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TRANSFORMING BUSINESS EDUCATION
It's about Time: A Systems Perspective on Incorporating Climate Change, Sustainability, and the Care for Our Common Future

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ABSTRACT

In this paper we define the nature of the climate change problem and we analyze the task of getting human society to act quickly enough and appropriately to solve this global crisis. We show how our current citizen mental models keep us locked into fossil fuels and prevent us from acting. We demonstrate how simple system dynamics models provide the necessary insight, expand the boundaries of our mental models, and give us the understanding to redesign how our business and governing systems work. We suggest transforming business education using these insights as the key to appropriate climate change action and setting us on the road to a prosperous and sustainable future.

KEYWORDS

Climate change; sustainability; system dynamics; short-termism

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INTRODUCTION

Our world has surpassed many ecological, planetary limits and is currently in a state of overshoot, living beyond our means (Rockström et al., 2009a, 2009b; IPCC, 2021). Systems cannot remain in a state of overshoot of the environment indefinitely. Either the human community finds ways to reduce our ecological footprint or nature will force the human economy back toward sustainable levels through sudden changes or catastrophic means (Meadows, Meadows, Randers, & Behrens, 1972; Meadows, Randers, & Meadows, 2004). The most serious limit that affects most of life on Earth and that must be addressed most urgently is climate change.

In this paper we define the nature of the climate change problem and we analyze the task of getting human society to act quickly enough and appropriately to solve this global crisis. We use a systems perspective to analyze how society takes in scientific information and acts to solve major problems. We take a high-level view of capitalism, markets, information flow, democracy, and citizen mental models. We show how citizen thinking based on constrained mental models keeps society reliant on fossil fuels and prevents fast action to tackle climate change.

Our current problem solving is stuck in an addictive pattern of short-termism. In this paper we show that education, especially business education infused with systems thinking, can help citizens update their mental models, see the bigger-picture, and put all of us on a path to solving climate change and to achieving more sustainable living and prosperity.

CLIMATE CHANGE: THE CRITICAL LIMIT THAT MUST BE ADDRESSED IMMEDIATELY

In his message to the United Nations Framework Convention on Climate Change, his Holiness Pope Francis said:

> The Paris Agreement has traced a clear path on which the entire international community is called to engage; the COP22 represents a central stage in this journey. It affects all humanity, especially the poorest and the future generations, who represent the most vulnerable component of the troubling impact of climate change and call us to the grave ethical and moral responsibility to

> act without delay, in a manner as free as possible from political and economic pressures, setting aside particular interests and behavior. (Francis, 2016)

Achieving the goals of the Paris Climate Agreement requires transformation to carbon-neutral societies within the next 30 years (Otto et al., 2020). The magnitude of the problem can be understood by computing a budget for CO_2 emissions indicating the maximum amount that can be released before the Paris Agreement's temperature target of 1.5°C is reached (Figureres, Schellnhuber, Whiteman, Rockstrom, Hobley, & Rahmstorf, 2017). Figure 1 portrays the harsh reality of the necessary and dramatic reductions that are required to keep climate change from crossing perilous tipping points in the Earth's climate system.

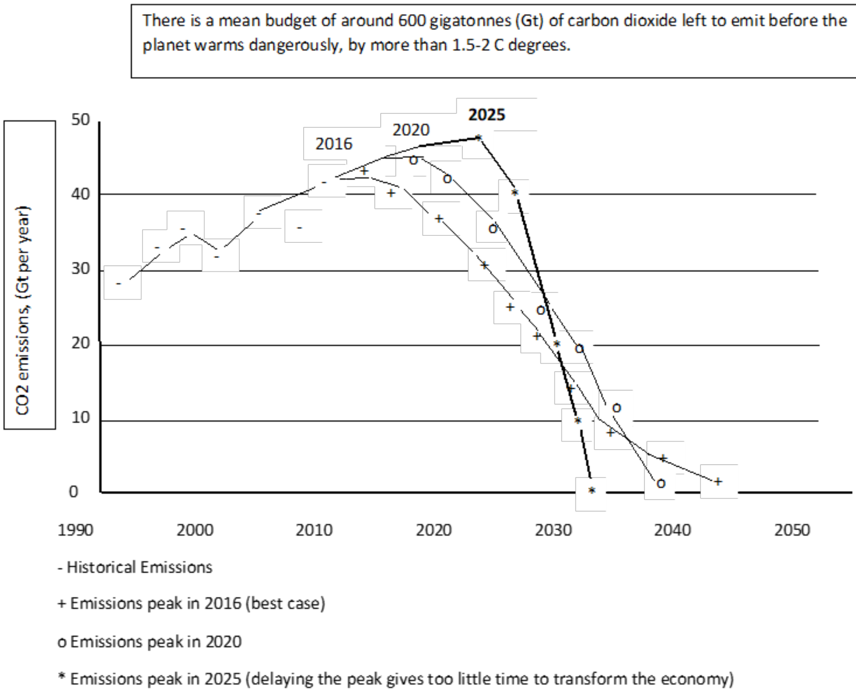

Figure 1: The Carbon Budget and Rates Required to Transform the Economy (adapted from Figureres et al., 2017)

Fortunately, the fossil-free energy alternatives are already cost-effective relative to coal and oil. However, there are signs that greenhouse gas emissions require considerable work to be decoupled from the economy. In 2020, US CO_2 emissions fell by 10.3%, but in 2021 emissions rebounded by 6.2% (Osaka, 2022). Recent evidence suggests that each unit of energy from non-fossil fuel sources only substitutes for approximately one quarter of fossil fuel energy use (York, 2012). Policy resistance within the system means that actors often change their behavior relative to new policy (Sterman, 2000; Garrity, 2012). For example, as resource efficiency increases, net prices drop and users respond by consuming more of the resource, thus offsetting efficiency gains (Jevons, 1866, 2001). This suggests that a range of policy initiatives will be necessary to fully realize net reductions in fossil fuel use.

Changes in public policy to combat climate change require citizen involvement in democratic societies. However, simple policy changes such as enacting a carbon tax have been met with strong political resistance. In principle, policies, and nudges to the market through environmental-economic tactics such as regulation, carbon taxes, and other incentives can stimulate businesses to develop alternatives and new technologies to combat climate change. Unfortunately, citizens in democratic societies are addicted to short-term rewards (Randers, 2012a, 2012b). How can we get citizens to consider and prioritize long-term goals?

CAPITALISM, DEMOCRACY, AND SHORT-TERMISM

Businesses in market economies are necessarily focused on short-term results for a number of reasons. First, managers act as agents of owners and must consider the goals of shareholders. Second, investments with long payback time are problematic because companies must make profits to stay in the market. Essentially, too much short-term sacrifice with delayed earnings can cause companies to crash. On the other hand, companies routinely make investments to seek efficiency improvements:

> There are a number of well-known causal factors that help make up a common mental model of consumption, production, and technology. For example, it is conventional wisdom that businesses should reinvest profits into the business and deploy technology to make operations more efficient. Increased specialization from technology and scale economies will cause lower variable expenses. Lower variable expenses then enable lower, competitive pricing strategies. In addition, companies seek increased size and specialization from growth in order to provide leverage for increased innovation. More innovation allows for new products and product improvements (higher quality) that lead to competitive advantages in the marketplace. Each of these business actions drives higher volume which then feeds the reinforcing feedback loop to higher profits. Higher profits can then be used to drive further investments. (Garrity, 2012: 2456).

Businesses are thus in a relentless pursuit of growth (Forrester, 2009). However, in the long run, physical growth cannot continue forever on a finite planet (Meadows et al., 1972, 2004). Unfortunately, while some business growth can be beneficial for mankind, excessive overemphasis on growth adds to the problem of climate change.

