Designing an environmental mitigation banking institution for linking the size of human activity to environmental capacity*

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ABSTRACT

While institutions are a key determinant of economic behavior and new institutions are often formed as a part of an economic policy, a systematic way to design these institutions and test their potential performance before they are created does not exist. I have attempted in this paper to create and test such a design for an environmental mitigation banking system using system dynamics modeling and computer simulation. Experimentation with my model suggests that a mitigation banking institution established in the market with the mandate of adding value to environment is able to balance human activity with environmental capacity and yield an optimal price for the mitigation credits without inputs from engineering methods connecting price to cost of mitigation. The delays associated with engineering calculations, when they are used to determine price, would curtail human activity by stifling its multiplier effects. Subsidization of mitigation banking would indirectly support human activity by reducing the price of credits, but for the same budget, direct subsidies support human activity more than the market-based subsidies. Connecting credit requirements to environmental conditions introduces instability in all cases due to the delays involved in this process. The experimental method used to test the efficacy of the mitigation banking system in this paper is seen in general to be a valuable process for mobilizing the powerful concept of institutional change for creating operational plans.

Keywords: Environmental economics, Institutional economics, ecological economics, sustainable development, environmental mitigation banking, wetlands preservation, infrastructure development, system dynamics, computer simulation.

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INTRODUCTION

While heterodox economics streams have widely recognized the role of institutions in influencing the behavior of an economy, a large part of the writings in institutional economics are devoted to interpreting classical thought on institutions rather than making use of this powerful instrument in designing a policy implementation framework (Neal 1987, Bush 1987). In particular, environmental policy, which should be aimed at creating environmental responsibility institutions that influence the every day conduct of business, continues to be implemented through command and control and rather arbitrary fiscal instruments, although a few market-based instruments such as tradable pollution permits have been proposed (Cropper and Oates 1992). Environmental mitigation banking has recently been suggested as an institutional innovation that should transmit restoration costs to the agents causing environmental damage while at the same time assuring that net damage to the environment remains zero in a development project so strong sustainability criteria are met.

Environmental restoration costs in an environmental mitigation banking system are transmitted to users through mitigation credits, which are earned by a mitigation bank through the restoration of a decayed environment and bought by a user prior to inflicting damage to the environment. Mitigation banking has been implemented in limited enclaves, mostly to conserve wetlands and forest areas. In the United States, mitigation banks are in operation in Minnesota, California and Florida since environmental regulation in these states calls for the equivalent restoration of the environment to offset any damage caused by infrastructure projects. The overall scale of this activity, however, remains small (Mitigation Banking *Website*, Mitigation Banks *Website*).

Many opinions exist about how the mitigation banking industry should be instituted and regulated, but few of them are based on a clear understanding of how the proposed institutional arrangements and regulatory policies would affect its performance in terms of supporting human activity, preserving the environment and minimizing organizational costs and social conflicts. Pricing of environmental credits is an important aspect of the mitigation banking system and complex engineering methods connecting price to cost have been proposed as pricing criteria. Also, environmental groups have often advocated subsidization of the environmental mitigation activity by the government or other outside agents, without clearly understanding the implications of such subsidies. Evidently, there is a need for perfecting design of this new institution before confidence can be placed in its ability to successfully meet the dual goals of maintaining environment and supporting human activity without a cumbersome and expensive command and control system in place.

Integrating concepts from economics and system dynamics, I have attempted in this paper to model the role of a mitigation bank operating with a variety of regulatory policies and interventions imposed by a government.[1] Computer simulation is used to reveal the dynamic behavior of the relationships included in the model. Experiments with my model suggest that a mitigation banking institution established in the market with a profit mandate that results in adding value to the environment is able to yield both an optimal price for the credits and an economic scale compatible with the environmental capacity without use of engineering methods connecting price to cost. These experiments also show that the delays associated with engineering calculations, when they are used to influence price of credits, would restrain economic growth by stifling its multiplier effects, even though they would achieve a compatibility between the scale of the economy and environmental capacity. Subsidies would indirectly support the economy by reducing the price of credits, but for the same budget, direct subsidies support the economy more than the market-based subsidies. Connecting credit requirements to environmental conditions introduces instability in all cases in view of the delays involved in the process, but helps to connect the scale of the economy to environmental capacity when market or cost-based mechanisms for pricing credits are not instituted. Most importantly, an environmental mitigation banking system, operating under a variety of appropriately designed institutional arrangements, appears to align economic activity with ecosystem size - a relationship that has been blatantly ignored in orthodox economics. Environmentalists and ecologists have emphasized such an alignment (Daly 1991, 1996), but the operational means for achieving it remain to be worked out. The experimental process used in this paper to arrive at an appropriate design for an environmental mitigation banking system is seen in general to be of significant importance to the design of new institutions and for improving the performance of existing ones since it creates a test bed for institutional design.

INSTITUTIONS AS INSTIGATORS OF POLICY IN AN ECONOMIC SYSTEM

Peter Soderbaum (1987) points out, "...institutionalists have made many theoretical and policy oriented contributions. They have also made suggestions about how inquiry in society can be carried out, about the potential benefits of planning and all. They have written less about specific approaches to decisionmaking, but the conceptual framework of institutional economics is certainly useful to any one who wishes to design more specific approaches." Michael Radzicki in a series of writings appearing both in system dynamics and institutional

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[1] The model programmed in *ithink* software and its equations are placed in the Appendix. A machine-readable version, only for noncommercial use, is available from the author on request. *ithink* is trade mark of High Performance Systems, Inc.

economics literature has drawn parallels between the qualitative models of how institutions create roles for the agents in an economic system and the formal models created through system dynamics modeling process (Radzicki 1988, 1990, 2003). In my observation, there is also a great similarity between the way an abstract system of roles that process information and return decisions is defined around an articulated problem in system dynamics (Saeed 2002) and how institutional economists define an institution – not as a manifestation of bricks and mortar, but as "a set of socially prescribed patterns of behavior" (Bush 1987), or as "activities of people in situations"... which includes: "1) people doing; 2) the rules including the situations in which they are followed, and 3) the folk views explaining the rules" (Neale 1987). My interpretation is that institutions are the role senders while agents, who may be a part of one or more institutions, are the role receivers as suggest by Katz and Kahn (1990).

The creation of institutions to act as policy agents is not new. Command and control institutions are widely used in numerous policy contexts and particularly in environmental policy context. Many institutions have also been created to constantly monitor information to create appropriate market interventions. The Federal Reserve Bank is an example of such institutions. I have earlier proposed the creation of a Natural Resource Board to constantly monitor a resource basket with respect to its regeneration rate and to vary a severance tax structure so what is consumed is regenerated (Saeed 1985). Herman Daly (1991) has suggested an innovative set of institutions for the proper functioning of a steady state economy. In all such proposals, institutional norms create agents that constantly process information derived from the system state and return decisions to alter this state if it deviates from designated goals.

Figure 1 illustrates the information processing and decision-making roles of the agents operating in a system of institutions. The decision rules in this system are formed by norms, values, expectations and sometimes explicit rules emanating over long term from institutions. The decision process is based on access of the agents to information and their manifest or informal contribution to the decisions delivered following those norms and rules. Clearly, this process constitutes a bounded rational rather than an absolute rational decision process as has been pointed out in the seminal work of Herbert Simon (1982). As Morecroft (1985) and Radzicki (1988) point out, such a bounded rational decision process is also a common construct, both in System Dynamics and Institutional Economics. An important point to note is that the creation of decision rules and actions occur in feedback loops that involve discerning system state. The former, however, involve a long time constant while the latter a short one.

A system dynamics model constructed as a test bed for institutional design may include both the role-sending functions of the institutions involved in the process and the role-playing functions of their agents, depending on the problem of interest. When the causes of an institutional change are to be investigated, the long-term process of changes in rules and norms must be included in the model; however, when the short-term impact of an institution is to be investigated, these long term processes need not be modeled since the activities to be addressed by the model constitute the performance of the institution, not the motivation for forming it (Saeed 1992).

Figure 1 Institutions as role senders and agents as role players

ENVIRONMENTAL RESPONSIBILITY AND ORTHODOX ECONOMICS

Orthodox economics excluded the environment from its formal analyses until early 1970s, although Harold Hotelling expressed passing concerns about market failure in the extractive resources industry as far back as 1931 (Hotelling 1931), Malthus postulated the relationship between population and resources in 1798 (Malthus 1926), and Ricardo stated the iron law of wages and rents in 1817 (McCulloch 1881). John Stuart Mills (1929) recognized the resource limitations observed by Malthus and Ricardo, but expressed faith in human prudence and intelligence to deal with scarcity. It should be noted that both Malthus and Ricardo apparently considered resources to be completely renewable since they equated them to land with fixed rather than depleting capacity, while Hotelling dealt with exhaustible resources with concerns that the market may not be able to return optimal rates of exhaustion, but without pessimism about the technology to bring to fore new sources as old ones are exhausted. These early concerns have been followed by a blissful confidence in the ability of the technological developments and prices to provide access to unlimited supplies of resources (Devarajan and Fisher 1981, Smith and Krutilla 1984). Environmental analysis seems to have appeared as an add-on in response to a careful re-evaluation of the resource constraints by Barnett and Morse (1963) and an environmental movement that received a substantial impetus from the famous *Limits to Growth* study (Meadows, et. al. 1972, 1992). In this add-on, the classical economics theory has continued to assume mineral resources to be unlimited expecting prices and technological developments to continue to unearth richer mines so less profitable existing mines may be abandoned (Robinson 1980).

Solow's 1974 Richard T. Ely lecture made a strong argument for integrating the depletion of resources into models of economic growth (Solow 1974), but the momentum of orthodox economics' effort has nonetheless not deviated much from its earlier focus on optimal rates of depletion and the pricing of resources (Nordhaus 1964, 1979) without concerns for environmental capacity, which are mostly expressed in passing. There have been some concerns also expressed about intergenerational equity, but its treatments remain tied to arbitrary rates of discount (Hartwick 1977, Solow 1986). Notable exceptions to this practice include the writings of Georgescu-Rogen (1971) and Kenneth Boulding (1981), and more recently, Herman Daly (1991) and Robert Costanza who have spearheaded the ecological economics movement (Costanza et. al. 1997) that emphasizes the importance of connecting the volume of human activity to the size of the environment. Barring these few exceptions, present day environmental economics texts are primarily built on micro-economic theory concerned mostly with the optimal pricing of resources and environmental degradation (Tietenberg 2003, Field and Field 2002) with only passing references to intergenerational equity and environmental capacity.

In a more practical policy context, the famous Brundtland Report (1987) defined sustainable development as "development that meets the needs of the present without undermining the ability of the future generations to meet their own needs." This definition was widely applauded at the famous 1992 Rio conference on environment, but its proponents continue to be seen as activists rather than scholars and its principles are rarely incorporated into what has appeared as orthodox environmental economics in which discounting the future is a norm and policy is driven by optimal rates of consumption rather than by the principle of keeping the intergenerational transfer of costs and benefits to zero. There also remain many missing links between the various theoretical threads and practice, in part because theoretical concerns, whether based on environmental pessimism or technological optimism, are difficult to translate into operational policy clearly defining goals and choice of instruments (Dietz and Straaten 1992). Hence environmental concerns have translated mostly to moral statements and activist values rather than to policy.

