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Using Systems Thinking to Understand and Enlarge Mental Models: Helping the Transition to a Sustainable World

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Abstract: Sustainability and climate change are massive global problems that stem from the industrial world's relentless pursuit of growth. Transitioning to a sustainable world requires understanding citizen mental models and our addiction to short-term rewards. This paper uses causal loop diagramming (CLD) to describe the general, prevailing citizen viewpoint and to propose a wider mental model that takes the natural world and sustainability into account. The corporate profit model that depicts the wider view acknowledges and describes the important impacts and influences of political pressure on our social, economic, and ecological systems. Adopting the wider mental model can help the industrialized world design better policy to achieve both national and United Nations (UN) sustainable development goals.

Keywords: sustainability; systems thinking; UN sustainable development goals; mental models; neoliberalism; ecological economics

1. Introduction: The Nature of the Sustainability Problem

In 1972, a team from the Massachusetts Institute of Technology (MIT) developed a world (computer) model and published a report to the Club of Rome, titled the "Limits to Growth" [1]. The report linked the world economic system with the state of our natural world. The main message from the report is that economic growth and material consumption cannot continue infinitely on a finite planet.

The world model was initially heavily criticized since it conflicted with the growth mindset and predominant worldview. A number of criticisms falsely claimed that the model predicted resource depletion and world collapse by the end of the 20th century. "Limits to Growth" did not make that claim. However, a recent empirical study did find that actual data very closely follow the "standard run" scenario of the world model and that we are in fact on an unsustainable trajectory unless there is substantial and rapid reduction in consumption coupled with technological progress [2].

Environmental Impacts

Environmental impact is defined as increases in use of resources (renewable and non-renewable) and degradation of the environment (land, water, air, and resources). The classic IPAT formula defines environmental impact as arising from the interaction of 3 major factors [3,4]:

$$I = P \times A \times T \text{ (IPAT)} \quad (1)$$

where I = environmental impact, P = population, A = affluence, and T = technology.

The use of the IPAT formula typically involves examining a specific impact, such as resource use (e.g., oil), from a source, with affluence represented by gross domestic product (GDP):

$$I = P\ (\cancel{\text{people}}) \times A\ (\cancel{\text{GDP}}/\cancel{\text{people}}) \times T\ (\text{billions of barrels}/\cancel{\text{GDP}}) \quad (2)$$

With resulting impact in terms of billions of barrels used [5].

Alternatively, another specific impact could be the result of human activity, i.e., dumping a waste or by-product into an environmental sink, such as CO_2 output to be absorbed by various sinks (ocean, atmosphere, rainforest):

$$I = P\ (\cancel{\text{people}}) \times A\ (\cancel{\text{GDP}}/\cancel{\text{people}}) \times T\ (10^6\ \text{metric tons}\ CO_2/\cancel{\text{GDP}}) \quad (3)$$

With resulting impact in terms of 10^6 metric tons CO_2 produced [5].

In both cases, i.e., excessive CO_2 output to the atmosphere (sink) or excessive use of resources like oil (source), the human system is generating these problems because of exponential growth in affluence (GDP) and population [1].

These environmental impacts contribute to unsustainability. Sustainability means (1) achieving reasonable rates of usage for renewable resources, such as fisheries or timber, that are less than or equal to their natural regeneration; (2) pollution, garbage, and byproducts of consumption cannot be generated faster than they can decay and be broken-down into harmless components; and (3) in the long-run, we cannot use non-renewables at all [6,7]. Therefore, the IPAT formula serves as a useful framework for understanding sustainability and/or areas where our world is unsustainable.

Unfortunately, as the poor nations of the world struggle with population growth and trying to increase their economic output to help reduce poverty, the rich nations continue to use too many resources in an effort to satisfy competitive consumption and excessive wants [8]. Meanwhile, political systems attempt to satisfy citizens' consumption needs by pushing for more economic growth. It's a political-economic system driven by short-term rewards for politicians, citizens, and corporations [5]. The ability to achieve a global balance in the system does not appear to be easy.

2. The United Nations (UN) and the Sustainable Development Goals

The essence of sustainability is to "live within our means", and global sustainability refers to living within the limits of a finite planet. The concept of sustainable development first became popularized in the 1987 report of the World Commission on Environment and Development, Our Common Future [9]. The report reinforced the "Limits to Growth" and again brought into public consciousness a crucial concern—that global economic growth must be reconciled with the reality of limited natural resources and the dangers of environmental degradation. The report defined sustainable development as:

> *. . . Development that meets the needs of the present without compromising the ability of future generations to meet their own needs* [9].

Implicit within the 1987 UN statement is the distinction between "the needs of the present" (a short-run focus) and "without compromising the abilities of future generations" (a long-run focus). This is an important distinction because of the fundamental worse-before-better (or better-before-worse) system property that "a policy that seems better in the short run is almost always worse in the long run" [10] (p. 365). Examples of this system property include normal business investments that increase short-run expenses but lead to long-run profit, or conservative quota policy in fisheries that restricts the catch and profit in the short run, allowing the fish stock to build back up and eventually leading to better long-run profit [11]. In essence, good policy aimed at long-run outcomes generally requires some short-run sacrifice.

Since 1987, many corporations, non-governmental organizations (NGOs) and governments have set sustainability goals, but global progress on sustainability has been limited. On 25 September 2015 the United Nations adopted a set of sustainable development goals (see [12]). The sustainable development agenda aims to end poverty, protect the planet, and ensure prosperity for all (equality). Unfortunately, as the world currently operates, these goals are almost certainly conflicting.

3. Mental Models

Inadequate mental models have contributed to the structure of our current system, where government has adopted the conflicting goals of: (1) protecting the common good and rights of individuals, and (2) seeking to create employment security and reduced poverty through promoting economic growth [13]. However, as shown in the IPAT formula, increases in GDP through economic growth produce many environmental impacts and depletion of resources, both of which harm future generations. In addition, promotion of economic growth typically comes through policies that reduce corporate taxes and relax government regulations, and these policies often have the adverse effect of increasing wealth disparity [14].