MARKET FUNDAMENTALISM AND NEOLIBERALISM

Market fundamentalism consists of two primary components. First, the belief is that societies' needs are best met in a market system where sellers produce products or solutions that meet the needs of buyers. The market design results in an efficient, self-organized system. The second component of market fundamentalism, referred to as neoliberalism, is the notion that markets represent distributed power. Neoliberalism (i.e., the liberty dimension used here refers to the freedom of markets) is the belief that markets are *the only way* to satisfy needs without harming personal freedom (Oreskes & Conway, 2014).

There is almost universal appeal for more economic growth to support job creation. Because of this predominant belief, citizens expect government to act in their benefit and assume the role of providing market support for growth (Garrity, 2018). At the same time however, the neoliberalism ideology also views government as an obstructive force impeding the free market (Oreskes & Conway, 2010; Steger & Roy, 2010). Neoliberalism ideology supports many policy measures such as massive tax cuts (especially for businesses and high-income individuals), reduction of social services and welfare programs, the downsizing of government, anti-unionization measures, deregulation of markets, and the creation of new political institutions and think tanks that help promote this mindset (Steger & Roy, 2010). As these beliefs are diffused throughout society, citizens vote for political leaders who support this viewpoint, since this appears to be in their best interests. Large successful corporations also help to further this viewpoint by pushing information and lobbying for favorable tax breaks and support for large status quo industries. However, direct support for the market often comes at the expense of government support (Garrity, 2018). This creates a system that satisfies short-run business but reduces the capability and power of government to provide often needed investments that can support long-run business success and the societal common good (Garrity, 2018).

The Private Depends on the Public

The development of the green economy requires significant help from government. This is largely because venture capitalists are not willing to invest in long-term projects that are required and that necessarily must compete against existing technologies and status quo companies (Mazzucato, 2014). Only the public has the deep pockets and long-term time horizon necessary to help new technologies be competitive with fossil fuels (Randers, 2012a).

Both supply side and demand side initiatives are required to transition. Significant infrastructure must be developed including transformation of the electric grid for renewables; but the market alone cannot handle this high level of risk and investment. On the demand side, carbon taxes, regulation, and subsidies can help drive consumers, and with it, increased private funding. However, public policy requires citizen buy-in. Given the current mindset or mental models of citizens, this level of support is not happening fast enough. In fact, there are forces that are working against the best, long-run well-being of citizens.

The Information War, Neoliberal Ideology, and the Concentration of Power

Fossil fuel and other status quo companies are fighting an information war to keep citizens believing that fossil fuels are good, necessary, and important to preserving our way of life (Mann, 2021; Oreskes & Conway, 2010). The information war against fighting climate change is further enhanced by citizens' mental models that are stuck on the belief that we need fossil fuels for more economic growth to support jobs, energy security, and prosperity. Vested interests have the money and influence to keep politicians on their side and to control the flow of information. The system involves several reinforcing feedback loops where corporations are able to exert excessive influence on citizens through propaganda that bolsters belief in: (1) fossil fuels are necessary for business growth, (2) money should flow to the private sector and away from government, and (3) government influence through regulation and taxes is harmful for society (see Garrity, 2018).

One of the main and most important differences in politics among citizens with regard to sustainability and climate change is the citizens' attitudes and beliefs in the role of government. The rise of neoliberalism can be traced back to the works of Adam Smith, David Hume, and John Locke in the eighteenth and nineteenth centuries and their reaction to the concentration of power inherent in European monarchies (Oreskes & Conway, 2014). Currently, however, neoliberalism has led to a lack of trust in government and an increase in the concentration of power in the private sector. A recent survey of economists found that (1) 85% thought corporate power was too concentrated, (2) support among economists for anti-trust policy and financial activism increased, and (3) that climate change has become a big economic risk (Geide-Stevenson & La Parra-Pérez, 2021).

Concentrations of power, whether in centralized governments ruled by autocrats or in large corporations within markets, can distort the will of the people and result in social injustice. The concentration of power is especially critical and problematic in a world that is characterized by ecological overshoot. Historical analysis reveals that resources are consistently and inevitably over-exploited, largely because wealth and its pursuit, generates political and social power that is used to exploit the resource (Ludwig, Hilborn, & Walters, 1993).

This concentration of power means an increase in the ability of a minority to control the flow of information in society (see Figure 2). Corporations can exert high levels of influence in public policy directly through lobbying and also through various forms of media directly to consumer-citizens (Garrity, 2018). Vested interests and powerful fossil fuel corporations have followed the propaganda campaigns of tobacco companies and have sought to undermine support for climate change action (Mann, 2021; Oreskes & Conway, 2010). The concentration of power has been further enhanced by the US Supreme Court, *Citizens United* ruling, effectively stating that "corporations are people" and can freely contribute to political campaigns (Lau, 2019).

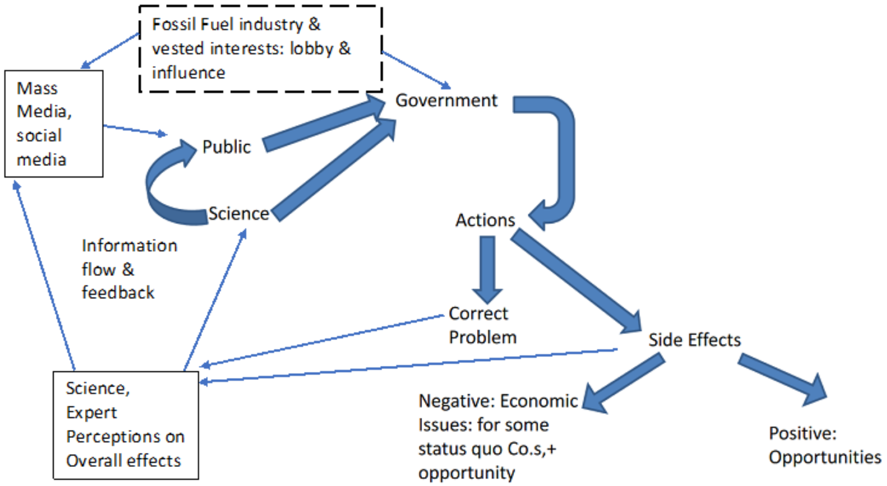

Figure 2: Model of Public Policy, Citizens, and Action

At present, government appears to be in conflict with itself as its two main interests are at odds: (1) the role of government to ensure that long-term public goods are not undermined by short-term private interests, and (2) the current role of government as an agent to stimulate and maintain economic growth (see Jackson, 2009; Garrity, 2012). This apparent state of conflicting goals of government is at the heart of our sustainability and climate change problems. Understanding citizen mental models is key to resolving this conflict regarding our conceptions of government. In essence, a better understanding of complex systems, dynamic behavior, and the role of citizens as components of these systems can help to achieve our multiple objectives.

MENTAL MODELS

Mental models are conceptual, cognitive maps of reality. In essence, people have mental representations of the world that help us to understand how things work (Craik, 1943). Essentially, mental models allow us to anticipate events, reason, and form explanations (Jones, Ross, Lynam, Perez, & Leitch, 2011).

Naturally, mental models are not complete but are simplifications of reality (Sterman, 2000). Setting the scope or boundary of our model is very important. The boundaries in our mental models allow us to simplify and focus our attention.

However, if the boundaries of our models and thinking are too narrow, then we risk excluding important interdependencies and feedbacks (Sterman, 2000).

In the case of climate change and sustainability, economic variables are of particular importance in developing our mental model (Garrity, 2018). One worldview presented in many standard economic textbooks shows the circular flow of the economy as a closed system where real-world ecosystem interactions are essentially ignored (Daly & Farley, 2004). This conceptualization or worldview leads to a mental model that is severely restricted and misses important feedbacks. A narrow and closed worldview implicitly assumes that resource extraction and waste disposal can continue indefinitely. Figure 3 compares and contrasts the traditional economic model, which is economic imperialism (a), with the ecological economics or steady-state subsystem (b). In Figure 3a (economic imperialism), the arrows highlight the notion that the economic subsystem can expand until it replaces the entire ecosystem. In essence, the entire system is conceptualized as the macro-economy, including the ecosystem itself. This viewpoint leads to mental models that only consider economic variables as being of primary importance; the ecological environment is viewed as important but only to the extent that the environment is directly helpful to human needs (Garrity, 2018).