Mitigation Banking is an institutional innovation, developed in most part by engineers, geographers and foresters and mentioned only in passing in the texts on environmental economics. It has been put to work only in few locations and in limited contexts like preservation of wetlands and forests, although it promises to be an important institution for restoring environmental responsibility into a society that has moved away from it on the false promise of technology's ability to make available a bigger and richer basket of resources in the foreseeable future (Saeed 1985). A new institution, however, cannot be created in a vacuum. It must be designed carefully to function and deliver its mandate in an existing system. Hence, as all institutions should be, a mitigation banking system needs to be carefully designed and tested before its scope is expanded to include a variety of environmental and regional contexts, so that its reliable performance is assured.

Designing and testing of prototypes is an integral part of the engineering and applied sciences, but this process has not been instituted in economics for lack of our ability to construct appropriate test beds. System dynamics modeling practice creates an opportunity for us to construct such test beds. I have in the past advocated the use of system dynamics modeling to develop operational implementation instruments for normative policy statements (Saeed 1992) and have attempted to demonstrate this process by constructing a model for operationalizing the recommendations of the Limits to Growth study (Acharya and Saeed 1996, Saeed 1998), and for designing innovation organizations (Saeed 1998a). I have attempted in this paper to extend this process to testing the performance of a mitigation banking institution working under a variety of regulatory and organizational arrangements, building on my earlier attempts presented in Saeed & Fukuda (2002) and Saeed & Fukuda (2003).

MITIGATION BANKING AS AN ENVIRONMENTAL RESPONSIBILITY INSTITUTION

As long as the scale of human settlements was small, and the resource basket used was constituted mostly by locally found renewable resources, the resource limits remained easily recognizable. It is not surprising that indigenous knowledge enabled traditional societies to live in a way that maintained a balance between development and environment. For example, ancient agricultural methods such as slash-and-burn farming were restricted to small ranges, desert cultures adopted nomadic ways to assure regeneration of the oases that sustained them, planting trees was believed to earn spiritual merit, and fallow practice and diversity of crops were widely used as standard farming practices that sustained land fertility.

The indigenous knowledge and beliefs at that scale allowed the human society to live in harmony with nature and the questions of conquering it or sustaining it did not arise (Daly 1991). As technological developments allowed access to huge stocks of nonrenewable resources that seemed to be unlimited, and this together with the availability of modern transportation networks allowed the scale of the human settlements to grow, multiple societal functions had to be broken away from individual roles to become resident in specialized institutions for the sake of expediency. Unfortunately, the societal function of environmental responsibility that came naturally to small-scale societies with holistic individual roles fell through specialization cracks since institutions taking over this function were never thought about until evidence of deterioration in environment appeared. The impending danger of disaster that can be created by indiscriminate growth and resource consumption raised some thirty years ago by the Limits to Growth study (Meadows et. al. 1972, 1974) is now quite widely recognized (Boulding 1993, Cleveland 1991).

Even when the need for restoring environmental responsibility to society has been recognized, creating reliable designs for incentives and institutions cultivating responsibility functions still remains difficult. Unlike engineering where technical innovations can be transformed into prototypes and tested extensively before being put into practice, social innovations are often implemented while they are still in the concept stage since the means to test their reliability have been limited. Indeed, a large variability has been widely experienced in the performance of social and economic development agendas (Saeed 1994).

Many institutional concepts have been proposed to restore environmental responsibility in society once its need was recognized. Examples of these include the creation of private national trusts that would purchase and maintain historical heritages and reserves; the imposition of environmental taxation on the production of commodities so their price is modified in accordance with the environmental burdens they create; the trading of emission rights so the cost of environmental degradation can be borne by the responsible parties with the help of the market, and mitigation banking so environmental degradation is off-set by a compensatory restoration effort while the cost of mitigation is borne by the parties who consume environmental resources (MITIGATION BANKING *website*). Whether these concepts can reinstate the environmental responsibility function in society cannot be ascertained, since designs based on these concepts have not been tested adequately to allow us to guarantee their success.

The compensatory mitigation concept supports the notion that the net loss of environmental value resulting from development and maintenance of infrastructure is maintained at zero. When mitigation is carried out within a developed area, a complete status quo in environmental resources can be maintained, but this may not always be a feasible solution. When the development and mitigation areas can be geographically separated, the net loss of environmental value might still be maintained at zero while the loss and gain areas are different. In such a case, mitigation banks can be formed to carry out the mitigation work and sell the credits so earned to a developer. The mitigation banking creates a trading system whereby deposits can be credited in advance of development by means of ecosystem creation or restoration. Since the restoration effort might be concentrated in a selected area, this process can also help to alleviate ecosystem fragmentation. Also, since a bank can specialize in particular types of restoration work, any restoration activity would be more reliable and ecosystem restoration failure may be avoided. Furthermore, unforeseen costs in the case of direct restoration by the developers may be avoided since the failure rate is progressively reduced as a mitigation bank develops technical expertise in its work. Last, but not least, since the regulation accompanying mitigation banking creates a cost for projects that degrade the environment, those projects are likely to be implemented in a way that minimizes this cost and hence the accompanying environmental damage.

A mitigation banking system may function under a variety of organizational and regulatory arrangements. It can be established in the public or private sector. The price of the mitigation credits it creates can be fixed, tied to costs using engineering methods, supported by subsidies, determined by the market, or influenced by combinations of all of these factors. Furthermore, the regulations governing the requirement of mitigation credits for the formation and operation of the built environment may be fixed or tied to the condition of the environment. Many views exist on what might be an appropriate way for a mitigation bank and mitigation regulation to function. Currently, the establishment and use of mitigation banks are being promoted in many countries. In the United States, active mitigation banking systems are in place in Minnesota, Florida and California for preserving forests and wetlands. In all cases, the implementation of the concept is in a nascent stage and its efficacy under a variety of arrangements needs to be carefully evaluated (Mitigation Banking *Website*, Mitigation Banks *Website*), before the scope of its use can be expanded to cover a variety of environmental contexts.

MODELING AN ENVIRONMENTAL MITIGATION BANKING SYSTEM

Key agents in an environmental mitigation banking system include 1) human activity that creates a built environment or man-made capital, 2) an ecosystem that is consumed by the building and operation of man-made capital, 3) mitigation banking that engages in the creation of environmental restorations and banking mitigation credits, 4) a regulatory process creating and modifying credit requirements, 5) a regulatory compliance process that enforces credit requirements on developers, 6) pricing norms imposed on mitigation banks – including price fixing by an authority, engineering models connecting price to cost, and market mechanisms connecting price to supply and demand considerations, and 7) government and foundation subsidies to speed-up restoration activity. Some of these agents were included in models presented earlier in Saeed & Fukuda (2002) and Saeed & Fukuda (2003), which assumed constant damage costs and restoration costs with a fixed requirement of credits for each unit of construction and operation. These assumptions have been relaxed in the model I have developed for this paper to represent interactions between the environment, conservation and development. I have also attempted in this paper to more clearly define decision rules at two levels for each agent: those for interaction between agents and those for making decisions within each agent.

a) Interaction between system agents

Figure 2 shows a map of the model at the level of interaction among its various agents. These agents are grouped according to the functions they perform. Thus, Human Activity represents the creation and operation of infrastructure and the built environment. This includes man-made capital and the production carried out with it. The Ecosystem represents the natural capital that is consumed by human activity. These are the only two agents in the system before the mitigation banking institution is introduced, and there exists a unilateral relationship between them in which Human Activity may only consume the Ecosystem.

The introduction of mitigation banking creates at the outset four new agents: 1) Mitigation Banking that undertakes to restore the environment, earn and bank mitigation credits in the process, and sell them to the Human Activity agent; 2) a Regulatory Policy that defines the requirements for credits for any human activity to go on, 3) a Compliance Process that enforces the regulatory requirements on human activity; and 4) a Credit Pricing process which returns a constant price in default unless influences from market and restoration cost considerations are activated.

Ecosystem restoration costs depend on the condition of the ecosystem. A better condition returns a lower cost. When the price of credits is linked to the restoration costs, the ecosystem's condition influences price, but after some delay, representing perceptions and engineering evaluation processes. Any market influence on price, on the other hand if in place, depends on the demand for credits arising from policy compliance and their supply created by mitigation banking. Mitigation banking, if influenced by market, in turn responds to price in forming its expectations of profit, while price also influences policy compliance through a similar expectation process. A high price creates a deferment of credit purchases, a low price leads to purchases for future use. Regulatory policy determines the requirements for credits either autonomously or on basis of ecosystem condition. Compliance of regulatory policy affects the demand for credits, which creates an input to the market-based pricing agent as well as to the mitigation bank through the purchase of credits, which in turn facilitates compliance. Credit price also affects human activity. A high price drains cash resources of the agent carrying out human activity, creating a constraint to growth. A low price conserves those resources and supports growth.

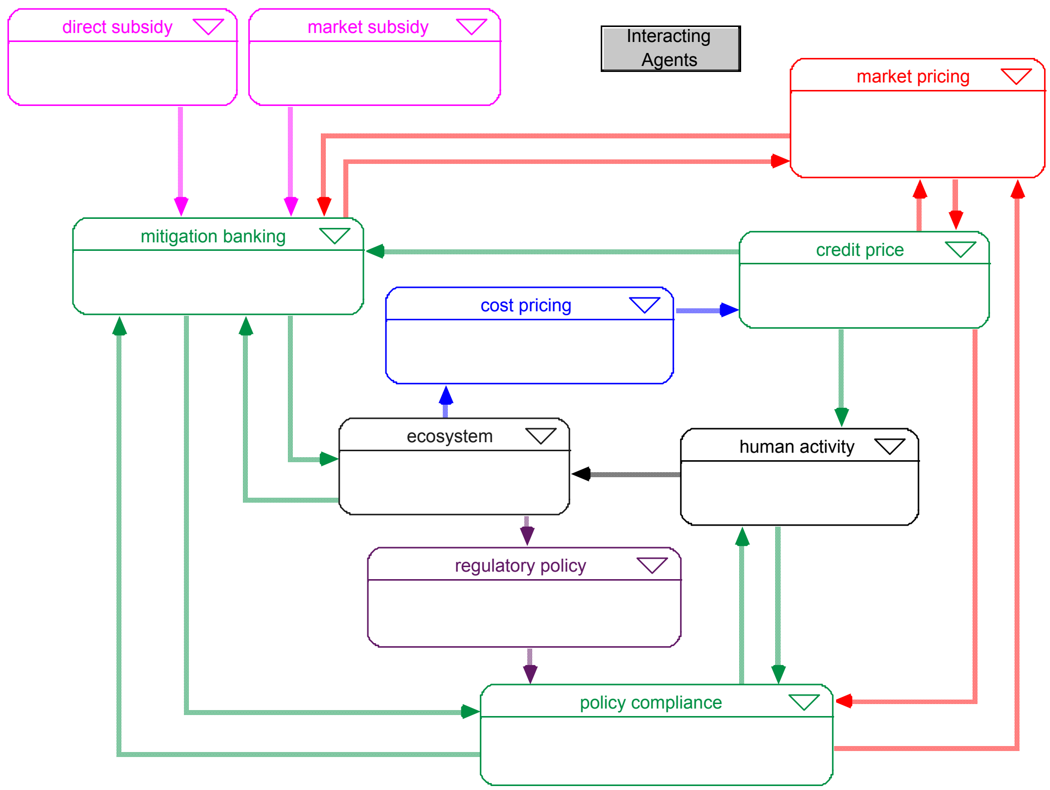


Figure 2 Agents created with introduction of mitigation banking and interaction between them.

Another important instrument affecting system performance is the subsidization of mitigation banking activity, which will indirectly support human activity by increasing credit supplies and lowering the price of credits. This subsidy can be provided as direct support to the mitigation bank in the form of tax rebates or cash for operation, or through the market by purchasing a designated amount of credits and retiring them so mitigation activity is supported while at the same time the shortage so created enhances credit price and further improves financial incentives for mitigation activity.

