OSU~EmEA-19

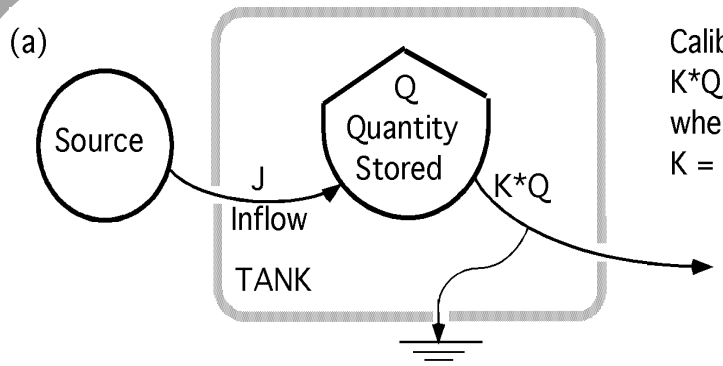
Models & Simulation

Theory, models, and simulation of economic interfaces, economic use of nonrenewable resources, environment, natural capital.

Review ...

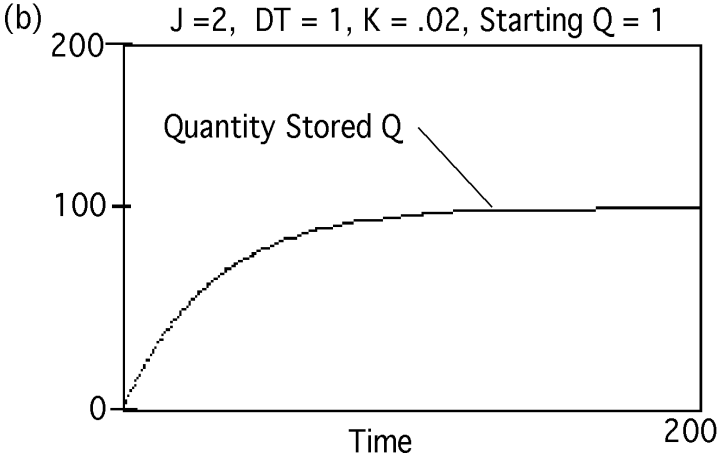
TANK: a Model of Storage

Storage "Tank" the rate of change is equal to the inflows minus the outflows



Rate of Change of Quantity Stored: DQ = J - K*Q

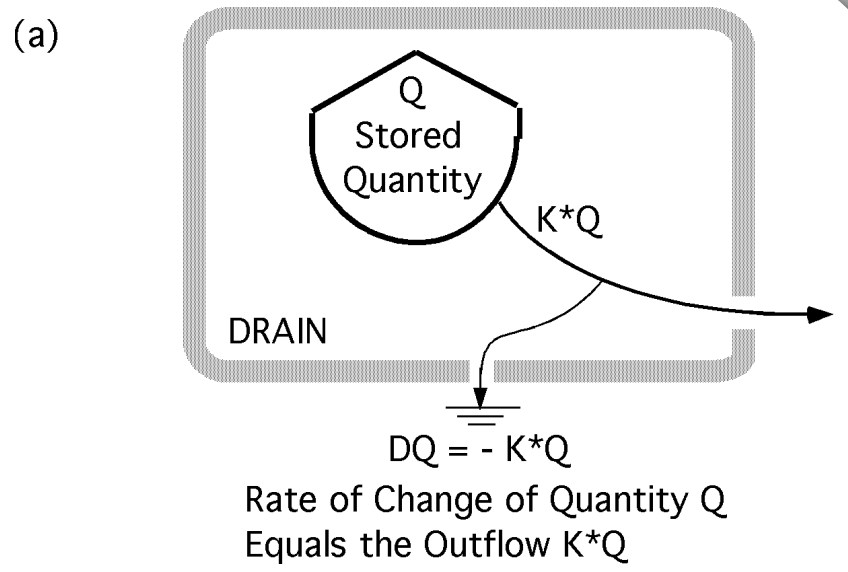
Stored Quantity: Q = Q + DQ*DT

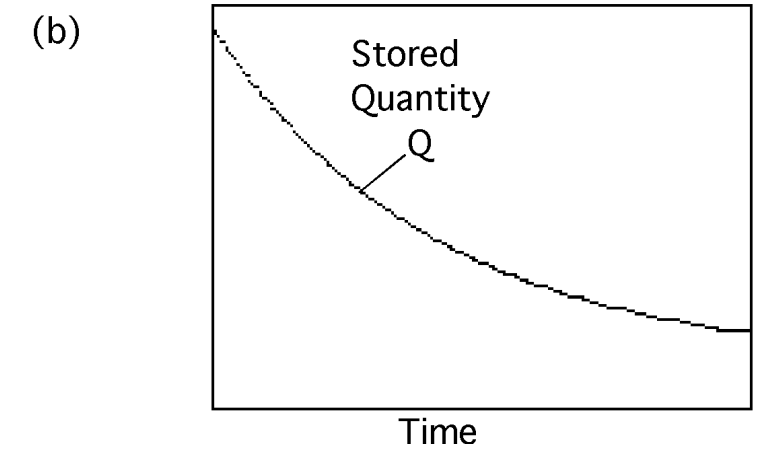