Mental models are cognitive representations of external reality. The notion of a mental model was originally postulated by the psychologist Kenneth Craik [15], who proposed that people carry in their minds a small-scale model of how the world works. These models are used to anticipate events, reason, and form explanations [16].

When examining global sustainability and climate change, mental models of economic variables are of particular importance. The number of variables considered and the boundary of the mental models used in the economic domain depend on one's world view. One view provided by many standard economic textbooks shows the circular flow of the economy as a closed system where interactions with the natural world are largely ignored [17]. This naturally leads to a restricted mental model; one that does not consider environmental limits.

This closed world view promotes the following ideas: resource extraction can continue indefinitely, and if any resources do become scarce, then the free market will simply use technology and substitution to allow economic growth to continue [18]. Figure 1 compares and contrasts the traditional economic model, economic imperialism (1A), with the ecological economics or steady-state subsystem (1B). In Figure 1a (economic imperialism), the arrows represent the idea that the economic subsystem can expand until it encompasses the whole ecosystem. In this view, the entire system is conceptualized as the macro-economy, including the ecosystem. Everything in the ecosystem is theoretically considered comparable in terms of its ability to help or hinder people in satisfying their wants [17]. Economic imperialism assumes that everything can be priced, and that subjective, individual preferences are taken as the source of all value. Since subjective wants are thought to be infinite in the aggregate, there is the assumption that the economy will grow infinitely in order to satisfy consumers. Such a view promotes the mental model that only economics and economic variables are important. Anthropocentric orientations are focused on human welfare and view the ecological environment as important, but only to the extent that the environment is directly helpful to human needs [19].

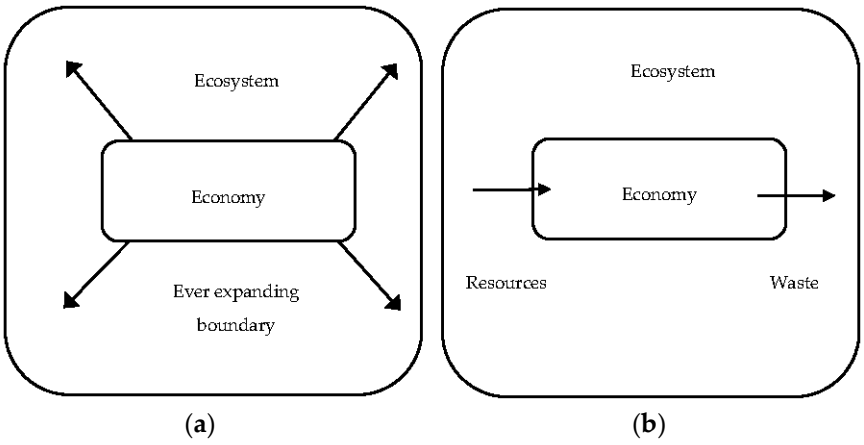

Figure 1. Economic Imperialism versus Steady State Mental Models: (**a**) Economic Imperialism Mental Model; (**b**) Steady State Mental Model.

In contrast, the field of ecological economics is based on the steady-state sub-system view of the human economy. Here, the economy is an open system that exchanges energy and matter with the Earth's ecosystem. The size of the human economy does have some optimal level determined by global society and the ecosystem. In the long run, the human economy must be ecologically sustainable by having the ecosystem maintain and replenish the economic subsystem [17]. A mental model based on this viewpoint naturally incorporates a wider boundary where ecosystem health must be considered with the human economy. The eco-centric orientation argues that nature has an intrinsic value, or a value independent of human interests. This viewpoint is consistent with the environmental sustainability requirement that the integrity of ecosystems be maintained. In essence, this is a long-run and holistic viewpoint as compared with the anthropocentric orientation.

The next section introduces systems thinking as an additional framework that can be used to provide insight into our mental models and to provide an enhanced understanding of the socio-economic variables involved with global sustainability.

4. Systems Thinking and Mental Models: Frameworks to Understand Unsustainability

4.1. Systems Thinking, Interconnection and Focus

Systems thinking tools help us to see the bigger picture and to enlarge our mental models. Enlarging the boundaries of our mental models is critical since decision-making often involves impacts that alter the decision-making environment and ultimately feedback to influence the current situation [20]. Alternatively, if we were to reduce the boundary of the system, we would not eliminate the interconnections that are found in reality. Not recognizing these interconnections in our mental models is a problem causing us to ignore important feedback. This typically leads to decisions that produce "unintended consequences" [20,21].

A more useful and truer picture of our complex systems will show the feedback structure involved. Although systems may involve many hundreds of variables or components variously interconnected, the long-run dynamic behavior of complex systems is generated by the interaction of just two basic types of feedback loops, either reinforcing feedback that increases or amplifies changes, or balancing feedback loops that counteract or oppose change [20]. Appendix A provides an overview of both reinforcing and balancing feedback loops, along with the corresponding causal loop diagrams and behavior-over-time graphs.

When considering the UN Sustainable Development Goals of (1) ending poverty, (2) protecting the planet, and (3) ensuring prosperity for all, we encounter head-on the divergent mental models and world views. The current conventional wisdom is that we need more economic growth to end poverty, produce a larger economic pie to ensure prosperity for all, and to produce the technology necessary to protect the planet [13,18]. On the other hand, the opposite view was concluded from "Limits to Growth," that in fact, economic growth is the cause of these world problems [1,14]. Recent empirical evidence further supports this view that economic growth is the major underlying problem, that economic growth has not been decoupled from consumption-based emissions, but is instead further contributing to climate change [22].

Additionally, although technology can improve resource efficiency, when viewed in a wider context, efficiency gains are often negated by increases in consumption behavior, known as the rebound effect [23].

While technology is indeed necessary to slow the pace of environmental destruction and climate change, the Limits to Growth World 3 model revealed that no set of purely technical changes in any of the computer runs was sufficient to bring about a desirable future. Restructuring social, economic, and political systems was much more effective [14].

4.2. Interconnection and Focus Based on Economic Imperialism

It is impossible to uncover the separate mental models of the millions of individual citizen decision-makers. However, we can narrow our focus to the economic imperialism viewpoint and then examine a subset of important economic variables and their interconnections (Figure 2). In this way, we can then make a comparison with the expanded view based on ecological economics and sustainability.