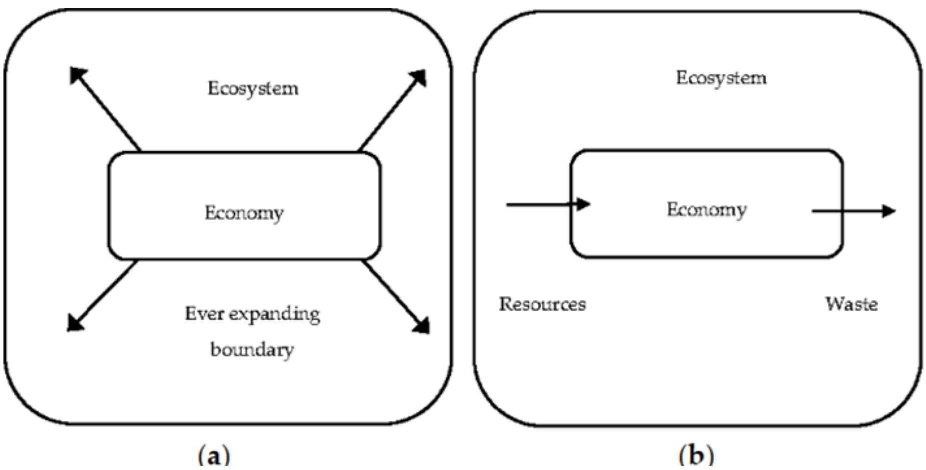

Figure 3: Economic Imperialism versus Steady State Mental Models: (a) Economic Imperialism Mental Model; (b) Steady State Mental Model (adapted from Daly & Farley, 2004)

The field of ecological economics is based on the steady-state subsystem view of the human economy. In contrast to economic imperialism, this view sees the economy as an open system that exchanges energy and matter with the Earth's ecosystem. An important distinction here is that the size of the human economy does have an optimal or maximum level determined by global society and the ecosystem. In the long run, the human economy must ensure that the ecosystem remains healthy as the two subsystems must support each other. Essentially, mental models based on the steady-state subsystem have a holistic and long-term orientation.

Citizen mental models can generally be mapped into one of the two economic worldviews in Figure 3, either Economic Imperialism or Steady State. The two world views draw very different system boundaries that lead to very different sets of variables being considered in citizen decision-making. For example, those who hold a Steady State worldview would be more inclined to promote environmental regulation or a pollution tax (e.g., a carbon tax) to curb excessive harm to the public from externalities generated by economic activity. However, if one holds the Economic Imperialism worldview, then such actions can be interpreted as constraining economic growth. Under this view, ecological variables are in the background and if they are considered, it is because they are viewed as resources supportive of the human economy. Even though environmental economic policies exist to solve pollution and ecological problems, they are not effectively implemented under this viewpoint because citizens ignore or downplay variables that are not considered to be of primary importance under Economic Imperialism. Of course, citizen votes are necessary to enact public policy.

This conflict in worldviews and mental models is at the heart of the sustainability and climate change crisis. Higher Education and business schools, in particular, are responsible for promoting a traditional narrow view. Business schools can help to develop a wider viewpoint and change mental models by incorporating systems thinking and system dynamics models.

TIMING IS EVERYTHING: CHANGING MENTAL MODELS AND TACTICS

Citizens' thinking and the mental models they use are key to unlocking the power of the market to help our battle with climate change. Currently, many citizens hold beliefs about our socio-ecological-economic system that are simply not true.

Much of the false information that informs citizens comes from the fossil fuel industry and other vested interests (see Figure 2; Mann, 2021). Fortunately, however, relatively simple system models can convey important underlying truths that can help citizens learn for themselves about the nature of these complex systems.

System Dynamics: A Research Tool to Produce Scientific Information and Inform Mental Models

It is important to base our mental models on an underlying foundation of truth and to avoid problems such as confirmation bias or motivated reasoning. The scientific process relies on a humble, democratic process of forming and framing hypotheses that can be disproven (Sagan, 1996). Science works by drawing tentative conclusions that must be validated and repeatedly tested in a process of error detection and self-correction. In many cases, experiments can be designed and real-world, externally valid information can be collected and tested. However, in the case of large-scale complex systems, experiments with the real system are often impossible. In the case of socio-economic-ecological systems, decisions and policies often cascade across multiple systems and across disciplinary and geographic boundaries (Sterman, 2015). Experimentation is often unethical such as releasing a live virus or disease in a population in order to test public health policies. Experimental replication is often impossible such as examining the impact of a policy on the Earth's climate (we cannot reset the climate) (Sterman, 2015). Since complex systems exhibit long time delays it is impossible to assess the full consequences of policies and decisions.

Fortunately, system dynamics incorporates stock and flow modeling in a computer simulation environment and can capture complex interactions and produce behavior-over-time (BOT) graphs of the important variables. Natural and social systems can be modeled and understood as stocks and flows. For example, inventory (stock) increases through production (inflow) and decreases through sales (outflow); and populations (stock) increase through births (inflow) and decrease through deaths (outflow). Underlying equations are used to represent the flows and these determine how the stocks change through time. Since many real-world systems involve non-linear dynamics, interconnections, information feedbacks, and delays, stock and flow simulations are extremely useful at capturing the long-run behavior and timing of complex systems (Sterman, 2000). In the case of complex economic-ecological systems, stock and flow simulations can be used to conduct experiments in a virtual world by testing the outcomes of policy changes. In addition, not only can system dynamics models be used to produce scientific information, but they are also useful as learning environments for expanding the narrow boundaries of our thinking (Sterman, 2015).

While changing mental models of citizens is crucial to battling climate change, the truth is that we do not have much time to implement the proper policies to make this happen. The next sections provide additional information and models to help inform citizens and reveal the importance of acting quickly. Since economic systems impact the natural environment, it is important to take a closer look at the impacts on both renewable and non-renewable resources.

RENEWABLE RESOURCES AND AN EXAMPLE OF A TIGHTLY COUPLED ECOLOGICAL-ECONOMIC SYSTEM: A FISHERY

An ocean fishery is a large-scale marine ecosystem that needs to be managed for long-term, sustainable use and profit. Fisheries are also common pool resources (CPR), which are areas where it is difficult to exclude users (*exclusion* property) and where one person's consumption or exploitation of resource units makes those units unavailable to others (*subtractability* property) (Ostrom, Gardner, & Walker, 1994). A fishery is a good prototype example of an economic system tightly coupled with an important ecosystem.

Appendix A shows the detailed stock and flow fishery model with equations, summary, and behavior-over-time output. The model depicts the interaction between business-economic decision making and its direct impacts on the ecosystem (Garrity, 2010). The simulation shows that information delay to decision makers (fishers) along with their profit incentive naturally leads to an ecosystem or fishery crash. Fishers often discount information provided by fishery managers when fish stocks are low. This is because fishers are able to maintain high catch levels despite lower stock levels (Palomares & Pauly, 2019). Fishers are able to keep catch efficiency high in low stock level environments because of a combination of technology gear, fisher' skill levels, and fish schooling behaviors (Garrity, 2020).

The BOT graph in Appendix A illustrates the unfolding story of how investment in fishing capacity can overwhelm the regenerative ability of the fish stock in an unregulated fishery (Morecroft, 2015). However, even in a managed fishery, overinvestment and overfishing can still occur. A quota system is a management tool to prevent this behavior. A particularly popular fishery management tool is the individual transferable quota (ITQ). An ITQ system sets an overall quota or total allowable catch (TAC). The rights to harvest a portion of the TAC is then allocated among fishing organizations. The ITQ can be freely traded in the market. In essence the ITQ confers a type of virtual ownership. ITQ holders are intended to act as private owners and stewards of the resource since ITQ shares increase in value for well managed fisheries. The TAC limit must still be properly set to balance the profit seeking interests of individual fishers against the ability of the fishery to regenerate.