Structuring the model, as shown in Figure 2, allowed testing its behavior with different combinations of agents for understanding the impact of their roles on human activity and the environment. It also provided an overall map of the interactions between the various agents in the system and the feedback loops formed through them.

b) Information structure driving each agent

Each agent shown in Figure 2 is driven by the decision rules created by its own working environment and reacts to information received from the other agents. The internal structure of each agent is discussed below:

Human Activity

Human Activity is represented by a supply chain that creates built environment and operates this infrastructure as shown in Figure 3.

Infrastructure building starts depend on a fractional growth rate, which equals the decay rate in equilibrium, but is stepped up exogenously to stimulate the dynamic behavior under study. The building starts are restricted by a cash constraint issued by the financial condition of this agent and also by the regulation that requires mitigation credits for any building and operation activity.

The financial condition of this agent is determined by a comparison of its cash balance to its desired cash balance. The agent's cash balance is increased by income from services provided by the built environment and depleted by expenditure on new construction, operation of existing built environment, and the cost of credits consumed for construction and operation for complying with the regulations. This is a rather aggregate and simplified model of economic growth, which should suffice here since the policy focus is not economic policy, but the working of the new institution.

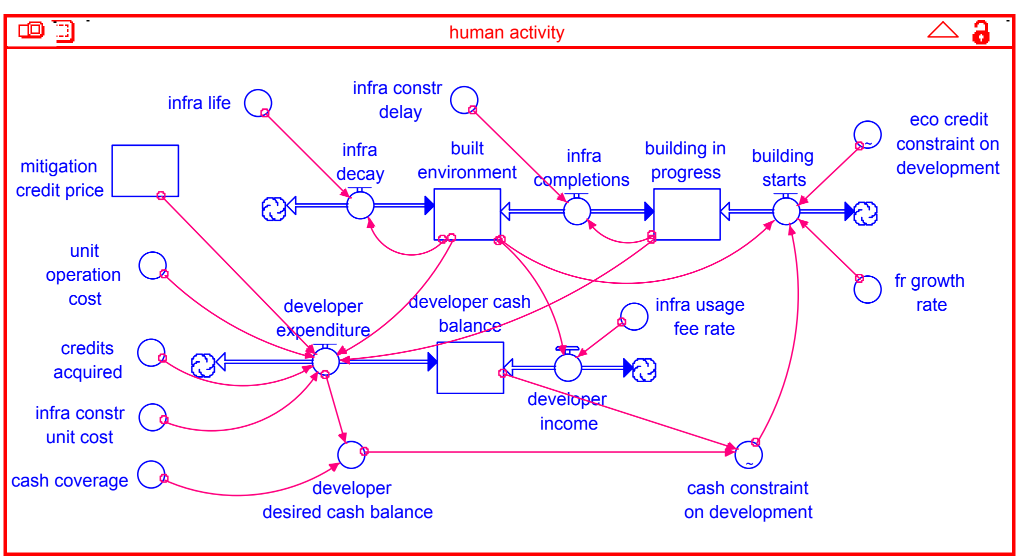


Figure 3 **The supply chain representing human activity.**

Ecosystem

The Ecosystem is represented as a supply chain incorporating both decay and restoration processes as shown in Figure 4. Since the restoration process might involve a considerable delay, a stock of restorations in progress is included in the supply chain. Marginal damage, both for new capital formation projects and for the operation of existing ones depends on the state of the environment.

Since ecosystem decay subsumes both decay and natural regeneration processes, the shape of the marginal damage index is complex as shown in Figure 4a. It forces the marginal decay rate to decline when the functional environment stock falls below its normal value, thus providing a first order control on this stock. It rises slightly when the functional environment stock exceeds its normal value, but then declines to a lower value with further increases in this stock. This logic implies that a more functional environment would invoke faster ecosystem recovery, thus reducing the net marginal damage. It also means that the normal value in the model is set at a precariously balanced condition in which the change corresponds to first order control in both directions in the first instance, but after some improvement has occurred in the environment, the marginal damage declines with further improvement.

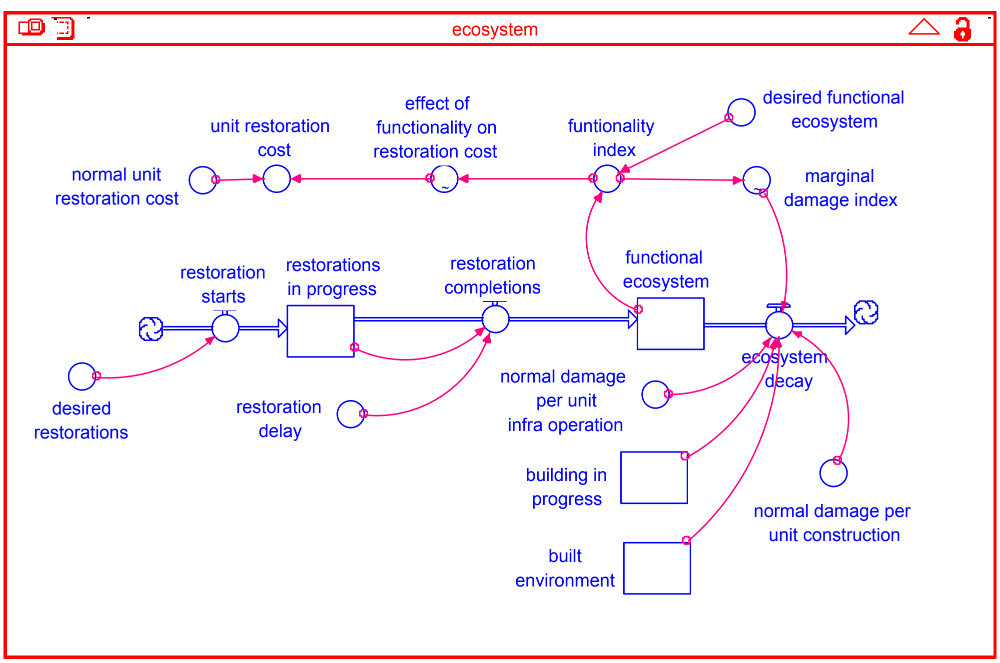


Figure 4 The supply chain representing the ecosystem

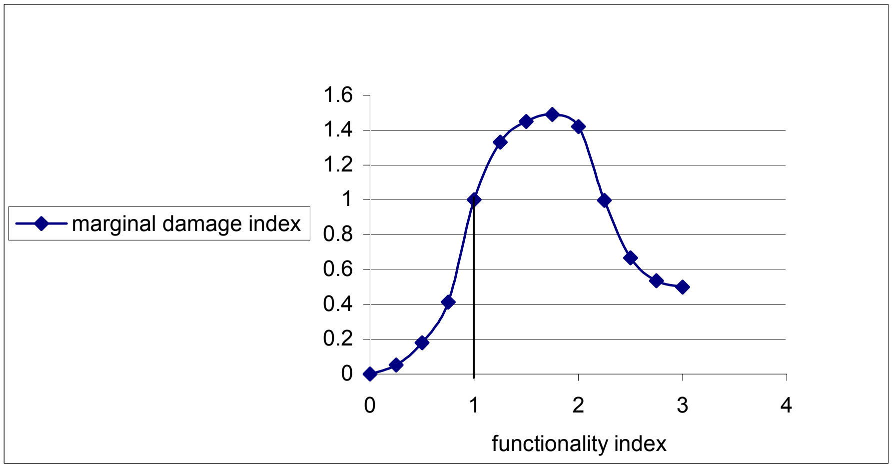


Figure 4a Relationship between functionality index and marginal damage index

The condition of the ecosystem also determines the unit restoration cost. The marginal restoration cost rises when ecosystem condition declines. The model was tested with many parameter values for these functions and the results showed little variation in the comparative patterns it generated for the inferred policy implications.

Mitigation Banking

The activities of the Mitigation Banking agent are shown in Figure 5. Mitigation banking is concerned with planning and carrying out environmental restorations, based on its cash resources and expectations of profit. Thus, its desired restorations depend on its cash balance (a fraction of which is earmarked for restoration plans), the unit cost of restoration (which determines how many projects can be undertaken), and expectations of profit (which depends on the price of credits) if the bank is set up in the private sector.

The banks expenditures are determined by the actual restorations in progress and the unit restoration cost, while its income depends on the value of the credits sold, both to human activity agents complying with the regulatory policy requirement and to organizations buying them to subsidize the mitigation activity.

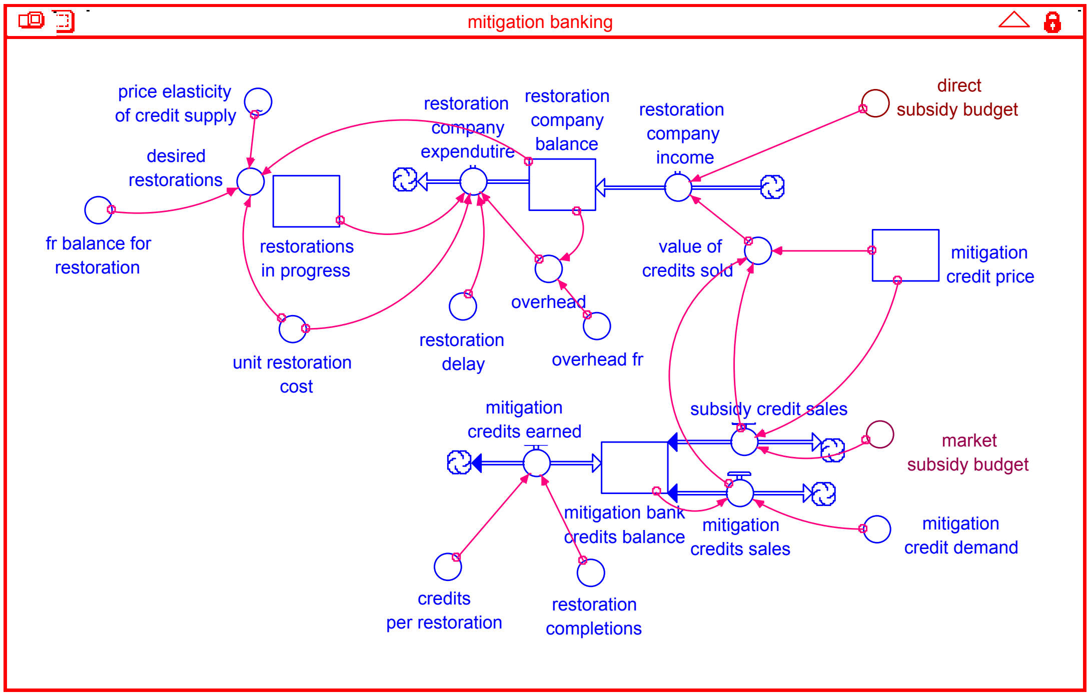


Figure 5 **Mitigation Banking managing its cash resources and mitigation credit balance**

Regulatory Policy and Policy Compliance

Regulatory policy formulation and its compliance are modeled as two different agents as shown in Figure 6. Regulatory policy only determines a modifier to the requirement of credits per unit of operation and new construction. In real life, it would require creation of an institution that continuously monitors environmental conditions to determine changes in credit requirements. When this agent is not connected to the rest of the system, credit requirements remain constant, which implies they are created only once and the expense of forming and running a monitoring institution is saved.