The bold-faced arrows in Figure 2 show a very narrow and focused view of our socio-economic world and one that we believe a citizen majority use to reason and vote for political leaders. We can state this with a rather high rate of confidence as a majority of political debates and campaigning in the US are centered on jobs and the economy. Climate change and sustainability are virtually never mentioned [24].

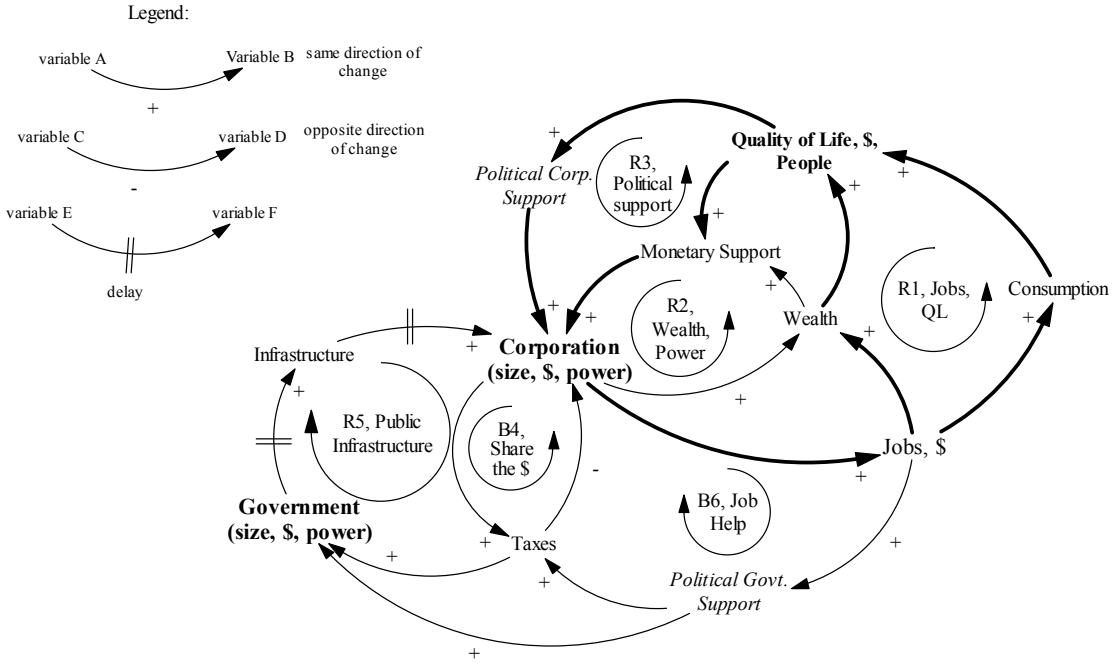

Figure 2. The Prevailing View of Citizens, Jobs and Corporations.

Reading the diagram from the center, as corporations gain size, money and power, this leads to an increase in jobs. The increase in jobs (employment) leads to increases in both consumption and wealth. Increases in consumption and wealth together increase quality of life, as implicitly measured by monetary increases (GDP), ownership increases, and chosen experiences. People then invest money and provide political support for corporations as well. This creates a reinforcing feedback loop that dominates and reinforces our mental models, supporting large companies and the private sector creates growth, jobs, and a higher quality of life for all.

Increases in corporate sector profit will lead to increased tax revenues, loop B4, allowing government to build up infrastructure, which again supports the corporate or private sector. Bold-faced arrows indicate loop dominance. Should job creation be weakened, then a decrease in jobs leads to a decrease in political government support, which then leads to a decrease in taxes and then to an increase in corporations (size, money, power). B6, job help, is a balancing loop, which can counteract any reductions in the ability to reinforce job growth.

Citizen political support is separated into two categories in the model: political corporate support and political government support. Political corporate support represents citizen support for policies that benefit corporations and private sector business. Political government support is citizen support for policies that increase taxes and support for government services and regulation. If citizens are primarily concerned with jobs, political corporate support should dominate political government

support and the corporation (size, money, power) variable should increase relative to government (size, $, power).

Reinforcing loops have a tendency to create exponential growth if left unchecked. The bold-faced, dominant loops in the model indicate an increase in support for corporations and the private sector. If taxes are sufficient from corporate profits, then long-run infrastructure support can help to keep the corporation (size, money, power) variable supporting jobs, consumption, and wealth. However, Figure 2 provides a restricted view of socio-economic variables, and one that does not take into account a wider impact on the natural environment or people.

4.3. The Scarcity Mindset, Focus and Tunnel Vision

In a simple sense, a gap between a desired resource amount and the actual resource level can be considered a problem of scarcity. In this sense, scarcity is a physical constraint. But, scarcity is also a broader concept. A scarcity situation invokes a mental state that captures our attention [25]. When individuals are in a scarcity mindset, they become more attentive, focused, and efficient. In a scarcity situation, whether it is a tight deadline (time scarcity) or a cash shortage, we fall into a scarcity mindset because the situation is important and demands our attention. We realize a short-term benefit from this mental state and perform better on our most pressing concerns. However, a hidden downside to the scarcity mindset is that it also causes us to ignore information outside the tunnel and to neglect other issues [25].

In the case of the prevailing view of citizens (Figure 2), mental models are directed at growing the economy and creating jobs. This is such an important consideration that it captures people's attention and helps to drive the R1, R2, and R3 reinforcing feedback loops and increase corporate influence in the economy. Unfortunately, this is an incomplete, narrow, and short-sighted view.

Figure 3 introduces an expanded view that incorporates impacts on our ecosystem and people, the corporate profit loop. The corporate profit loop shows where our current mental models are dominant (bold-faced loops) and it reveals our shortcomings. In order to transition to a sustainable world, we need to move citizens toward a deeper understanding of how our socio-economic system impacts our wider environment.