The empirical evidence on ITQ fisheries is somewhat mixed. There is evidence that ITQs or catch shares help to prevent fishery collapse (Melnychuk et al., 2012), but there is less evidence that ITQs are beneficial in rebuilding fisheries. Chu (2008) reported that in 20 stocks managed by ITQ, 12 stocks showed improvements in biomass but 8 of the 20 fisheries continued to decline after ITQ implementation.

An additional, enhanced stock and flow computer model to incorporate an ITQ quota-based management scheme with a detailed financial model is overviewed in Figures 4 and 5 (see Garrity, 2011 for model details). Individual fishers (and fishing companies) have profit incentives to seek the highest TAC that will still keep the fishery sustainable. Figure 4 shows the total discounted fishery profit under two quota schemes: (1) a liberal quota and (2) a more precautionary (lower TAC) quota. Businesspeople prefer discounted profit and cash flow for decision making and this perspective favors the liberal quota. However, as shown in Figure 5, a precautionary quota policy generates higher overall, long-run profits. In addition, the precautionary policy preserves the fish stock for better long-run sustainability outcomes. Also, the higher level of fish stock can yield better long-run employment. Thus, a win-win-win outcome for sustainability (people, profit, and planet measures) can be achieved. Unfortunately, using discounted profit decision models means there is a general bias toward seeking short-run profits at the expense of sustainability and better long-run outcomes (Garrity, 2020). Business schools teach discounted cash flow and decision models based on the time value of money because this helps individual firms optimize market performance. However, many long-run, common good outcomes will be neglected if only a narrow perspective is taken on public policy issues.

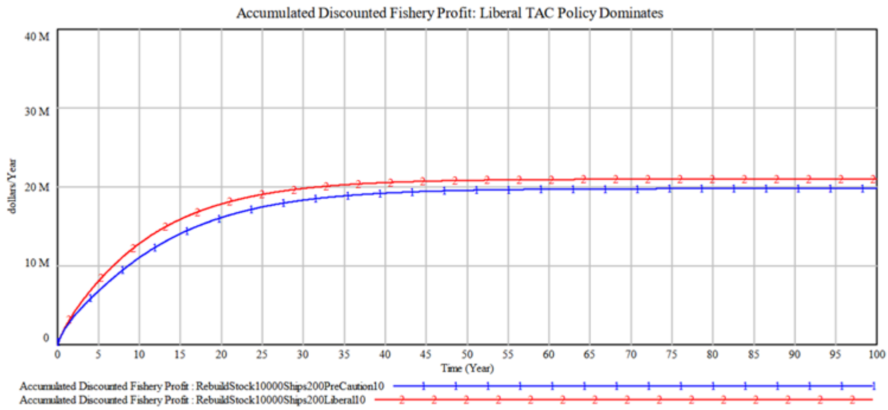

Figure 4: Comparing Precautionary with Liberal TAC (Quota) Setting on Accumulated Discounted Fishery Profits (adapted from Garrity, 2011).

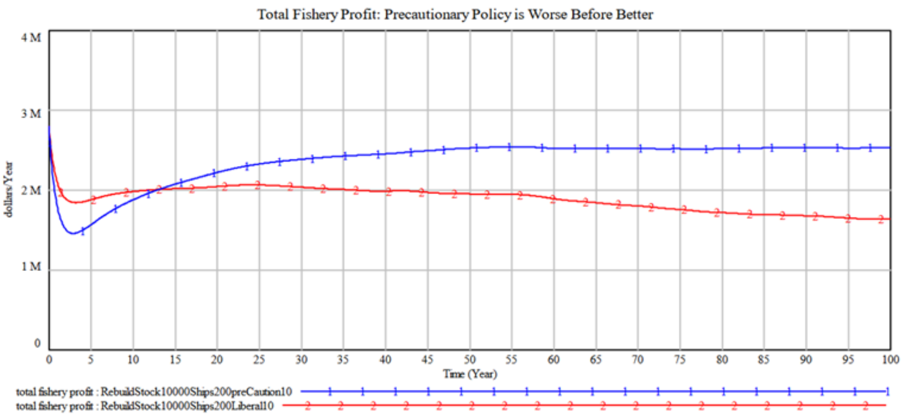

Figure 5: Comparing Precautionary with Liberal TAC (Quota) Setting on Total Fishery Profits (adapted from Garrity, 2011). Note: Economic decision making is myopic, with narrow time-frame-only thinking; but complex systems exhibit "worse before better" behavior.

NON-RENEWABLE RESOURCES AND TIGHTLY COUPLED ECOLOGICAL-ECONOMIC SYSTEMS

In the case of non-renewable resources (e.g., fossil fuels), a simple system dynamics model (see Appendix B) can show how critical it is to act quickly to transition away from fossil fuels. Figure 6 shows the results from the simulation model that as more capital is invested for resource extraction, the more profits are generated and the faster the resource and profits are driven down. In essence, higher capital invested in fossil fuels drives higher extraction and produces higher profits, but as resources dwindle, the profits crash quickly (see Meadows, 2008 and Appendix B for additional details). In fact, the higher the capital investment grows, then the faster the resource will crash (see Figure 7). The two graphs together show the concept of reduction in energy return on investment (EROI). As resources decay it takes more effort, energy, and money to extract more difficult to access resources (Meadows et al., 2004; King & Hall, 2011). Thus, costs of extraction increase and profits sink (Heinberg, 2011). This implies that there will likely be further disruptions to the global economy if countries fail to transition away from fossil fuels fast enough. These disruptions could occur simultaneously with climate change impacts and lead to more severe problems. Ultimately, this leaves little time to transition society away from fossil fuel addiction. Unfortunately, the status quo fossil fuel companies are doing everything in their power to wage a disinformation war on citizens and prevent climate change action (Mann, 2021); Oreskes & Conway, 2010), while deceptively painting a picture of themselves as helping in the climate fight (Li, Trencher, & Asuka, 2022).