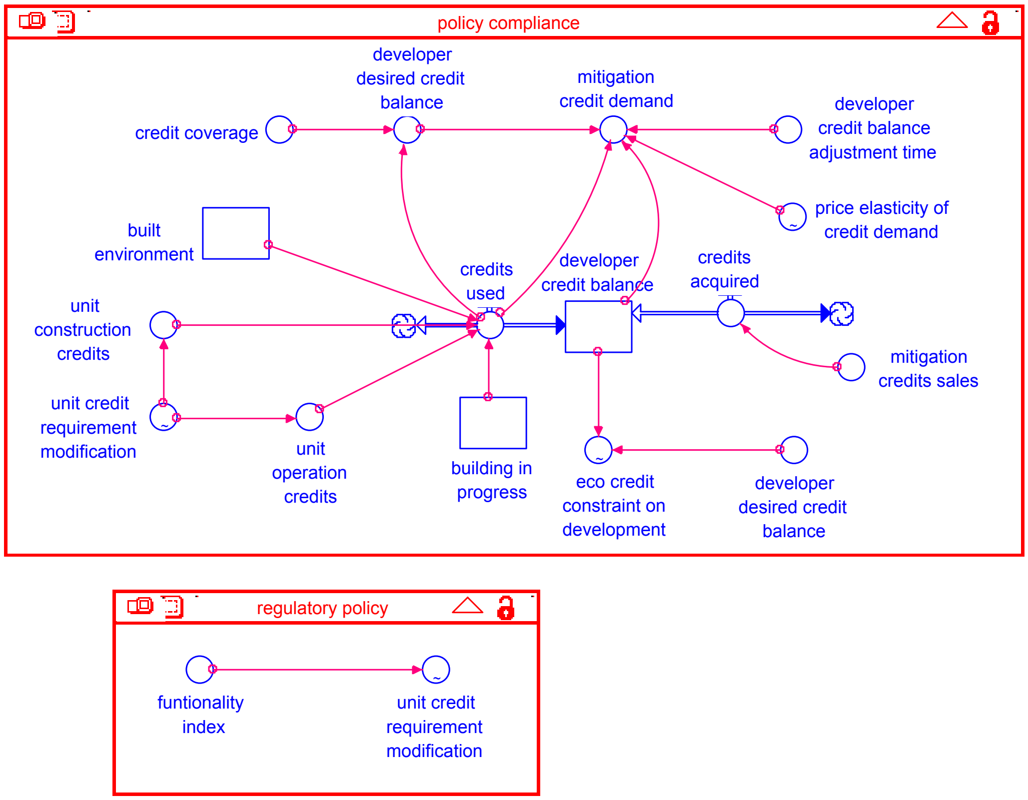


Figure 6 **Information structure created by regulatory policy and its compliance**

The compliance process occurs at the user end. The users maintain a balance of credits so they can buy them when they are offered at a good price and use them as needed. The demand for credits depends both on their rate of use and any purchases needed to maintain a desired credit balance, which is determined by an average of the usage rate and a coverage time. The credit balance is increased by the acquisition of credits and depleted by a usage rate. The usage rate depends on a combination of new construction and operation activities since the developers are required to acquire credits both for new capital formation and the operation of current infrastructure. A shortfall in this balance creates a constraint on expansion of new capital formation activity since the operation of existing infrastructure must go on. The demand for credits also affects their price, which is dealt with by the Market Pricing Agent.

Credit Price

As shown in Figure 7, Credit Price adjusts towards an indicated price, which is determined by the effects from cost-based pricing when such a pricing norm is practiced, and the elasticity of price when the market is allowed to determine price. In the absence of these two influences, price remains constant.

Price in all instances affects the demand for credits. Since credits are in most instances used by the private sector, the price elasticity of credit demand is determined by the pricing agent. On the other hand, the price elasticity of supply, and the elasticity of price, influence the expectations of the mitigation banking activity and the credit price determination respectively only when mitigation banking functions in a free market. Since these influences are determined by the market pricing agent, they are switched off when market pricing agent is not activated. In the absence of a market pricing agent, credit price may be determined by a regulatory authority, possibly on the basis of the cost of mitigation or even on arbitrarily.

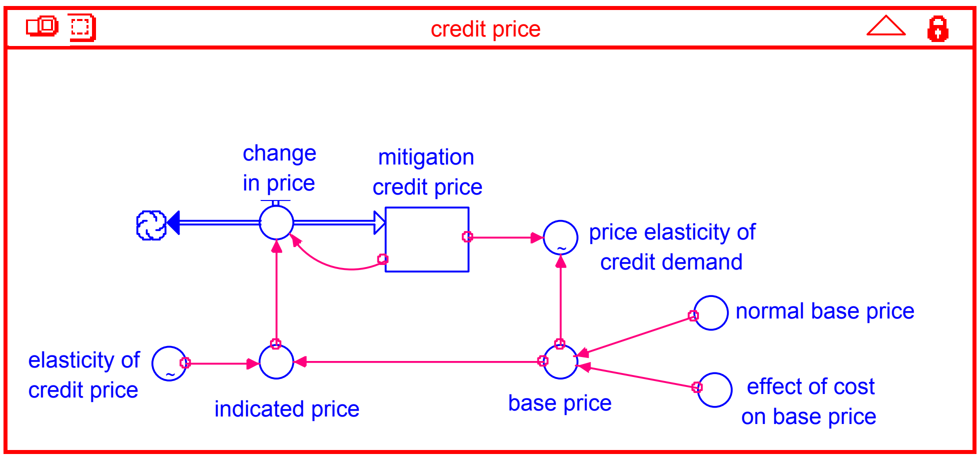


Figure 7 Determination of credit price

Pricing and Subsidization policy agents

The price elasticity of credit supply and the elasticity of credit price are determined in the market pricing sector and are activated when this sector is connected to the system during experimentation with the model. If the mitigation banking activity is carried out in the public sector, or if its pricing and production processes are highly regulated, these elasticities will be irrelevant and become constants in the model.

When price is based on restoration cost, it will be affected by the functionality of the environment. Lower functionality returns a higher restoration cost. There would, however, be a considerable delay involved with the recognition of restoration costs and their subsequent incorporation into price. These relationships are represented in the Cost Pricing agent presented in Figure 8.

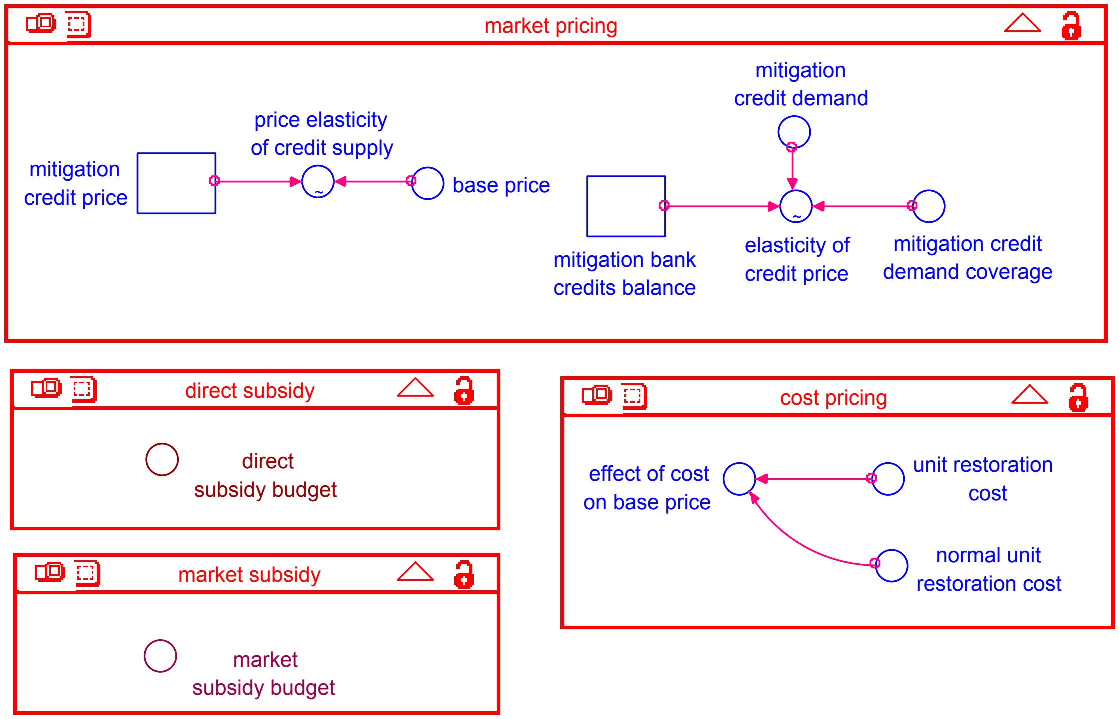


Figure 8 **Pricing and subsidization policies experimented.**

Finally, if a subsidization of mitigation activity is in place, the model provides options to include this in the system. Two types of subsidies are represented in the respective agents shown in Figure 8, and the budget for the two is kept exactly the same so that their impact for the same subsidy cost can be compared. Direct subsidy is added directly to the bank's cash balance, possibly in the form of tax rebates and grants. Market subsidy is implemented by acquiring credits for the budgeted amount at the going price and retiring them.

BASE SIMULATION RUN

As a reality check, the first experiment with the model is conducted by connecting only the human activity and the ecosystem agents, with human activity proceeding oblivious to the ecosystem and consuming it in the process. Figure 9 shows the simulated behavior of the model. As would be expected, human activity grows while the ecosystem declines, which should be expected since human activity size is not controlled in any way by the ecosystem size as has repeatedly been emphasized by ecological economists. Further simulation experiments with the model described in the next section attempt to understand the implications of establishing a mitigation banking system that imposes size considerations on human activity, via different institutional, pricing, and regulatory arrangements to arrive at an appropriate combination of policies that should align human activity to the environmental capacity.

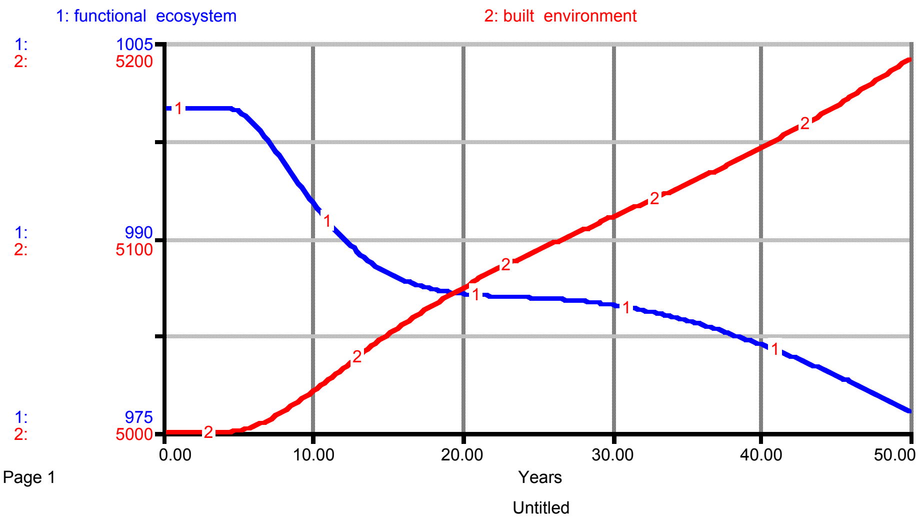


Figure 9 Growth of human activity in a declining ecosystem in the absence of an environmental responsibility institution.