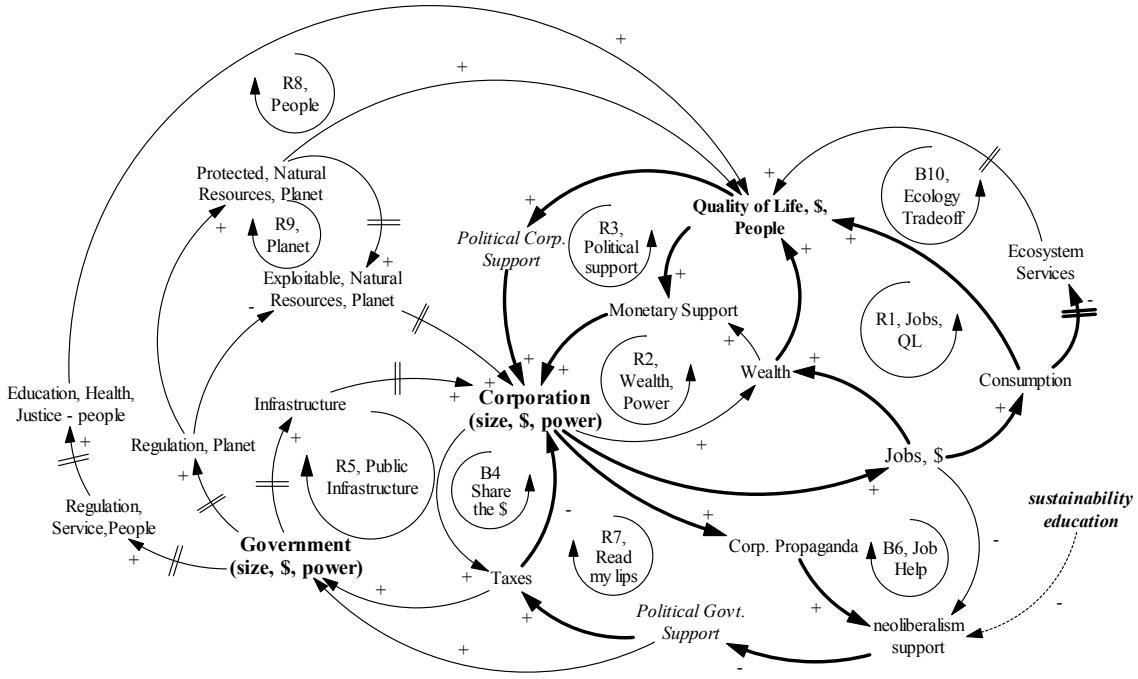

Figure 3. Jobs, Corporations and Power: The Corporate Profit Loop.

5. Expanding Citizen Mental Models: The Corporate Profit Loop

Figure 3 shows the corporate profit loop model, which represents a preferred view and mental model in order to produce a more sustainable world. The corporate profit loop model depicts the interplay between government (size, money, and power) and corporations (size, money, and power). The causal loop diagram represents most of the important known causal impacts involved in this system, but it is important to stress that although a link may indicate causality, it does not indicate what will necessarily happen in such a complex system (Note: dominant links are again shown boldfaced; and the dotted line from sustainability education shows a preferred leverage point). That is, certain causal links may be strong at one time, but weaker at another. Which causal links become dominant depends on both what has happened in the past (i.e., path dependence) and also on what individuals in the system decide to do in the present. That is, social systems are highly dependent on various decisions of individuals within the system.

The "corporate profit loop" model incorporates sustainability thinking, as the three pillars of sustainability are represented throughout, especially: people (as seen in R8, "people" variable), profit (implicitly represented in loops R1 and R2), and planet (R9 and B10).

Another important aspect of the "corporate profit loop" model is that the left portion of the diagram, reinforcing loops R5, R8, and R9, all follow from the public "government size, power, $ variable" and all contain delays. For example, government investment in infrastructure takes time to actually build up roads, bridges, airports, and investments in education, and R&D take time to produce an educated workforce and new knowledge that can lead to improved technologies. Similarly, government can act to protect natural resources, and this can eventually have long-run positive impact on companies (loop R9). For example, fisheries are managed, and stocks remain healthy to produce long-run food supply and jobs. Additionally, non-renewable resources can be used in the short-run to drive economic growth, or they can be conserved (loop R9), for future availability. Government investment is also used to support people directly, through the "Education, Health, Justice-people" variable and R8 People loop. This variable is used to broadly denote the work of government to promote the physical (health care) and financial health of citizens (transfer payments). Obviously, not all details of government can be shown, but the major benefits are summarized. The costs are shown in the form of taxes and represent the costs to the private sector, loop B4.

Delays in the model are significant because outcomes are not achieved quickly, and instead, causal forces may unfold quietly over time and significantly impact long-run behavior.

Naturally, the model can also operate with the left-hand portion dominating. In this case, taxes can be overwhelming and can stifle corporations. This is a dangerous condition because the free market drives employment, wealth creation, and quality of life (as measured by GDP). In addition, as consumption is reduced and corporations lose profits, tax inflows are reduced, which also weakens government and further reduces quality of life. This can behave as a vicious reinforcing feedback loop as lower levels of employment also lead to further citizen dependence on a weakened government.

Reflecting the current citizen mental models, the bold-faced loops in the right section of Figure 3 are shown dominant because of short-termism behavior. Corporations must generate profits and increase shareholder wealth and this puts great pressure on short-term financial results.

5.1. Neoliberalism

Given the almost universal appeal for economic growth and citizen expectations that government should support job creation, reduce poverty and provide more public services, it is not surprising that the pro-growth, neoliberalism ideology has become more widely adopted by governments and policy makers. Neoliberalism is an ideology that strongly emphasizes economic growth as the single most important objective while depicting government as an obstructive force impeding the free market [26–28]. Specifically, neoliberalism supports many policy measures to promote the free market, including massive tax cuts (especially for businesses and high-income earners); reduction of social services and welfare programs, downsizing government, anti-unionization measures, removal

of controls of global financial and trade flows, and the creation of new political institutions, think tanks, and practices designed to reproduce the neoliberal paradigm, among others [28]. The variable neoliberalism support is shown as a significant leverage point in the Corporate Profit Loop model and it represents the degree of support for this paradigm. Higher neoliberalism in the model leads to less government support, lower taxes, higher corporate propaganda (promotion of the neoliberalism paradigm), and higher corporate power, and thus, increased job support.