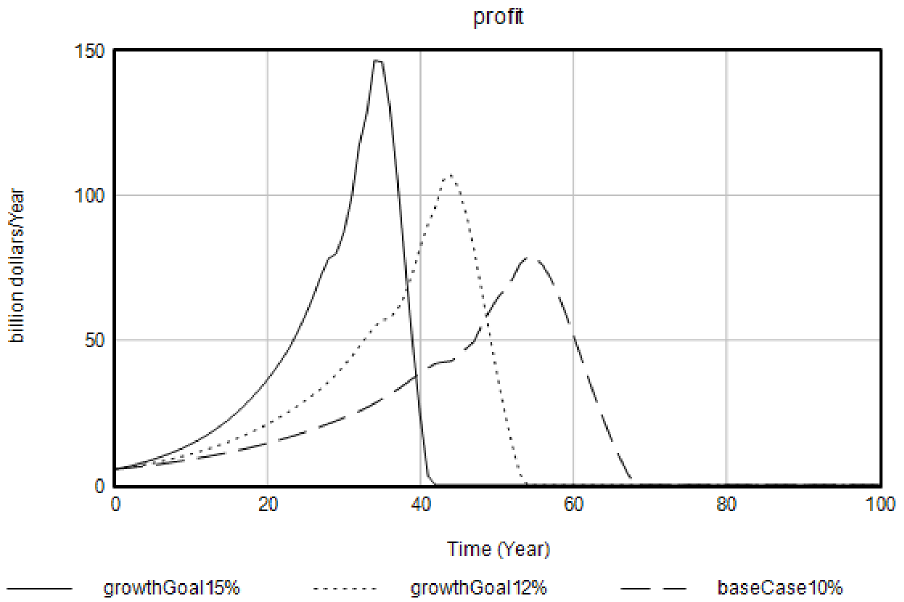

Figure 6: Profit from Resource Extraction Under Various Growth Goals

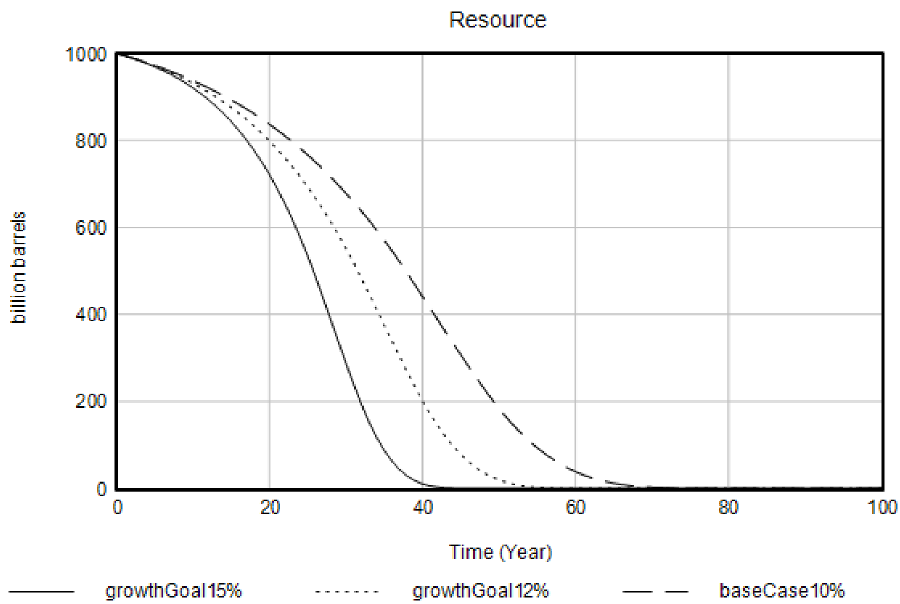

Figure 7: Behavior Over Time of Resource Depletion Under Various Growth Goals

The strategies preferred by fossil fuel companies and their political supporters is to simply find more fossil fuels. However, supply side strategies are not effective in the long term. Figure 8 shows the impact of finding twice the initial resource volume. Results from the computer simulation reveal that a resource that lasts approximately 66 years (useful life with ending resource at about 1% of initial stock level) will only last another 6 years if the resource *doubles in size* (72 years useful life). Further, if we somehow manage to explore and find a resource level that is *four times* (4x) the original fossil fuel stock size, the resource lasts only an additional 15 years beyond the base case (81 years total lifetime)! In essence, the supply side solutions pushed by entrenched status quo fossil fuel companies are simply not feasible.

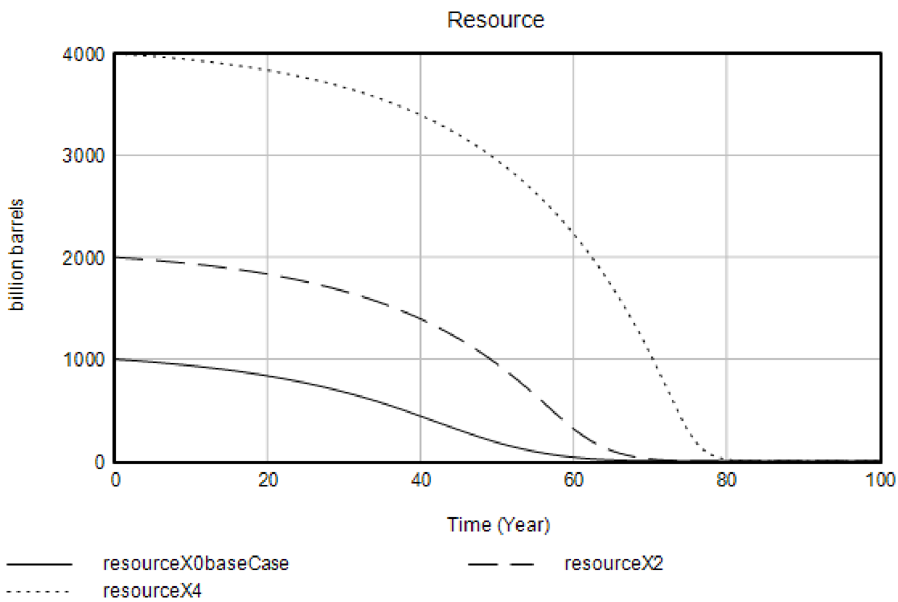

Figure 8: Resource Lifetime Under Various Stock Sizes

THE NEED FOR PRECAUTION AND FAST ACTION

System dynamics models signal the need for precaution because our business economic systems interact with natural resources and ecological systems. Business systems can overexploit resources through over harvesting renewable resources, over-extracting non-renewable resources, or through discarding waste into global common pool resources (e.g., oceans and atmosphere). However, this precautionary perspective runs counter to many citizens' mental models. Citizens have developed their thinking and mental models based on many years of experience and history with systems that are grounded on high levels of natural resource stocks. The oceans have appeared limitless, oil and fossil fuels have been abundant, and climate change was never an issue. Today, the environment has changed radically. There is much empirical evidence that we have crossed many ecological limits (Rockström et al., 2009a, 2009b). Now, under such radically different circumstances, citizens must rapidly change their mental models and thinking to handle the demands of complex systems. However, the ability to act fast is hampered by our broken democratic-societal-economic system. This is an overwhelming dilemma because the predominant paradigm of social and economic development remains largely oblivious to the risk of human-caused environmental disasters at planetary scales (Stern, 2007). A basic structural problem is that we do not have adequate information feedback to citizens and policy makers and they lack the mental models to properly deal with this new environment. As mentioned, much of the poor information feedback is purposeful, designed disinformation produced by status quo, fossil fuel companies and their associated vested interests (Mann, 2021). In addition, poor information feedback is also a feature of our tendency to overfocus on our man-made economic systems and ignore our place as part of natural ecosystems.

BUSINESS EDUCATION, SHORT-TERMISM, CHANGING MENTAL MODELS, AND LEARNING

There are several promising avenues for educating university business students and for changing citizen mental models to support climate change action and promoting a sustainable future. First, small system dynamics models can reveal important lessons and insights that can help with public policy problems like climate change (Sterman, 2015). Public policy problems and initiatives are difficult and lead to counterintuitive results because they involve complex systems that exhibit characteristics such as long delays, policy resistance, dynamic complexity, feedback, and stock and flow accumulation (Sterman, 2015). Small system dynamics models can give rapid feedback to users and provide insights that would otherwise be impossible to obtain by experimenting with an actual system. Additionally, these models reveal that complex ecological-economic systems often exhibit "worse before better" long-run behavior. Both politically conservative and politically liberal citizens share a common concern for a prosperous economy. Better economic outcomes result from both protecting renewable resources and protecting our global common pool resources (oceans and atmosphere) from climate change (Stern, 2007). Indeed, Stern estimates not addressing climate change could cost up to 20% of global GDP.

Second, disruptive innovations driven by the global movement to green products and services will likely transform businesses. We can expect better economic outcomes for businesses that respond to these challenges and innovate first. However, a common characteristic of disruptive technologies is that they originate with a set of performance attributes that existing customers do not value. Over time they improve to invade established markets and can quickly overtake and disrupt industries (Bower & Christensen, 1995). The changes in products and technologies can occur in a fast, non-linear fashion (see Figure 9). Technology disruptions are often missed because managers remain overly focused on short-term results (Gallaugher, 2021). This is understandable as managers are instructed by business schools to do just that: to listen to customers and shareholders and to pay attention to short-run profits. Eastman Kodak is a widely known example of a firm that stayed with film technology for too long, largely because it was so lucrative, and they failed to transition to digital photography fast enough (Hardy, 2018). The same fate could fall on numerous industries linked with fossil fuels. Record profits have been reported by fossil fuel companies (see Reed, 2022; Milman, 2021) but green alternative technologies could quickly cause major disruptions. When disruptions occur to isolated companies, the impacts are limited. However, when dealing with a country's energy supply, the impacts could be quite substantial (Garrity, 2018).