Review ...

TANK: a Model of Storage

With no inflow, the storage tank declines at a decreasing rate since the pressure (Q) decreases as the tank empties

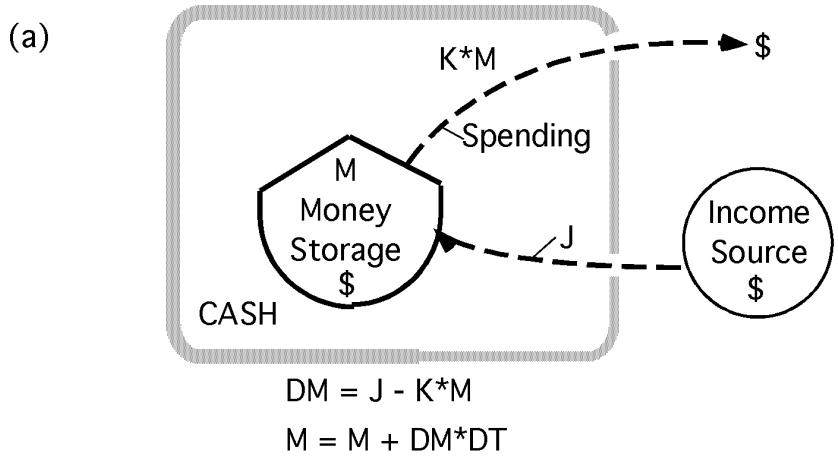




Review …

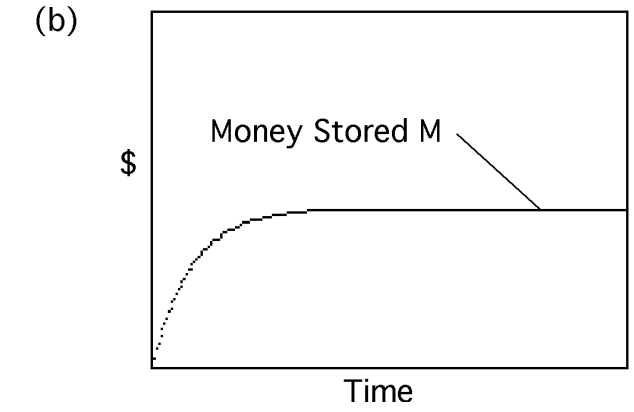
MoneyStor: a Model of Money Storage

Money is represented by a dashed line. The money storage acts just like any other storage…the rate of change equals the inflow minus the outflow



DM = J - K*M

M = M + DM*DT



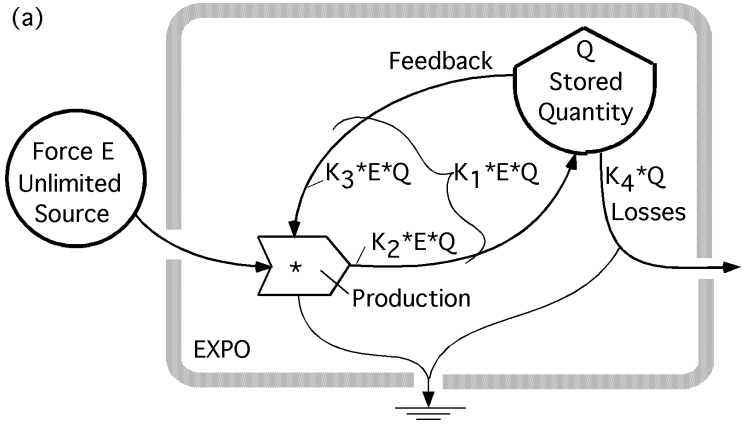
Review ...