The corporate profit loop model illustrates that as corporations become more powerful, they reinforce neoliberalism and citizen mental models through propaganda efforts that contribute to the growth mindset. Corporate influence can be dangerous because political leaders will feel compelled to support policy that favors short-run corporate interests. Further, citizen support adds to the likelihood that government policy will be aimed at short-run business concerns over the common good.

5.2. The Anthropocene: A New World Created from Human Values, Viewpoints and Narrow Focus

Anthropocentric orientations, together with economic imperialism, can be viewed as a positive force that have generated tremendous wealth for human society. However, this wealth has come at a cost. Externalities from the economic imperialism viewpoint have resulted in extreme changes in biodiversity, habitat and biomass loss, and climate change [29]. The changes are so great that many scientists are now referring to these human impacts as a new geological age—the Anthropocene. Of course, people who view humanity as isolated from nature tend to have a very different value system and may hold a completely distinct set of goals and objectives for society from those with an eco-centric orientation.

Human values can thus have a dramatic impact on the objectives and directions chosen by society. An overly narrow focus on economic imperialism, for example, means that citizens place greater emphasis on gross domestic product (GDP) over sustainable development goals such as conservation of the natural world, economic equality, and social justice.

Historical analysis reveals that resources are consistently and inevitably over-exploited primarily because wealth and its pursuit generates political and social power that is used to exploit the resource [30]. This situation is graphically depicted by the imbalance portrayed in the corporate profit loop and the dominance of feedback that reinforces corporate size, money and power. The further this growth mindset plays out in the global scene as competition among countries, the more industries move to locations with lower cost structures. In essence, we get a standards-lowering competition with increasingly lower labor and environmental regulation [5,6]. Lower costs mean the ability to price lower and further drive growth. More growth, especially in physical products, further drives unsustainability.

The power of global corporations and neoliberalism has created a power imbalance in the world, allowing tremendous bargaining power to corporations, enabling lower cost production for industrialized countries while not necessarily helping poorer countries rise out of poverty [31]. The term neocolonialism has evolved to describe the economic power imbalance [32]. Neocolonialism is also in obvious direct conflict with the UN sustainable development goals.

Poverty in the developing world creates additional problems for sustainability. Indigenous farmers in the developing world often slash and burn rain forest and prime habitat in order to increase their acreage and boost income [33]. Meanwhile, large multi-national corporations such as Monsanto, Dupont, Syngenta, BASF and Dow promote industrial, mono-culture farming practices. The stated idea is to increase agricultural productivity in an effort to help with world hunger. However, such practices require increases in pesticides, herbicides, fertilizer, and water. Adopting these techniques in the developing world is expensive for farmers, who must purchase genetically engineered seeds and additional fertilizer while profits return to the large corporations [34].

The long-run prospects for industrial agriculture are also loaded with risk. Climate change makes farming far riskier as it increases the likelihood of extreme weather along with the potential for pest damage. A far simpler way to handle adverse conditions is to use traditional farming methods.

Agro-ecological farming uses traditional seed and diverse crops for resilience and climate adaptation. This approach has added benefits such as reduced pollution (less fertilizer), reduced costs, and fewer side effects, such as pesticide poisoning of bees and beneficial insects [34,35].

5.3. Lock-In and Deadlock

We cannot expect the free market to develop products and services fast enough to solve our global environmental problems and especially climate change [36]. The primary reason for this is short-termism on the part of citizens, politicians, shareholders, and business owners—all of us. Short-termism can be thought of as a built-in part of capitalism. Specifically, most firms are not in a position to postpone short-term profitability for higher, but time-delayed profits later. Only the government can afford to make many of the larger, riskier and time-delayed investments necessary to combat climate change [36].

Thus, neoliberalism has emerged as an ideology at direct odds with global sustainability and climate change [26,27]. Figure 4 depicts the situation where consumers in the market economy are unable to purchase "green products" due to deadlock or lock-in.

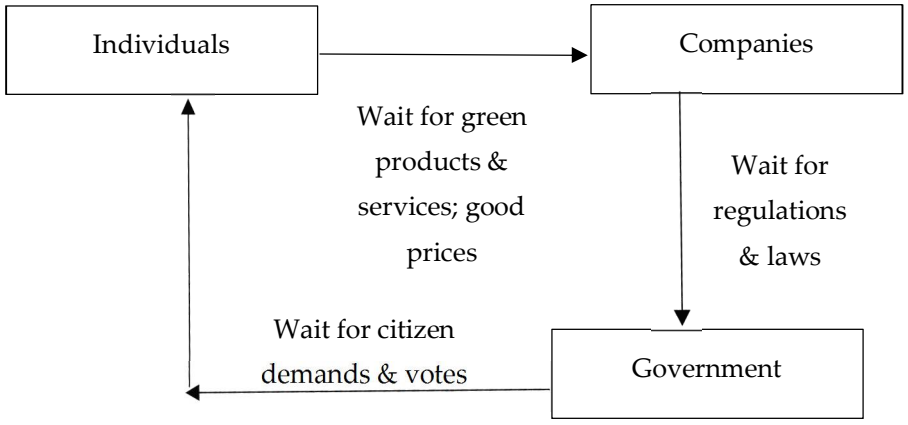

Figure 4. Lock-in and Deadlock: Actors in the Global Sustainability System Exhibiting Diffused Responsibility.

Lock-in occurs in the following way: companies are reluctant to produce green products (e.g., electric or hybrid cars, solar panels) without sufficient demand from consumers. Consumers are reluctant to buy green products because the prices are too high; but prices are too high because production volume is insufficient, a vicious loop [5]. Cutting-edge companies look to government to initiate regulation, but government will not act in democratic societies without substantial support from the public, and legislation that hinders one group will be resisted, even if it benefits the majority [36]. Ultimately, responsibility lies with us—citizens, voters, consumers, and employees. However, realizing the wider system view brings to light the especially important role for citizens/voters in democratic societies, and this is where our deadlock really resides.