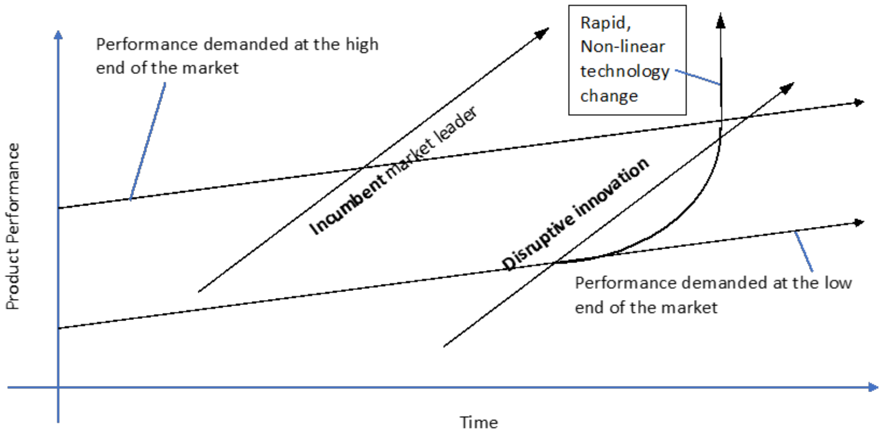

Figure 9: Characteristics of Disruptive Innovations, Performance Trajectories (adapted from Christensen, 1997)

Citizens are beginning to see the effects of climate change as more and more climate change related events are having an impact now. The need for businesses to change quickly and adopt green products and strategies is becoming evident. There are always first-mover advantages to companies that adopt new technologies. Economies of scale and learning curve effects can mean significant economic advantages to those firms that innovate and adopt sustainability and climate change initiatives. Instilling the proper mindset for business graduates is thus imperative. Business education should help students to focus on the bigger picture, systems thinking, innovation, and the global impacts from climate change. Real world problems also present opportunities for business products and services. A greater understanding of the interface between public policy and business strategy is critical as a global society responds to the climate change challenge. Education should also stress the dual importance of business action and the need for all citizens to support public-private cooperation.

ENVISIONING CONSERVATISM AND PROGRESSIVE POLITICS USING A SYSTEMS LENS: BALANCING LONG-TERM WITH SHORT-TERM

Some public support is required in order to engage the power of the market to tackle climate change and sustainability. In the case of major product and technology categories like moving to electric cars, the free market cannot do it alone. Considerable infrastructure must be developed to support electric vehicle charging stations. As with all major industrial activity, large public investment is needed to support the market. Public investment is necessary for business logistics such as support for airports, roads, bridges, and even the development of the Internet. The private (or market) depends on the public (or government; see Mazzucato, 2014). Environmental regulations can actually be used to speed along market efforts to develop innovative green technologies and products. Government regulations, however, need the support of well-informed citizens. Thus, changing mental models is a priority.

We need everyone on board to solve the climate crisis, both conservative and progressive citizens, since citizen votes are necessary to support climate action and effective policy. Both the free market and government support are needed to make massive transformations in our energy systems and we need to make these transitions quickly to prevent the worst effects of climate change. An all of society strategy can achieve climate goals in the US (Bridgewater, Kazanecki, Cyrs, & Kennedy, 2021), and as a world leader in commerce, this can help set off a chain reaction in global markets. Tighter environmental regulations and a carbon tax in large global markets can help to drive global commerce in a green direction. Corporations that manufacture and sell products globally are better off adhering to the tightest regulations since manufacturing and sourcing of materials are more efficient with standardized, high-volume processes, rather than multiple, complex assembly and sourcing requirements (Nidumolu, Prahalad, & Rangaswami, 2009). A number of social tipping points can be reached by setting in motion educational changes, changes in economic mindsets, and changes in lifestyles (Otto et al., 2020).

This is a new and counterintuitive mindset for political conservatives, the idea that markets and government can work together in a cooperative partnership to promote a balanced set of goals and outcomes that affect both short-term and long-term economic outcomes. Without public investment and cooperation, a transformation to a green economy will not happen fast enough to solve the climate crisis (Randers, 2012a, 2012b). In addition, environmental regulation and a carbon tax are necessary to promote the transformation to the green economy in the near term. There are significant first mover advantages to moving quickly and developing scale economies (Bower & Christensen, 1995; Nidumolu et al., 2009).

Both conservatives and progressives (liberals) can agree that a good, strong economy is beneficial for society. A vibrant economy can be supported by conservatives because of the general belief in individualistic hard work to achieve a prosperous future. Progressives (liberals) desire a strong economy that supports all levels of workers. Government interference in markets is widely viewed as a negative, but private-public partnerships that lead to a strong economy could be packaged, marketed, and appropriated into a valid cultural viewpoint. A unified cultural viewpoint would allow for fast action toward solving our climate crisis and putting us on a sustainable path. Building a new mindset around the new, necessary requirement to match business strategy with the reality of our world order and ecological environment is the job of education.

SUMMARY AND CONCLUSIONS

The information generated by the stock and flow computer simulations for both the renewable and the non-renewable resource cases in this paper are both driven by the underlying business growth goals in the system. The profound idea that there are limits to growth and that mankind is still on course to overshooting our ecological footprint has been empirically validated (Meadows et al., 1972; Meadows et al., 2004; Turner, 2008). Changing our current trajectory and living in a stable balance with our natural world requires a change in thinking or mental models. Business schools and higher-level education should incorporate a wider view of the relevant systems so that individuals can understand how pursuing sustainability goals can produce better outcomes for both business and the greater good. More detailed system models can also be built to study specific impacts and more in-depth assessments.

Our common future is the idea that we need to think in terms of development that incorporates our common home (our planet or ecological environment) and our common humanity (people and care for all of humanity, not just the wealthy and fortunate), and do so in a way that supports the notion of prosperity for current and future generations.

This paper has shown that current thinking is limited by three major factors: (1) our mental models are limited in scope to focus primarily on economic variables (economic imperialism); (2) the market is primarily focused on short-term results without the needed balance of long-term goals and public partnership and cooperation; and (3) citizens are mis-guided by information flows from fossil fuel vested interests and outside influence from external nation states that are dependent on fossil fuels (Stengel, 2019).

The mindset that only the market is necessary for freedom and economic prosperity is false. Over 30 years have passed since James Hansen testified before Congress that mankind's activity and the Greenhouse Effect is causing climate change. However, the market and private business have not acted fast enough. Acting now with urgency can put us on the right track for solving the climate crisis and achieving a sustainable prosperity.

Only the government has the resources and long time horizon to consider large public investments to combat climate change. However, government action must be supported by citizen votes. Changing citizen thinking or mental models, thus, becomes a critical leverage point in the system.