PERFORMANCE OF MITIGATION BANKING INSTITUTION UNDER VARIOUS PRICING AND REGULATORY POLICIES

Many experiments were performed with the model with different combinations of pricing and regulatory conditions. Space limitations preclude a description of all of them, but I'll attempt to describe key experiments that help to identify the best policy set from the stand-point of linking the size of human activity to environmental capacity with minimal institutional overhead and without transient instability. The experiments described here include testing the model with different pricing, subsidization, and credit requirement policies.

a) Performance of a mitigation banking system with a fixed price for credits

A mitigation banking agent charging a fixed price for credits and devoting all its resources to environmental restoration will essentially be a public sector organization without any profit motives. The plots labeled 1 in Figure 10a show the behavior of such a system.

When the growth rate of human activity is stepped up, it increases the gain of the positive feedback loop 1 shown in Figure 10b, which represents the simplified causal structure of such a system. A slowdown occurs, however, in this growth from the cash drain caused by the negative feedback loop 2, created by the purchase of credits needed for new construction and maintenance. This feedback loop progressively decays the gain of the positive feedback loop 1, connecting human activity and development cash.

The purchase of credits also supplies bank cash for mitigation work that slows down the environmental decay. However, as growth creates mode decay, the cost of mitigation rises above the fixed price of credits, causing the bank cash resources to drain, which reduces the number of mitigation credits it can create. The shortage of credits imposes another constraint on the growth of the built environment through negative feedback loop 3. Hence it goes into a tailspin, bringing down mitigation banking with it since the mitigation bank cash depends on the sale of credits to support human activity.

The subsidization of such a banking agent can support mitigation activity to a level that prevents credit supply constraint from stifling human activity, which can now grow to a sustainable level. At this level, mitigation credits will be used for operation and replacement investment rather than for new capital formation. A fixed subsidy budget was experimented with and the resulting behavior is shown in the plots labeled 2 in Figure 10a. Such a budget lifts the credit supply constraint created by loop 3 to the extent determined by the subsidy budget. The improvement of the environment in the process, however, brings restoration costs down, generating surplus cash for the bank to continue its mitigation work so the ecosystem continues to improve. However, a cash drain created by the credit requirement for operation, constrains further growth in human activity.

In such a system, the growth of human activity can be further supported by varying the requirement of credits depending on environmental condition. Such a change would require establishment of an ecosystem monitoring institution that would continuously modify the credit requirement, increasing it when ecosystem conditions decline and decreasing it when conditions improve. This process, represented by negative feedback loop 4 in Figure 10b, should however be expected to involve considerable delays, which would create some instability in the adjustment of prices and costs, since measurements and decision making in the presence of consumer and producer lobbies will prevent the instantaneous adjustment of credit requirements.

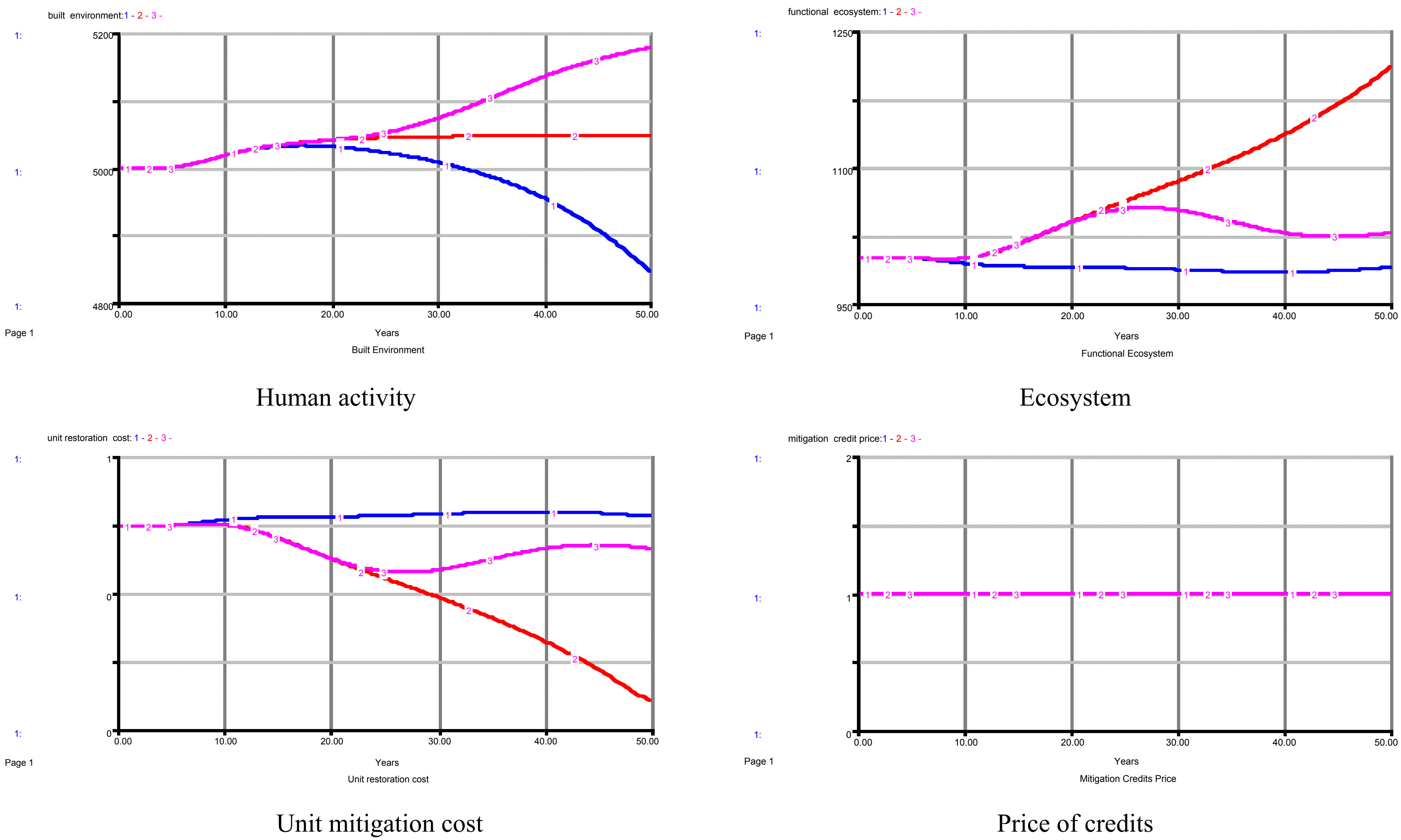


Figure 10a Behavior of human activity, ecosystem and unit mitigation cost with fixed price of credits.

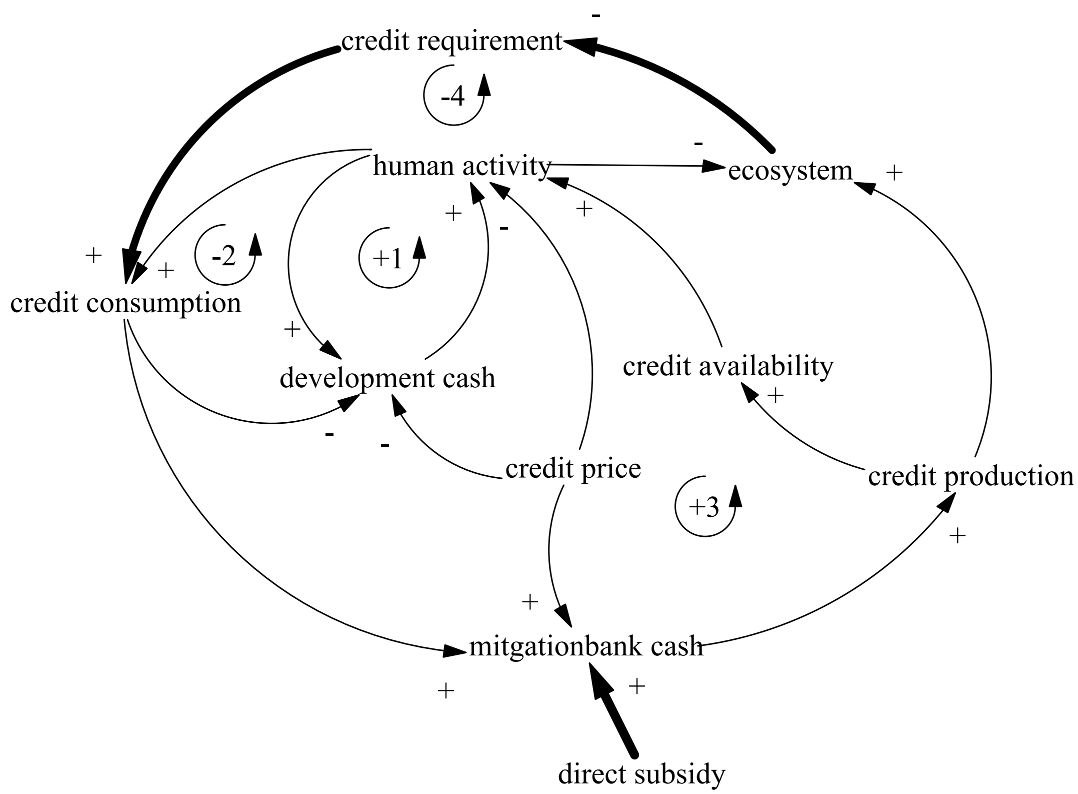
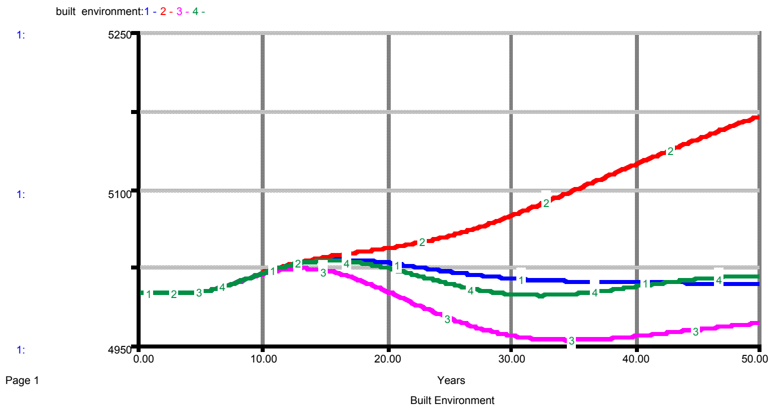


Figure 10b **Causal structure for the case of a mitigation bank operating with fixed credit prices.**

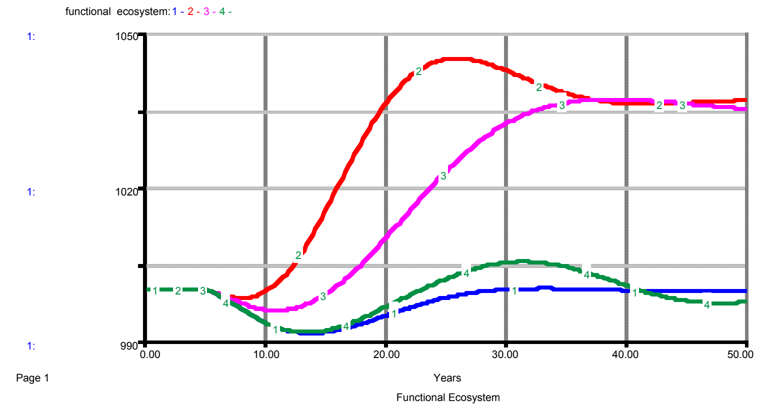
The presence of such a mechanism will, however, align mitigation costs with the price of credits and help create a level of mitigation activity that can support the growth of human activity, depending of course on the subsidy budget as shown in the plots labeled 3 in Figure 10a, which also exhibits the expected instability.

b) Performance of a mitigation banking system with price of credits tied to restoration costs

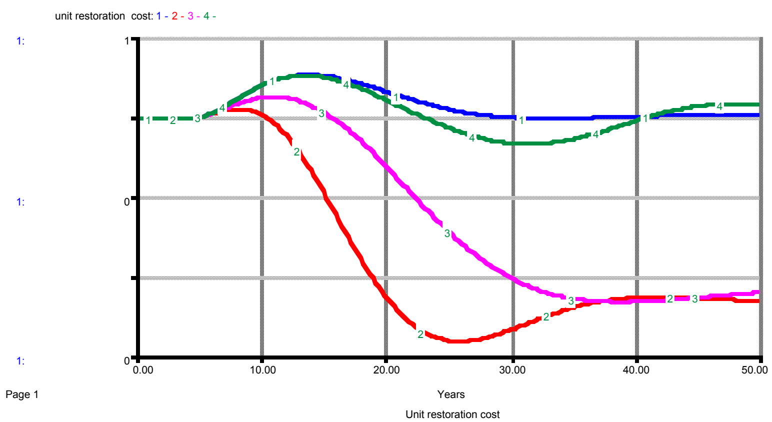
A mitigation banking agent working with a variable price of credits tied to restoration cost can take the form of a public sector monopoly or highly regulated private sector agents or NGOs. Figure 11a shows the behavior of such a system under different conditions. Figure 11b shows the simplified causal structure. Please note two new negative feedback loops labeled 5 and 6 are created by connecting the credit price to the restoration cost. Plots labeled 1 in Figure 11a show the model behavior in the absence of any subsidies and with credit requirements held constant.