Finally, just as the lack of environmental regulation causes a lock-in effect with status quo products, the inability to correctly price energy and incorporate a carbon tax can also be directly linked to citizen votes. Once again, neoliberalism ideology and propaganda influence citizen mental models. Political interference means information feedback (via price signals) is lost as social costs are not incorporated into energy prices. In essence, stressing the free market and economic growth as the answer to our problems causes traditional economic corrections to be rendered ineffective.

The way out of this trap is to first see that we are in an addictive cycle. The Corporate Profit Loop is another portrayal of "the loop you can't get out of" [5,37]. A basic problem is that we are all enticed by immediate rewards (short-run results) and most of our systems are predicated on short-run feedback, including the stock market, quarterly profits, political elections, and consumerism (pursuit

of novelty). Once we start down this path (the right-hand side of Figure 3), the system rewards corporations with more money and power to influence the political system and consumer society. Corporate propaganda drives ideological support for neoliberalism. Since corporations influence the political system, neoliberalism creates a reinforcing feedback loop. The more this dynamic operates, the more influential corporations become relative to government. The underlying problem is that the real, physical world does not operate under an economic imperialism model, but we do have limits within a finite planet, and it is becoming increasingly clear that we are living beyond our means and outside of the safe operating space for humanity [2,29]. Eventually, resources become eroded (See Figure 3; R9, Planet Loop) and the balancing loop, B10 Ecology Tradeoff, will also become dominant. Finally, ecosystem services and environmental degradation will reduce our quality of life.

6. Competitive Strategy and Making the Transition to Sustainability

Currently, our mental models remain fixated on the dominant loops in the right-hand portion of the Corporate Profit Loop. This is a dangerous position as corporations have tremendous power to influence government policy and to promote short-termism. Rather than realizing the necessity to transition to renewable energy, policy is used to favor status-quo companies and to keep fossil fuel subsidized. Not realizing or accepting that disruptive technologies are coming does frequently happen in the private sector (e.g., with Eastman Kodak and digital photography [38]). When this occurs in the private sector, it is largely due to the management dogma of listening to customers and shareholders, that is, focusing on short-run concerns [39]. Disruption in the private sector is limited. However, when it occurs on a grand scale, such as with a country's energy supply, the economic impacts can be substantial. Currently, China has plans to invest $360 billion dollars in renewable energy by 2020 [40]. Furthermore, Germany is getting one third of their energy needs right now through renewables [41]. The United States energy policy could thus be putting US companies and the economy at a substantial disadvantage. First-mover advantages can be extremely beneficial for green technologies and products because of learning curve effects [42] (p. 215) and the typically large initial investments required. This is where balancing the Corporate Profit Loop can be beneficial to the economy while simultaneously advancing green initiatives and helping to achieve the UN Sustainable Development goals. Making this happen, however, requires citizen buy-in to break the current deadlock or lock-in.

Unlocking the Freedom of Markets and Government with Systems Thinking and Ecological Regulation

The current world view of US citizens is focused on the high volume, neoliberalism of the right-hand side of the corporate profit loop. While reduced regulation by outsourcing production has helped to keep costs low in the past, this approach is dependent on global consumer and citizen thinking. This is changing. That is, as people's thinking evolves to a "greener" mindset more and more of the global market will be dominated by renewable energy, green products, and innovative services. We know this will happen because we know we are pushing up against more limits. The sooner industrialized countries adopt more stringent environmental and labor regulations, the faster cutting-edge companies can plan, invest, and support innovations [43]. Designing products and services for the strictest regulations will actually streamline manufacturing and logistics and save costs because multiple product versions will not be necessary for international markets [43]. Thus, regulations and economic nudges will be critical to help develop new disruptive technology.

Newer market-based incentives hold great promise for providing the right environment for environmental innovations and technologies [44]. First, a broad natural capital depletion tax could be used to ensure that resource use is sustainable while also providing incentives for new technology development (applicable to Loop R9, Planet in Figure 3). Second, the adoption of a flexible environmental assurance bonding system can be used; this is where an estimate of the largest potential environmental damage is used to purchase a bond, kept in an interest-bearing escrow account, to offset the potential of a catastrophic future effect. This approach is consistent with the precautionary principle, and it requires committing resources in the present. Again, such an approach would

encourage technology innovation as the burden of proof, and cost of uncertainty is shifted from the public to the resource user (applicable to Loop B10, Ecology Tradeoff in Figure 3). Finally, the use of ecological tariffs could be used to "level the playing field" for those countries that do not adopt these market-based incentives. In fact, given recent global commitments and UN sustainable development goals, such ecological tariffs could be politically possible [44] (pp. 247–256).

Therefore, sustainability education is vitally important because it can inform citizens who must vote and pressure policy makers to create the most responsible business climate for sustainable innovation. Sustainability issues are extremely complex because they are embedded in a global web of systems, political processes and dynamic interactions [45]. Systems education is a necessary and ideal complement to sustainability because tools like stock-and-flow diagramming and computer simulation can contribute to a better understanding of sustainable business and socio-economic-political systems.

Over-focus on only one part of the corporate profit loop can lead to excessive exploitation of people and planet. This narrow range of concern or focus can be rationalized, but this type of rationalization can more accurately be portrayed as bounded rationality. Liberal arts education that opens minds to concerns beyond short-term profits and economics can be beneficial. Rationality that is more open to different views, cultures, feminism, and the natural world can develop a more just and equal society [46]. In fact, the rationality and value system that focuses on and seeks endless economic growth is at the heart of our multiple crises of ecological destruction; economic, gender, and racial inequality; and poverty [47,48]. Indeed, corporations that can open up from just a shareholder profitability perspective to a wider concern for all stakeholders will have reduced risks and better prospects for sustained profits [49]. A sustainable world requires an equitable distribution of wealth and resources [33]. We cannot expect the poor in the developing world to go without food, nor can we expect the poor in industrialized countries to be able to afford green products and energy while the rich use up excessive resources.

Education that opens citizens' mental models and expands the boundary of their thinking will help to reveal important feedbacks and long-run dynamic behavior. The corporate profit loop model is a fairly concise and simple model that reveals where our current citizen mental models fall short. Sustainability education, coupled with systems thinking and system dynamics, can inform citizens and help us rebalance the corporate profit loop.

