ecosystem model with humans as predators and nature as prey. This is then modified with assumptions about natural resource regeneration, the neutrality of technology, and inequality. The optimum economic output occurs when half of the natural resources (i.e., largest regeneration rate). Besides environmental impacts, and the economic productivity, a major construct is the stratification into two populations, the elite and workers. The division into two specific groups was motivated to establish a mechanism for delay between decisions and impacts. For example,

the elites are able to temporarily maintain their lifestyle by using accumulated wealth, even if the current worker productivity with degraded natural capital is unsustainable. With different starting parameters, this model also displays an array of scenarios, including positive scenarios with smooth transitions, cyclical scenarios as the population and nature partially collapse and then recover, and two forms of complete collapse. The two modes of collapse are scarcity of labor and nature exhaustion. In the scarcity of labor scenario everyone becomes elites living off of accumulated wealth but nature is able to recover after the wealth (and population) are reduced. In the nature exhaustion scenario, natural resources are depleted beyond the ability to support population.

To gain better understanding, historical civilizations were identified as possible examples of these scenarios. These civilizations included Mesopotamia, Egypt, Greek, Roman Empire, Indian, China, American, African, Pacific Island, and Neolithic Age groups. In the Neolithic group, when agriculture was being developed and spread, there have been 23 collapses identified of which 19 of them seemed to be from internal causes resulting in a 30-60% drop in the local population. Besides this, in some regions, there were multiple collapses with a cycle period of about 300-500 years. The scarcity of labor collapse scenario is indicated by recovery of nature similar to the case of the Mayan civilization where the jungle recovered. There are two nature exhaustion scenario types depending on the level of exhaustion. In the reversible case, civilization collapses to a much lower level but nature and civilization eventually recovers (Greek and Roman). In the irreversible case, civilization collapses and nature is not able to recover (Easter Island and Fertile Crescent).

Korotayev & Turchin Model

In 2006 Turchin and Korotayev [9] proposed a model of agrarian societies with major variables being the population, the state, and warfare. Warfare was assumed to be more probable with increasing population densities (more likely for different tribes to interact) and decreased by the level of the state (wanting to maximize productivity). The basis of the state collapse leading to a period of instability is that the states revenues (taxes) increase logistically with population (i.e. $N*(1-N/K)$) however, state

expenditures grow linear with the population. Therefore, above a certain critical population level, the expenditures are greater than the revenues can support. Delays in the system due to accumulation can lead to oscillatory behavior. With simple considerations of parameters, the oscillatory time is expected to be about a couple hundred years. The model was compared favorably with realistic parameters for the historical cases from England (1450-1800), Han and Tang China, and the Roman Empire.

New Sustainable Model

The current transition towards a sustainable civilization where energy and population are balanced, and technological growth may eventually slow. In a historical context, technological society, with its growing dependence on a variety of limited natural resources, requires increasingly more complex organization. The transition to sustainability is complicated by the need to speed innovation to solve current problems without creating overwhelming new ones. If the transition proceeds too slow, the resources will not be concentrated enough and the solutions will not be found. If the transition goes too fast, the unresolved unintended problems will accumulate [9].

A simple systems dynamics model was constructed with a population, whose growth rate is dependent on a resource supply. The population not only consumes the resource but also determines, - through research and development - how fast the resource regenerates. The research might lead to a regeneration rate larger than the consumption rate, resulting in a stable condition. However, since both the regeneration rate and the consumption rate are proportional to the population, a dynamic race entails. The final state of stability or collapse is determined by how these consumption and research functions depend upon population level. Again, collapse, sustainable, and continued growth scenarios are seen depending on parameter values. Collapse occurs if the development is either too fast or too slow.

Approach to Solutions

One way to approach the question of inter-generational justice is to hypothetically ask what future generations would say if they could. For example, would they support greater development to

create more efficient technologies and reduce poverty, or would they regard development as greater resource consumption waste? Would they rather invest in medical research to reduce potential hazards from pollutants or would they require that air, land, and water resources be cleansed to currently acceptable levels? Would they encourage investment in greater understanding of natural and social processes to reduce the uncertainty before an action is taken, or would they encourage exploratory action while the uncertainties are reduced over a longer period?

But how should we balance our present needs with considerations of future generations? Is it justified, for example, to spend some amount now (on research, consumption, or development) that may put later generations in debt? And what contributions towards those decisions should come from distributed markets and collective organizations (e.g., governments)? One ethical approach that might offer viewpoints for considering environmental and technology options is an extension of John Rawls' concept of fairness through the consideration of the 'veil of ignorance'. In his social contract theory, freedoms and inequality are balanced by considering how a person would choose rules from behind a 'veil of ignorance', that is, as if they have no idea who or what they will be when they enter society. This approach was extended to include inter-generational justice [11] by considering a hypothetical person who would set rules before knowing the specific time period and location in which he or she would live, that is, if an individual did not know what time period he or she would be alive, how would they arrange for a just system of technology development with its inequalities, problems, benefits, and risks? From this perspective, the rule setter might recognize that very rapid technology development would lead to greater disparity and unresolved unintended consequences. However, technology development that experiences hinderence would slow the spread of development and not solve previous environmental issues.

This inter-generational criterion is complicated by uncertainty. For example, how much information would a hypothetical observer have about the state of the future? One historical strategy to reduce future risk is the formation of insurance mechanisms. For example, ...The formation of

civilizations relied on the state to maintain backup supplies of food in case of a bad harvest. Another example is the formation of incorporated organizations for commerce which allowed large risky projects to fuel the industrial revolution.

Insurance in the current epoch might include maintaining options while continually reviewing and assessing technologies. For example, consider the potential investment in energy technologies [12]. Each energy technology has a portfolio of various risks and benefits. The risks include loss of financial investments, potential misuses, pollution control, long-term sustainability, short-term variability and potential accidents.

Conclusion

Four models of societies have been explored with attention to their assumptions concerning technology, the environment, the historical context, and potential lessons. The table below summarizes and compares these model characteristics.

Model	Technology Assumption	Historical Context	Potential Lessons
Wonderland Scenario Generator	Continuous improvement in reducing pollution impacts	Considers developing and developed world with potential environmental policy levers	Increase diffusion of environmental technology and assess using model robustness under uncertainty
Human and Nature Dynamics (HANDY)	Neutral (technology changes but causes equal efficiency and consumption impacts)	Historical modes of collapse including nature exhaustion and scarcity of labor	Watch for wealth inequality and delays between behavior and impact
Turchin and Korotayev	Although an agrarian society model, the economic returns to the state from the population is a general technological concern	Agrarian cycles of population, state control, and war. Compared favorably with medieval England and Han and Tang China	Watch for state return as population grows past optimum level based on technology
New sustainable system dynamics	Rate of progress needs to be balanced to focus development without too much depletion	Balanced route to sustainability	Foresight and insurance mechanisms may facilitate balance

An integrated foresight system [10,13] can be viewed as encompassing (1) historical context; (2) information processing to gather, interpret, and communicate the current status; (3) modeling to gain understanding and predict policy results; (4) engineering and designing alternatives to help reach goals; and (5) tools to help balance future and current needs under large uncertainties.

Note:

The four models have been constructed in an Excel workbook for educational purposes in exploring relationships and scenarios. It can be found at: <https://sites.google.com/site/davidlepoire/papers>.

References and Notes

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