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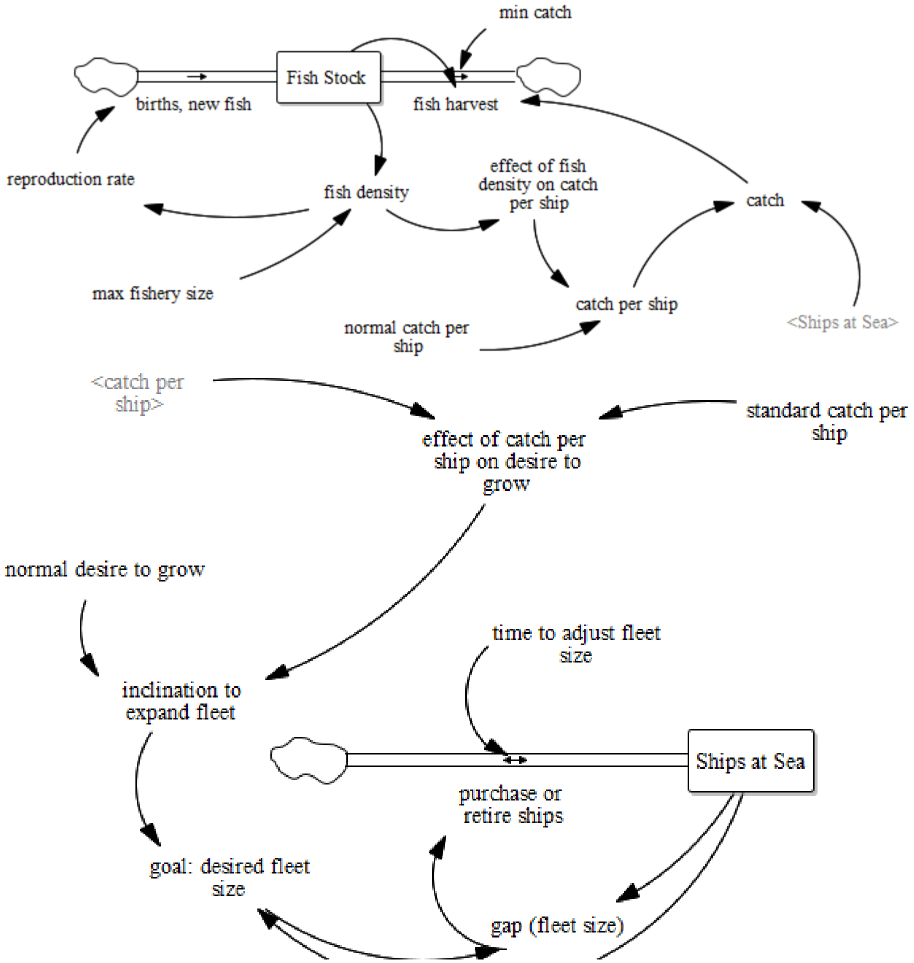
APPENDICES

Appendix A: System Dynamics Model of a Tightly Coupled, Ecological-Economic System: A Fishery (adapted from Morecroft, 2015; Garrity, 2010)



Equations for Ships at Sea View

catch per ship=

normal catch per ship * effect of fish density on catch per ship

Units: fish / ship / Year

"goal: desired fleet size"=

Ships at Sea * (1 + inclination to expand fleet)

Units: ships

effect of catch per ship on desire to grow = WITH LOOKUP (
catch per ship / standard catch per ship,
([(0,-0.6)-(25,1)],(0,-0.48),(2.5,-0.45),(5,-0.37),(7.5,-0.27),(10,0),(12.5
,0.64),(15,0.9),(17.5,0.995),(20,0.995),(22.5,1),(25,1)))
Units: Dmnl

"gap (fleet size)"=
"goal: desired fleet size" - Ships at Sea
Units: ships

inclination to expand fleet=
normal desire to grow * effect of catch per ship on desire to grow

Units: Dmnl

normal desire to grow=
0+STEP(0.1, 11)
Units: fraction

purchase or retire ships=
"gap (fleet size)" / time to adjust fleet size
Units: ships / Year

Ships at Sea= INTEG (
purchase or retire ships,
10)
Units: ships

standard catch per ship=
1
Units: fish/(Year*ship)

time to adjust fleet size=
1
Units: Year

Equations for Fish Stock View

“births, new fish”=
reproduction rate
Units: fish/Year

catch=
catch per ship * Ships at Sea
Units: fish / Year

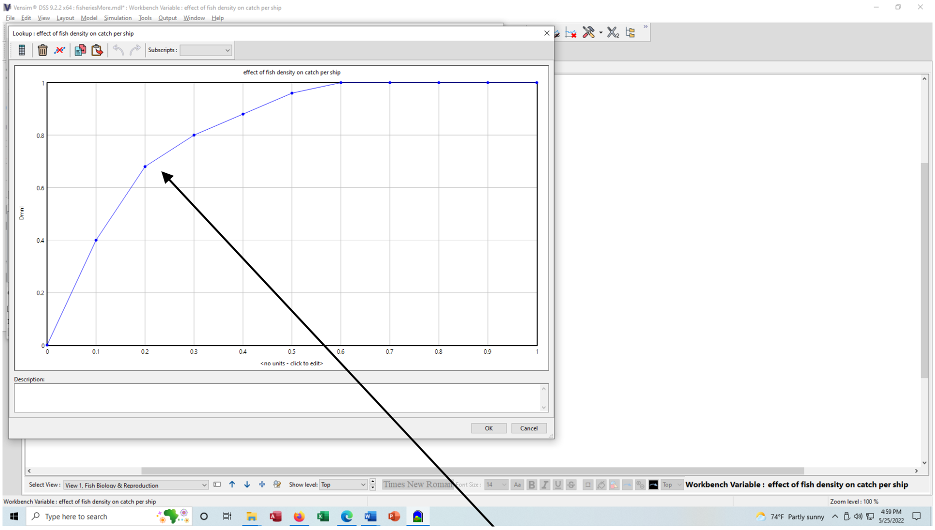
catch per ship=
normal catch per ship * effect of fish density on catch per ship
Units: fish / ship / Year

fish harvest=
IF THEN ELSE(catch < (Fish Stock * min catch) , catch, Fish Stock * min catch)
Units: fish/Year

Fish Stock= INTEG (
“births, new fish”-fish harvest,
3370) Units: fish

effect of fish density on catch per ship = WITH LOOKUP (
fish density,
([(0,0)-(1,1)],(0,0),(0.1,0.4),(0.2,0.68),(0.3,0.8),(0.4,0.88),(0.5,0.96)
,(0.6,1),(0.7,1),(0.8,1),(0.9,1),(1,1)))
Units: Dmnl

Effect of fish density on catch per ship, Graph view



Fish density on X-axis; Even at low density, catch/ship remains high; reflecting gear technology, fish schooling behavior, fishers' skill (in essence we have <u>delayed information feedback</u> to decision makers)

fish density=
Fish Stock / max fishery size
Units: Dmnl

max fishery size=
4000
Units: fish

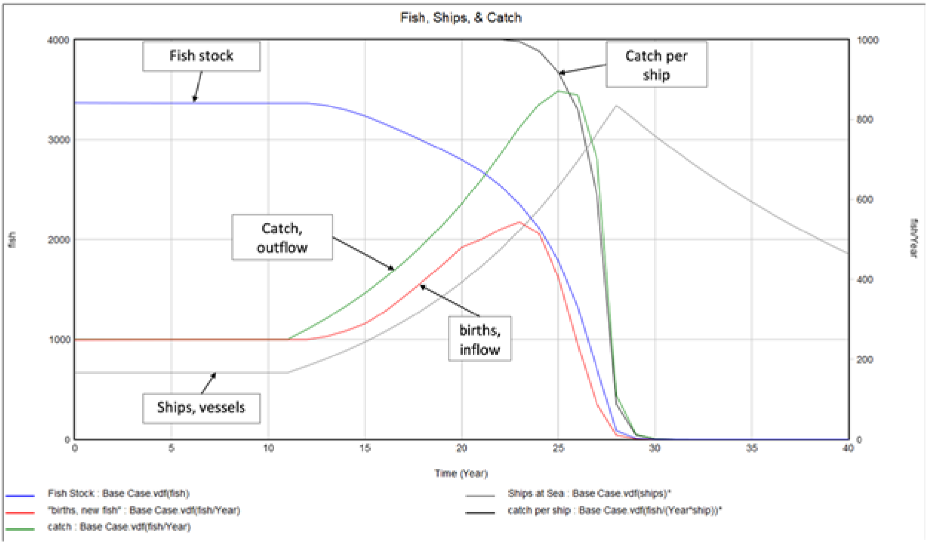
min catch=
1
Units: fraction/Year

normal catch per ship=
25
Units: fish/ship/Year

reproduction rate = WITH LOOKUP (
fish density,
([(0,0)-(1,600)],(0,0),(0.1,50),(0.2,100),(0.3,200),(0.4,320),(0.5,500),(0.6,550),(0.7,480),(0.8,300),(0.9,180),(1,0)))