7. Conclusions

This paper has proposed the corporate profit model as an expanded view of the important variables from the economic, social, political, and ecological systems that interact with and impact our ability to achieve a sustainable world. In particular, corporate power is shown to be a primary cause of political influence, policy formation, and perpetuation of neoliberalism. Corporations have often co-opted or appropriated the language of environmental citizenship and have positioned themselves as ideal environmental citizens, all the while driving their companies and customers to be unsustainable over-consumers [50].

Enhancing citizen mental models is necessary for the implementation of good public policy and market-based incentives to promote global sustainability. Moving citizen understanding from narrow conceptions of the economy to a wider view is an essential first step. Fortunately, ecological-economic precautionary policy instruments exist and show promise to halt our ecological crises.

Neoliberalism and excessive focus on economic growth are actually hindering both our long-run prosperity and our ability to make progress on the UN Sustainable Development Goals. Our system of defining public policy has deep flaws. Our policies are based on short-run pressures that inevitably produce long-run failure [10]. Pushing economic growth, especially using neoliberalism tactics, is a short-run strategy. Complex non-linear feedback systems exhibit better-before-worse dynamics [10]. In the long-run, our market economy will inevitably become more focused on green products and technology, especially renewable energy. This is because we are increasingly pushing up against ecological or planetary limits. Pushing for more economic growth using neoliberalism actually hinders

our economy in two ways: (1) Over consumption of material goods produced with fossil fuel energy harms our ecosystems and is beginning to cost the economy more than the benefits we receive [6] (see Figure 3, B9, Ecology Tradeoff); and (2) the neoliberalism focus on the right-hand side of the Corporate Profit Loop is a reinforcing feedback loop, and it diminishes the ability of government to protect our long-run, common good interests (e.g., protecting and conserving natural resources, maintaining and building infrastructure, initiating sustainable business support and protecting the rights of individuals).

Corporations influence much of the public policy formation in the US democratic system. Powerful lobbying is largely a function of money and resources, and US corporations are able to have their voices or free speech heard. Although long-run policy issues like global sustainability and climate change are important for the general public, large corporations that are tied to the fossil fuel economy are making more profits now by focusing on short-run concerns.

The ability to increase our quality of life, reduce our environmental impacts, reduce poverty, and increase economic equality all require restoring a balance in the Corporate Profit Loop.

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Appendix A. Understanding Reinforcing and Balancing Feedback Loops

A behavior over time graph and a causal loop diagram (CLD) of reinforcing feedback are shown in Figure A1. A reinforcing feedback relationship produces an exponential growth pattern. The causal loop diagram illustrates that a *higher* amount of births leads to a *higher* population, and a *higher* population (increase) also leads to *higher* births (increase) (i.e., the '+' symbol indicates the same direction of change). Such a graph over time can be generated from all reinforcing feedback loops: for example, the higher the amount on deposit in the savings account will lead to higher interest income that adds to a higher bank balance. Reinforcing feedback loops can also operate to produce a decay pattern over time. If a population is declining due to greater predation, hunting or fishing (or other influences), then a lower population level leads to a lower net birth rate. Thus, a *decrease* in births leads to a *decrease* in the population (i.e., the '+' symbol indicates the same direction of change), which then leads back to a *decrease* in births.

Naturally, rabbits (or any population) do not generate infinite or astronomical population levels, as shown in Figure A1. Eventually limits are reached. In Figure A2, the reinforcing loop, R1, generates rapid growth in the rabbit population in the beginning, but the balancing loops, B2, and B3 and B4, begin to dominate as the population pushes up against the carrying capacity of the environment (note: the || delay mark between population and resource adequacy in Figure A2, causal loop diagram b; and the '–' symbol indicates the opposite direction of change, so as the population *increases*, the resource adequacy *decreases*. The reverse would also be true: if the population was *decreasing*, then the resource adequacy would be *increasing*). When resources decrease and the balancing feedback loops dominate, we observe the common S-shaped behavior-over-time graph. This pattern is quite common in many natural populations since there are often many limiting factors to place a check on runaway (exponential) population growth.