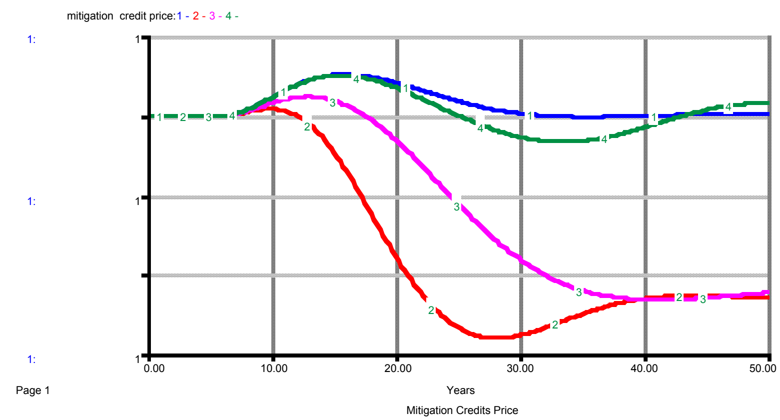
Human activity



Ecosystem



Unit mitigation cost



Price of credits

Figure 11a Behavior of human activity, ecosystem, unit mitigation cost and price of credits with price of credits tied to restoration costs.

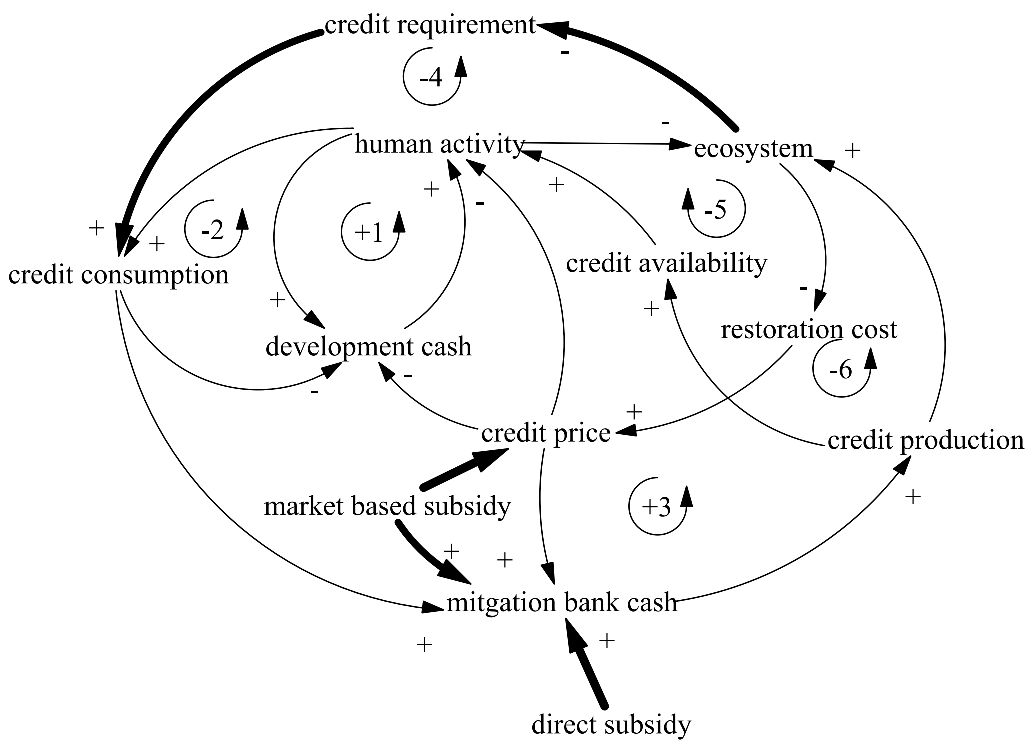


Figure 11b Causal structure for the case of a mitigation bank operating with restoration cost-based credit pricing policy.

Evidently, this pricing arrangement very nicely links human activity size to the ecosystem size, bringing both to a compatible balance, even without having a regulatory body to change the credit requirements. Negative feedback loops 5 and 6 provide the necessary controlling mechanisms needed to accomplish this.

A fixed subsidy budget directly added to the mitigation bank cash allows human activity to grow while also improving the condition of the ecosystem and lowering both credit price and mitigation cost as shown in plots 2 in Figure 11a. Such a subsidy provides additional cash for mitigation, improving environment and consequently reducing mitigation costs, which also lowers the price of credits. Low cost credits promote growth in human activity, which generates more mitigation bank cash. In the process, both better environmental quality and a modest growth rate can be accommodated.

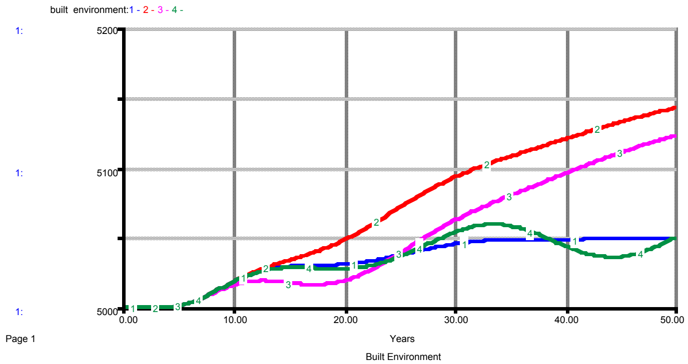
A similar subsidy budget can be given to the mitigation bank through purchasing credits and retiring them, which I have called market subsidy. Plots labeled 3 in Figure 11a show how a market subsidy performs along with a cost-based credit pricing policy. This type of subsidy increases the bank's cash resources, while also simultaneously creating a credit shortage in the system. Since the credit price is not determined by the market, the credit shortage does not increase price or fuel further production of credits. This shortage, however, stifles human activity when enough credits cannot be found for new construction. As building activity slows down, the growth created by feedback loop 1 is greatly weakened. Hence human activity suffers because of this subsidy while it is supported by a direct subsidy. The environmental quality, restoration cost, and the price of credits in both types of subsidization end up to be similar, although their transient paths are different.

Finally, the activation of negative feedback loop 4 by creating an institution to vary the requirements of credits for operation and new construction, implemented along with a cost-based credit pricing policy, further assists with the creation of compatibility between human activity and ecosystem size. However, the cost-based pricing process already delivers such a compatibility, and the delays involved in further linking the credit requirements to environmental condition also leads to some instability, which might exacerbate the business cycle activity widely found in market-based economies.

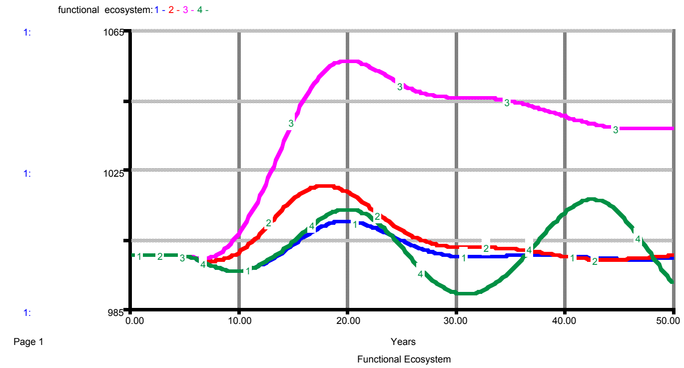
c) Performance of a mitigation banking system with credit price determined by the market

A mitigation banking agent working with prices determined by the free market would be located squarely in the private sector. It would respond to high prices by raising its profit expectations and investing more in restoration activity. It would likewise limit this activity when prices came down even when it had cash resources. Figure 12a shows the behavior of the mitigation system working in a free market with various subsidization and credit requirement determination policies. Figure 12b shows the simplified causal structure of such a system. Please note negative feedback loops 5 and 6 which linked price to restoration cost are now substituted by negative feedback loops 7 and 8 which represent influences of supply and demand of credits on their price.

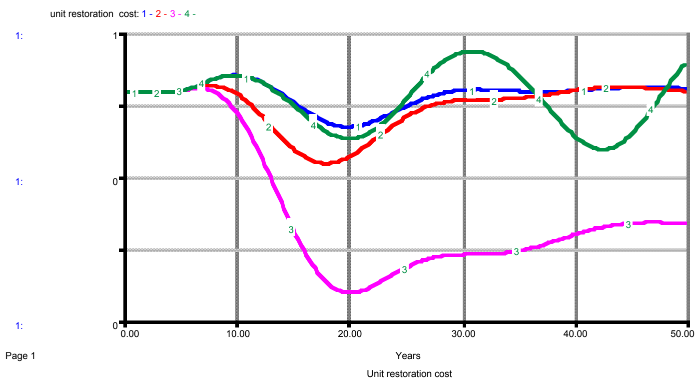
The plots labled 1 in Figure 12a show the behavior of the model with market pricing of credits, with fixed credit requirements for operation and new construction, and without any type of subsidy in place. Apparently, the market related control mechanisms in feedback loops 7 and 8 are able to align the growth rates of human activity and ecosystem so there again appears a size-compatibility between them. The price of credits and mitigation costs also come to a balance although at different levels since restoration costs as modeled exclude administrative overhead of mitigation banking. It should be noted, however, that the mandate of the mitigation banking activity, even when it operates in a free market, is not to add value to the economy (by subtracting value from the environment), but to add value to the environment, which is different from other production activities operating in the market.



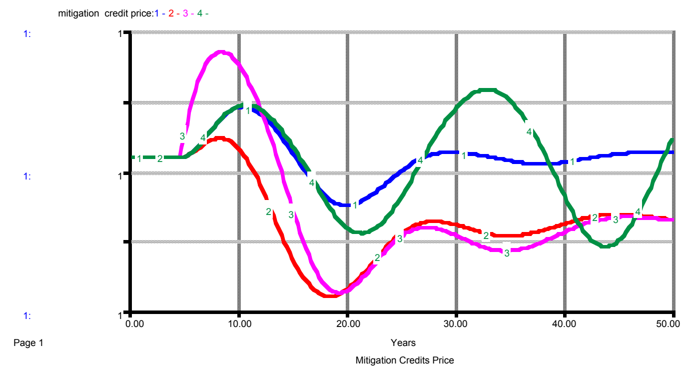
Human activity



Ecosystem



Unit mitigation cost



Price of credits

Figure 12a Behavior of human activity, ecosystem, unit mitigation cost and price of credits with credit price determined by free market.