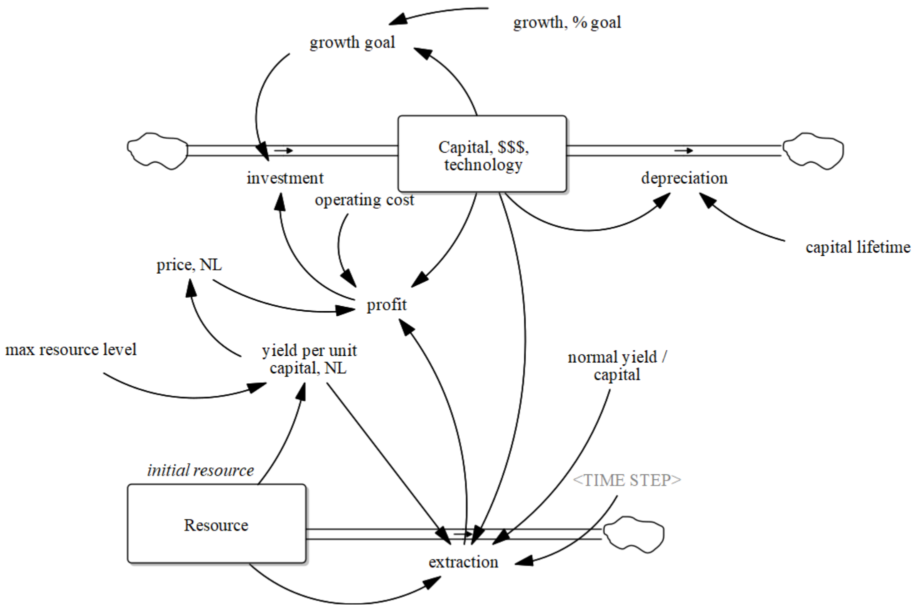
Units: fish/Year

Ships at Sea= INTEG (
purchase or retire ships,
10)
Units: ships



<u>Summary of base case</u>: In year 11, outflow (catch) exceeds inflow to stock (births), so fish stock begins to fall. Early in the simulation the stock level is high and there is a corresponding high level of catch efficiency, measured as "effect of fish density on catch per ship," Or catch per unit effort (CPUE). Since efficiency is high, fishers invest in more ships, "effect of catch per ship on desire to grow." As in most industries, there are scale advantages and a strong desire to grow the business, see "inclination to expand fleet." Notice that inflow is at the maximum (and thus the stock size is optimal for maximizing the fish harvest) around year 23. However, the catch is at maximum in year 25 while the inflow is crashing.

Appendix B: System Dynamics Model of Resource Extraction, Stock and Flow Simulation (adapted from Meadows, 2008)



"Capital, $$$, technology"= INTEG (
investment-depreciation,
5)
Units: billion dollars, 5 is initial value

capital lifetime= 20 Units: years, 20 initial value

depreciation=
"Capital, $$$, technology" / capital lifetime Units: billion dollars / Year

extraction=
MIN ("Capital, $$$, technology" * "yield per unit capital, NL" * "normal yield / capital"
, Resource / TIME STEP) Units: billion barrels/Year

The resource is equal to the computed extraction. However, as the stock dwindles the resource is reduced in a smoothed fashion. Similar to or based on, "all outflows require first order control," (Sterman, 2000: 545-546). Generically, outflow = min(desired outflow, maximum outflow) where, maximum outflow = stock / minimum residence time.

growth goal= max ("Capital, $$$, technology" * "growth, % goal", 0) Units: billion dollars/Year

Use the max function with 0 because we never want to use a negative value for the investment.

"growth, % goal"= 0.1

Units: fraction / Year 0.10 initial value.

initial resource= 1000 Units: billion barrels

1,000 billion barrels, base case. Sensitivity using 2X and 4X (2,000 and 4,000).

investment=

MIN(max (profit, 0), growth goal)

Units: billion dollars/Year

First, we take the Max of profit or 0. If profit is ever negative, then we simply use 0. Next, we take the smallest of profit or the growth goal because even if our growth goal is very large we can never invest more than we make through profit. On the other hand, if our profits are really large, the most we will invest is up to our growth goal.

max resource level=

1000 Units: billion barrels

"normal yield / capital"=

1 Units: billion barrels/(Year*billion dollars)

operating cost=

0.1 Units: fraction/Year

"price, NL"= WITH LOOKUP (

"yield per unit capital, NL",

([(0,0)-(1,10)],(0,10),(0.1,8),(0.2,6),(0.3,4),(0.4,3),(0.5,2.2),(0.6,1.8

),(0.7,1.7),(0.8,1.5),(0.9,1.3),(1,1.2)))

Units: billion dollars / billion barrels

3 dollars initially.

profit=

max((("price, NL" * extraction) - ("Capital, $$$, technology" * operating cost

)),0)

Units: billion dollars/Year

Resource= INTEG (

-extraction, initial resource)

Units: billion barrels, 1000 is the initial value.

TIME STEP = 1

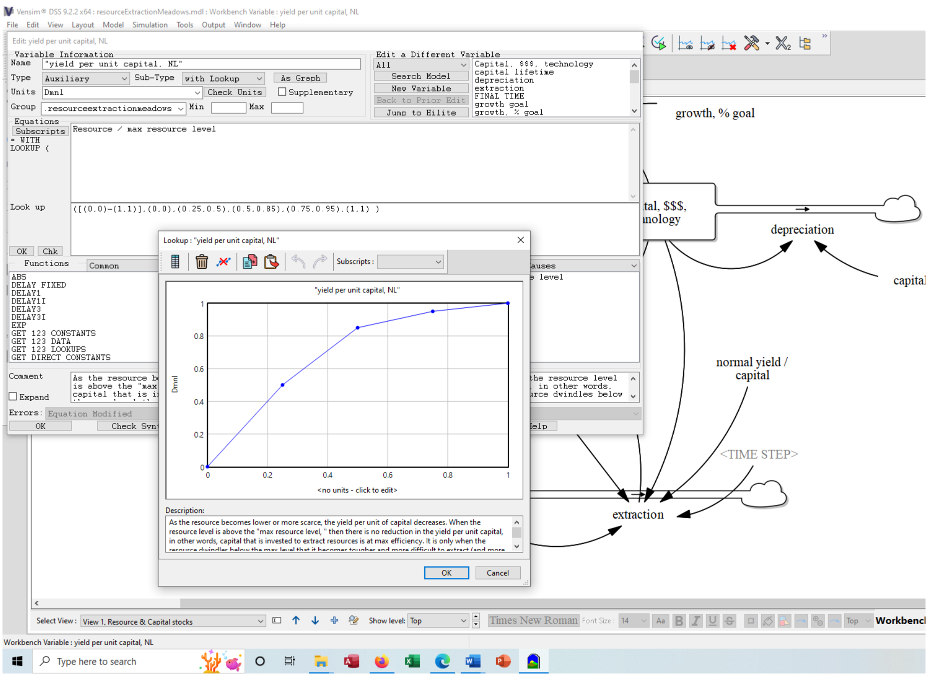
Units: Year [0,?] The time step for the simulation.

"yield per unit capital, NL"= WITH LOOKUP (

Resource / max resource level,

([(0,0)-(1,1)],(0,0),(0.25,0.5),(0.5,0.85),(0.75,0.95),(1,1)))

Units: Dmnl



As the resource becomes lower or scarcer, the yield per unit of capital decreases. When the resource level is above the "max resource level, " then there is no reduction in the yield per unit capital, in other words, capital that is invested to extract resources is at max efficiency. It is only when the resource dwindles below the max level that it becomes tougher and more difficult to extract (and more costly).

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