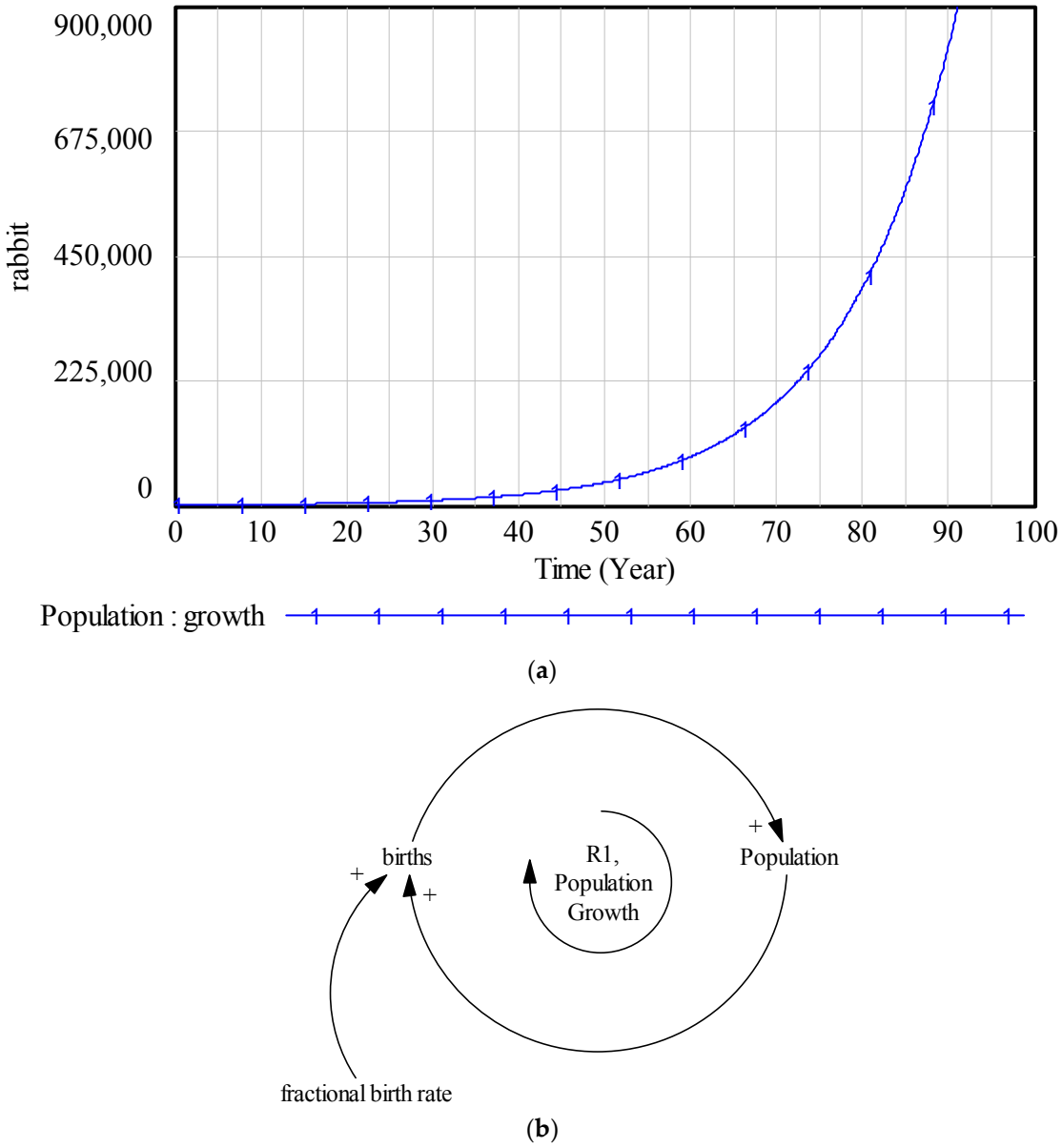

Figure A1. Graph and Causal Loop Diagram of Reinforcing Feedback. (**a**) Rabbit Population Graph, Behavior over Time of Reinforcing Feedback. (**b**) Causal Loop Diagram (CLD) of Reinforcing Feedback.

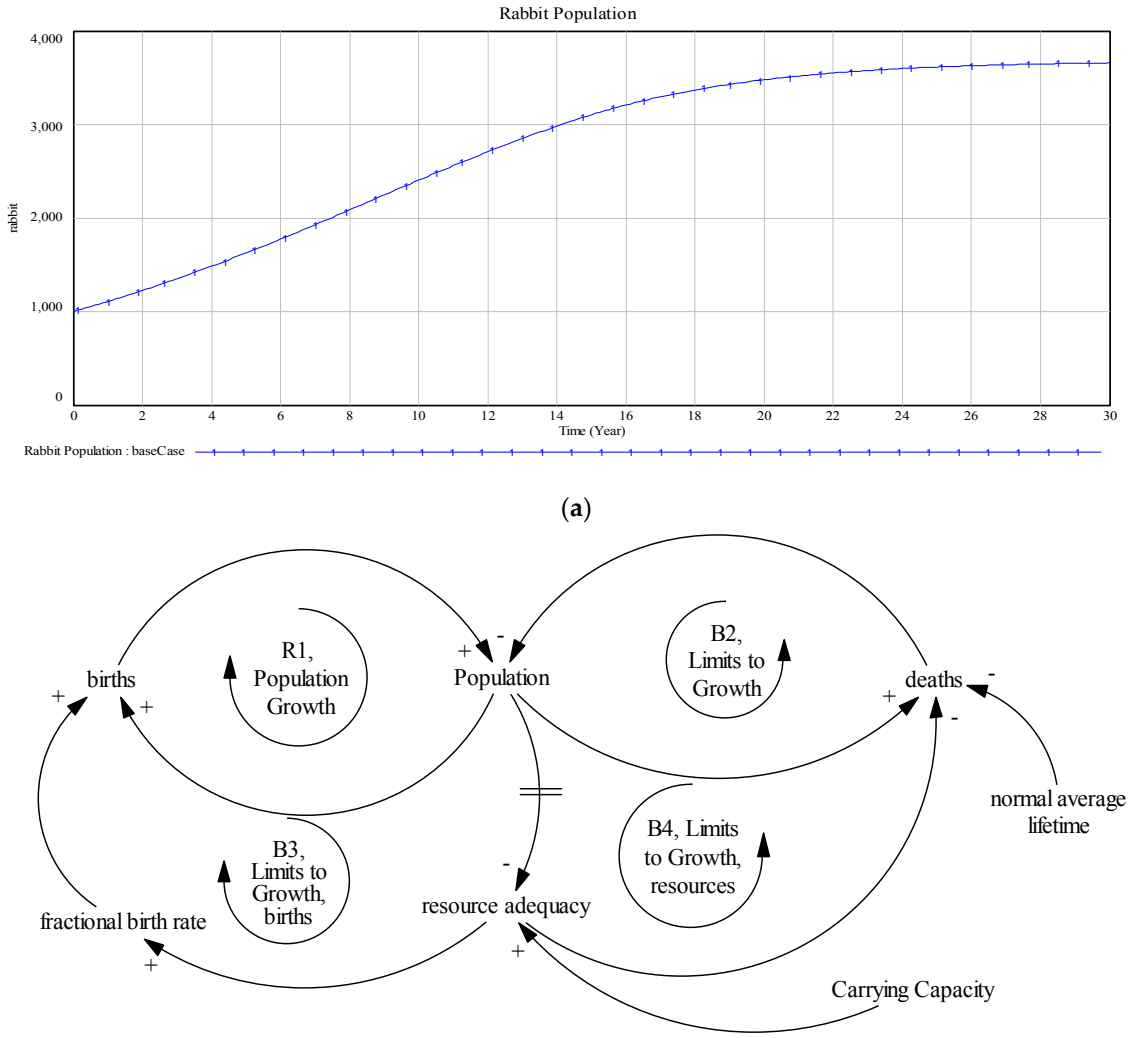

Figure A2. Graph and Causal Loop Diagram of Reinforcing and Balancing Feedback. (**a**) Rabbit Population and Behavior-over-Time Graph. (**b**) Causal Loop Diagram of both Reinforcing and Balancing Feedback, Rabbit Population.

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