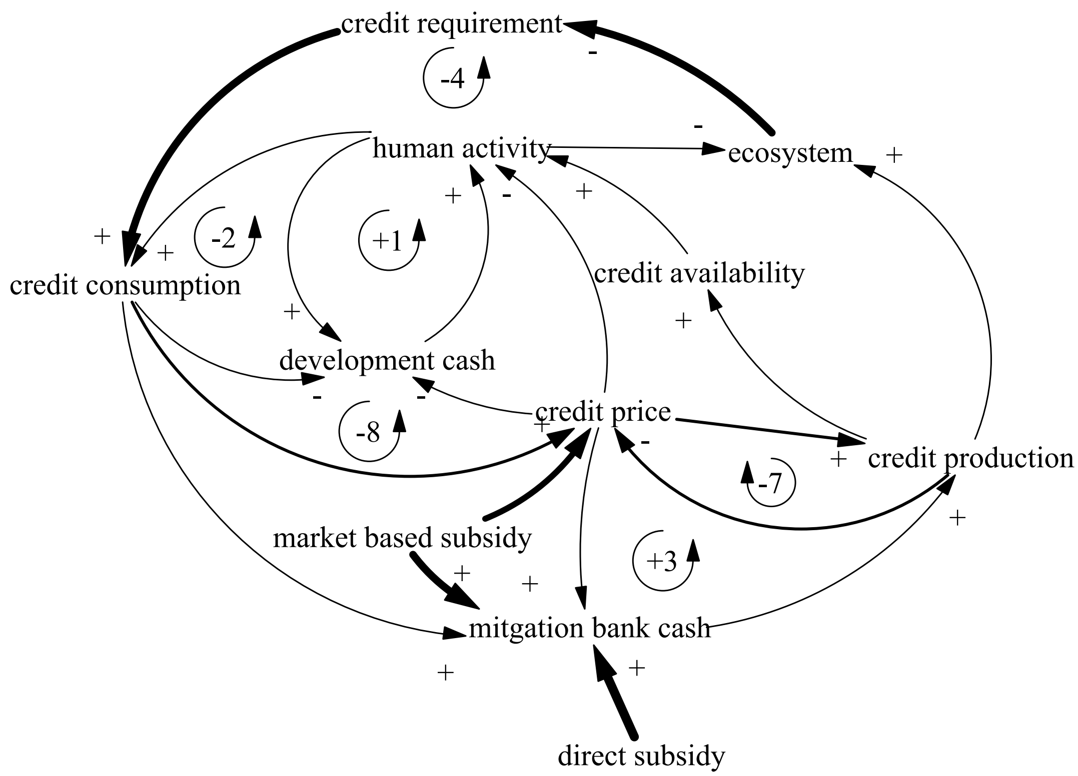


Figure 12b Causal structure for the case of a mitigation bank operating with credit price determined by the market.

Provision of a fixed and direct subsidy budget in this system leads to the plots labeled 2 in Figure 12a. Such a subsidy at first fuels restoration, increasing credit supply and lowering credit price. Consequently these two factors support the growth of human activity, which generates further cash for credit production, further increasing their supply and lowering their price. While enlarged human activity also increases ecosystem decay rates, a lower price of credits decreases profit expectations of the mitigation bank, which slows down credit production. Hence the ecosystem declines to come to a balance at its original level. However, the growth impetus provided by the profit expectations of the mitigation bank creates high economic growth rates allowing for a high level of human activity along with a high level of mitigation activity, until the two become compatible.

A market-based subsidy implemented together with a market-based credit pricing system lead to the plots labeled 3 in Figure 12a. Please note this type of subsidy creates a lower human activity growth rate together with a much higher ecosystem level than the direct subsidy. A market subsidy would increase credit prices simultaneously while adding to the mitigation bank cash. This would stifle the growth of human activity while restoration work is fueled. Hence, the system would end up with better environmental quality with slower growth in human activity.

Finally, plots labeled 4 in Figure 12b represent the presence of a monitoring system that continuously adjusts credit requirements in relation to the ecosystem condition. Apparently, this adjustment process adds considerable instability to the system, while the mean values around which this instability occurs are the same as in the case of only a market-based credit pricing system in place. When a mitigation banking institution is legislated to be a part of a free market, another institution for monitoring credit requirements may in fact be counter productive, as it would lead to instability without improving compatibility between the size of human activity and the ecosystem capacity.

d) Comparative analysis of the three cases

The simulation experiments described above show first that a mitigation banking system can help to create a compatibility between the level of human activity and the environment, and thus reintroduce environmental responsibility into the system through a variety of institutional arrangements, and second that policies that are appropriate for one type of institution may not work with another type. Thus, a policy to change credit requirements in response to changes in environmental conditions helps to align the level of human activity to environmental capacity when credit price is kept fixed, but creates instability when other alignment mechanisms such as a cost-based or a market-based pricing process is in place. The general lesson to be learned here is that an institution cannot be categorically superior to another because it exists in the private or public sector, as has been postulated in the waves of developmental concepts, which have vacillated between favoring one or the other type of institutions (Saeed 1996). Both private and public institutions can be designed to perform well, but under different regulatory norms.

A public sector mitigation bank would function well if the price of credits is kept fixed, but the credit requirement is varied according to environmental conditions and the restoration activity is subsidized to some extent if the initial price is based on current costs, which would rise with further environmental decay. There are of course costs involved with the subsidy program and the institutional arrangements for the determination of credit requirements, however, there might be economies arising from scale and specialization in the long run that have not been considered in my model.

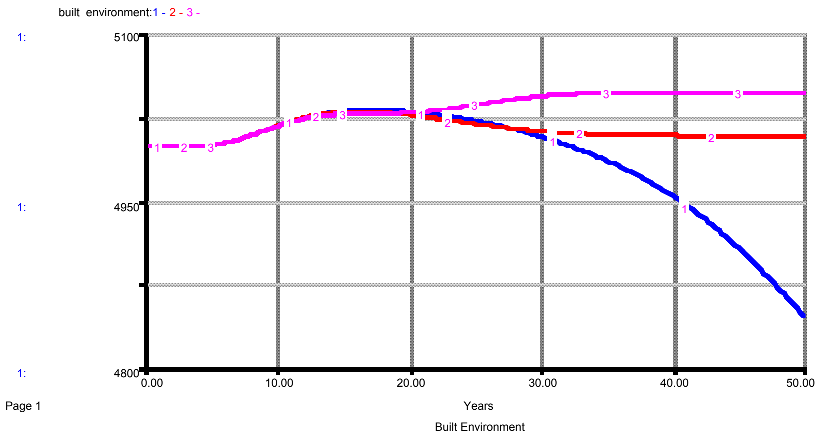
A highly regulated private or public sector mitigation banking operation that offers credits at a price based on its costs of restoration and administration may also create a compatibility between the size of human activity and environmental capacity, without the need for a subsidy or changes in credit requirements, although linking prices to costs would involve expensive engineering computations and considerable delays.

A privately administered mitigation banking system with the price of credits determined by the market can also create a compatibility between the size of human activity and environmental capacity, without the need for subsidies and expensive institutional arrangements linking costs to credit price and environmental capacity to credit requirements, (which appear to create instability rather than additional benefit), although the quality of restorations might need to be closely monitored in such a case, which would of course involve another cost.

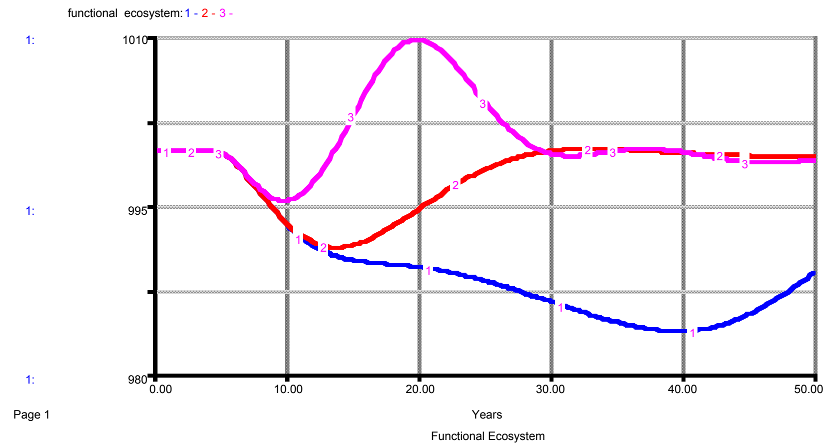
Figure 13 shows a comparison of the performance of the three types of mitigation banking institutions.

For consistency, the three cases are compared without any of them being subsidized, and without linking credit requirements to environmental conditions, which would require the expense of maintaining another institution. Plots labeled 1 represent the behavior with a fixed credit price, plots labeled 2 with credit price linked to restoration cost, and plots labeled 3 with credit price determined by the free market and mitigation activity driven also by expectations of profit. While the price of credits and mitigation costs tend to converge in all cases, the first case clearly fails to sustain either the environment or the human activity. The latter two cases lead to sustainable levels in human activity and environmental capacity, but the level of human activity is higher in the last case.

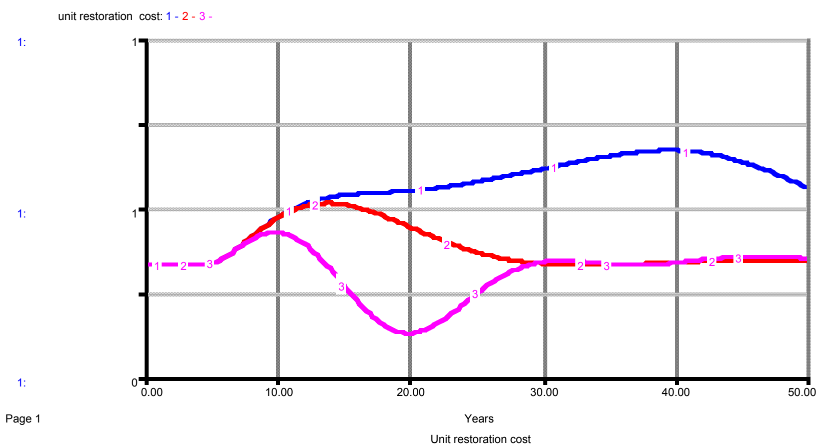
Apparently, the adjustment processes created by the market work swiftly to maintain a rate of growth that leads to a higher sustainable level in human activity than the other two cases, assuming of course that the private sector mitigation banking system will deliver reliable quality restorations. An institutional innovation that legislates value addition to environment as a market activity can change the market tendency to over-consume the open access resources of the environment and come to balance at a sustainable level.



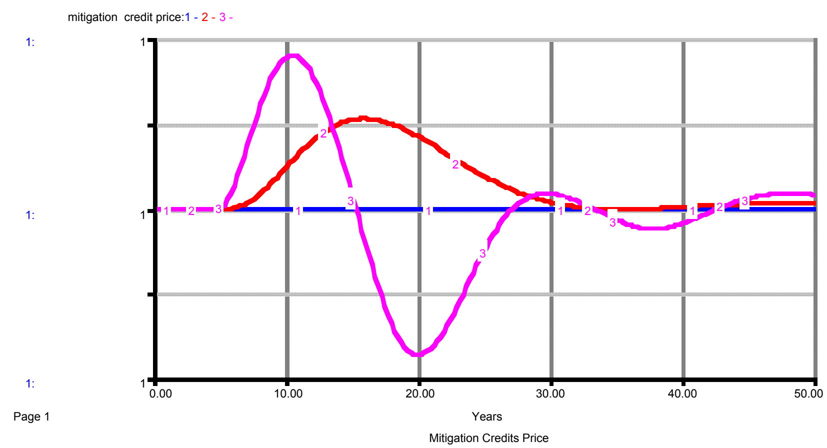
Human activity



Ecosystem



Unit mitigation cost



Price of credits

Figure 13 Behavior of human activity, ecosystem, unit mitigation cost and price of credits under different credit pricing policies governing mitigation banking.

LIMITATIONS OF THE STUDY

The model developed in this paper has several limitations.

First, human activity is modeled as a supply-side activity while in reality both demand and supply determine the rate of capital formation. While the economic growth process is approximately captured by the feedback created by the dependence of infrastructure growth on the infrastructure stock, the delays in the process are not captured. A simple model of the economy should substituted for the existing model of the human activity to capture economic growth process more realistically.

Second, the quality of restorations is assumed to be always satisfactory, whereas in reality it might be influenced by financial, organizational and technical considerations. These considerations need to be investigated.

Third, the extent of damage a developer may cause might be sensitive to the price of credits, which will create more careful construction techniques, if it is high. This aspect of development needs to be further investigated.

Fourth, government intervention can be implemented in a variety of ways, including through the general support of mitigation organizations, the support of selected projects, the allocation of general taxation to general or earmarked support of mitigation, the remedial taxation of infrastructure, price supports for mitigation credits, etc. Likewise, private organizations might also be involved in the finance of mitigation activity in a variety of ways. The impact of all such options needs to be further investigated.

Fifth, when the mitigation area is geographically separated from development area, there appears the issue of costs and benefits accrued to the various cross-sections of the population, which should determine the bounds for the operation of the mitigation system. This needs to be carefully delineated.

Last, but not least, the mitigation banking concept has to date been applied largely to wetlands and forests. Its relevance to other areas of the environment, such as air quality, atmospheric temperature, and water quality, etc., needs to be investigated.

CONCLUSION

The analysis of this paper first of all provides a way to test the design of institutional reforms before they are implemented so their impact has fewer surprises. A system dynamics model of a mitigation banking system is developed and experimented with under different organizational and regulatory conditions to illustrate the design process.

Viewed as an environmental responsibility institution for transmitting the cost of restoration to the agents responsible for damage and assuring at the same time that net damage to the environment remains zero, environmental mitigation banking has been introduced in limited niches like forests and wetlands and operated mostly in the private sector, but at a scale that its impact on human activity and environment cannot be ascertained. Many opinions exist about how this industry should be instituted and regulated, but without a clear understanding of how proposed institutional arrangements and regulatory policies would affect its performance in terms of supporting human activity, preserving environment and minimizing organizational costs and social conflicts.

Environmental restoration costs in a mitigation banking system are transmitted to users through mitigation credits, which are earned by a mitigation bank and bought by a user prior to inflicting damage to the environment. Pricing of these credits is an important aspect of the banking system and complex engineering methods connecting cost to price have been proposed as pricing criteria. Also, environmental groups often advocate subsidization of the environmental mitigation activity by the government.

Experimentation with my model suggests that the market is able to yield an optimal price without inputs from engineering methods connecting price to cost, while the delays associated with engineering calculations, when they are used to determine price, would reduce growth of human activity by stifling its multiplier effects. Subsidies would indirectly support human activity by reducing the price of credits, but for the same budget, direct subsidies support human activities more than the market-based subsidies. Connecting credit requirements to environmental condition introduces instability in all cases due to the delays involved in this process.

The model seems to perform satisfactorily in these preliminary experiments. Many more extensive experiments with additional policy space to study the implication of fiscal instruments need to be conducted to understand the role of the government and the modes of its support for mitigation activity. Furthermore, the model has many limitations that are outlined in this paper. Further work should address those limitations. The experimental method used to test the efficacy of the mitigation banking system is seen in general to be important to the design of new institutions and improving performance of existing ones.

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APPENDIX: MODEL EQUATIONS

cost pricing
effect_of_cost__on_base_price = SMTH1(unit_restoration__cost/normal_unit__restoration_cost,1)

credit price
mitigation__credit_price(t) = mitigation__credit_price(t - dt) + (change_in_price) * dt
INIT mitigation__credit_price = 1

INFLOWS:
change_in_price = (indicated_price-mitigation__credit_price)/1
base_price = normal_base_price*effect_of_cost__on_base_price
indicated_price = base_price*elasticity_of__credit_price
normal_base_price = 1
price_elasticity_of_credit_demand = GRAPH(mitigation__credit_price/base_price)
(0.00, 2.00), (0.2, 1.94), (0.4, 1.82), (0.6, 1.59), (0.8, 1.27), (1.00, 1.00), (1.20, 0.8), (1.40, 0.64), (1.60, 0.53), (1.80, 0.45), (2.00, 0.4)

direct subsidy
direct__subsidy_budget = 0+STEP(5,4)

ecosystem
functional__ecosystem(t) = functional__ecosystem(t - dt) + (restoration_completions - ecosystem__decay) * dt
INIT functional__ecosystem = 1000

INFLOWS:
restoration_completions = restorations_in_progress/restoration_delay
OUTFLOWS:
ecosystem__decay = (built__environment*normal_damage__per_unit__infra_operation+building_in__progress*normal_damage_per__unit_construction)*marginal__damage_index
restorations_in_progress(t) = restorations_in_progress(t - dt) + (restoration__starts - restoration_completions) * dt
INIT restorations_in_progress = 500

INFLOWS:
restoration__starts = desired__restorations__
OUTFLOWS:
restoration_completions = restorations_in_progress/restoration_delay
desired_functional_ecosystem = 1000
funtionality__index = functional__ecosystem/desired_functional_ecosystem
normal_damage_per__unit_construction = .1
normal_damage__per_unit__infra_operation = .01
normal_unit__restoration_cost = .5
restoration_delay = 5
unit_restoration__cost = normal_unit__restoration_cost*(effect_of__functionality_on__restoration_cost)
effect_of__functionality_on__restoration_cost = GRAPH(funtionality__index)
(0.00, 5.00), (0.2, 3.25), (0.4, 2.20), (0.6, 1.64), (0.8, 1.25), (1.00, 1.00), (1.20, 0.75), (1.40, 0.62), (1.60, 0.54), (1.80, 0.5), (2.00, 0.5)
marginal__damage_index = GRAPH(funtionality__index)
(0.00, 0.00), (0.25, 0.0525), (0.5, 0.18), (0.75, 0.413), (1.00, 1.00), (1.25, 1.33), (1.50, 1.45), (1.75, 1.49), (2.00, 1.42), (2.25, 0.997), (2.50, 0.667), (2.75, 0.535), (3.00, 0.5)

human activity
building_in__progress(t) = building_in__progress(t - dt) + (building__starts - infra__completions) * dt
INIT building_in__progress = 500

INFLOWS:
building__starts = built__environment*fr_growth__rate*cash_constraint_on_development*eco_credit__constraint_on__development
OUTFLOWS:
infra__completions = building_in__progress/infra_constr__delay
built__environment(t) = built__environment(t - dt) + (infra__completions - infra_decay) * dt
INIT built__environment = 5000

INFLOWS:
infra__completions = building_in__progress/infra_constr__delay

OUTFLOWS:
infra_decay = built__environment/infra_life
developer_cash__balance(t) = developer_cash__balance(t - dt) + (developer__income - developer__expenditure) * dt
INIT developer_cash__balance = 400

INFLOWS:
developer__income = built__environment*infra_usage__fee_rate
OUTFLOWS:
developer__expenditure = building_in__progress*infra_constr_unit_cost+credits_acquired*mitigation__credit_price+unit__operation__cost*built__environment
cash_coverage = 2
developer__desired_cash_balance = SMTH1(developer__expenditure,2)*cash_coverage
fr_growth__rate = .02*(1+STEP(.1,4))
infra_constr_unit_cost = .1
infra_constr__delay = 5
infra_life = 50
infra_usage__fee_rate = .04
unit__operation__cost = .01
cash_constraint_on_development = GRAPH(developer_cash__balance/developer__desired_cash_balance)
(0.00, 0.00), (0.2, 0.28), (0.4, 0.5), (0.6, 0.7), (0.8, 0.86), (1.00, 1.00), (1.20, 1.13), (1.40, 1.24), (1.60, 1.32), (1.80, 1.37), (2.00, 1.40)

mitigation banking
mitigation_bank__credits_balance(t) = mitigation_bank__credits_balance(t - dt) + (mitigation__credits_earned - mitigation__credits_sales - subsidy_credit_sales) * dt
INIT mitigation_bank__credits_balance = 100

INFLOWS:
mitigation__credits_earned = restoration_completions*credits_per_restoration
OUTFLOWS:
mitigation__credits_sales = MIN((mitigation__credit_demand),mitigation_bank__credits_balance/1)
subsidy_credit_sales = market__subsidy_budget/mitigation__credit_price

restoration_company_balance(t) = restoration_company_balance(t - dt) + (restoration__company__income - restoration_company__expendutire) * dt
INIT restoration_company_balance = 200

INFLOWS:
restoration__company__income = value_of__credits_sold+direct__subsidy_budget
OUTFLOWS:
restoration_company__expendutire = (restorations_in_progress*unit_restoration__cost)/restoration_delay+overhead
credits_per_restoration = 1
desired__restorations__ = ((restoration_company_balance*fr_balance_for__restoration)/unit_restoration__cost)*price_elasticity_of_credit_supply
fr_balance_for__restoration = .25
overhead = restoration_company_balance*overhead_fr
overhead_fr = .25
value_of__credits_sold = mitigation__credit_price*(mitigation__credits_sales+subsidy_credit_sales)

policy compliance
developer__credit_balance(t) = developer__credit_balance(t - dt) + (credits_acquired - credits_used) * dt
INIT developer__credit_balance = 200

INFLOWS:
credits_acquired = mitigation__credits_sales
OUTFLOWS:
credits_used = built__environment*unit__operation__credits+building_in__progress*unit__construction__credits
credit_coverage = 2
developer_desired_credit__balance = SMTH1(credits_used,2)*credit_coverage
developer__credit_balance__adjustment_time = 5
mitigation__credit_demand = ((SMTH1(credits_used,2)+(developer_desired_credit__balance-developer__credit_balance)/developer__credit_balance__adjustment_time))*price_elasticity_of_credit_demand

unit__construction__credits = .1*unit_credit__requirement__modification
unit__operation__credits = .01*unit_credit__requirement__modification
eco_credit__constraint_on__development = GRAPH(developer__credit_balance/developer_desired_credit__balance)
(0.00, 0.00), (0.2, 0.29), (0.4, 0.51), (0.6, 0.7), (0.8, 0.86), (1.00, 1.00), (1.20, 1.11), (1.40, 1.21), (1.60, 1.29), (1.80, 1.33), (2.00, 1.35)

regulatory policy
unit_credit__requirement__modification = GRAPH(SMTH3(funtionality__index,5))
(0.00, 4.00), (0.2, 3.06), (0.4, 2.26), (0.6, 1.70), (0.8, 1.30), (1.00, 1.00), (1.20, 0.74), (1.40, 0.46), (1.60, 0.26), (1.80, 0.1), (2.00, 0.00)