EXPO: A model of Exponential Growth

The autocatalytic module grows exponentially with a unlimited source.

(as long as the k2 is greater than k3)

(a)



Stored Quantity Q: $DQ = K_2*E*Q - K3*E*Q - K_4*Q$

Computer Equation: $DQ = K_1*E*Q - K4*Q$

(b) Other Forms of the Equation:

Differential Equation: $dQ/dt = K_1*E*Q - K_4*Q$

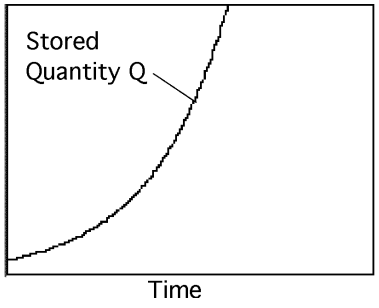
When E is Constant: $\frac{dQ}{Q*dt} = (K_1*E - K_4) = K$

Integral Equation: $\int \frac{dQ}{Q} = \int K*dt$

Logarithmic Form: $\text{Log}_e\ Q/Q_0 = K*T$

Exponential Form: $Q/Q_0 = \exp^{K*T}$

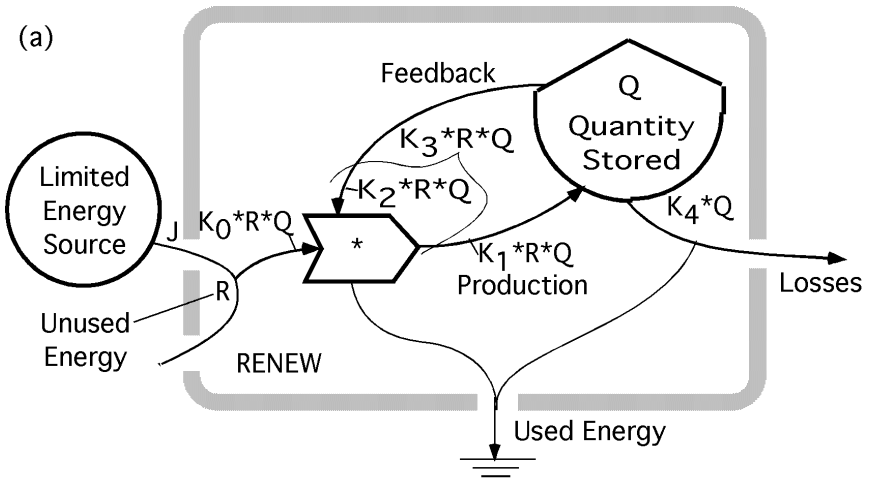
(c)



Review ...

RENEW: Autocatalytic Growth on a Renewable Source

The model RENEW has a renewable energy source also known as a flow limited source. Growth on a flow limited source exhibits diminishing returns as the available energy (Unused energy) is used up.



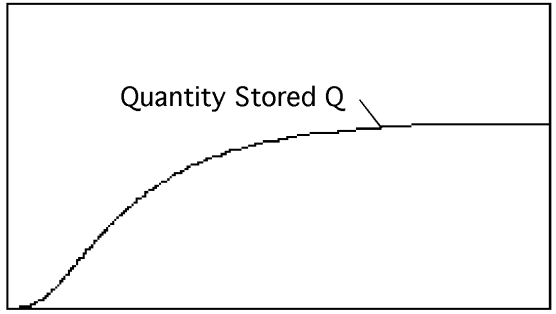
Energy Available: $R = J - K_0*R*Q$ and $R = J/(1 + K_0*Q)$

Quantity Stored Q: $DQ = K_1*R*Q - K_2*R*Q - K_4*Q$ or

By Combining Pathways $DQ = K_3*R*Q - K_4*Q$

where $K_3 = K_1 - K_2$

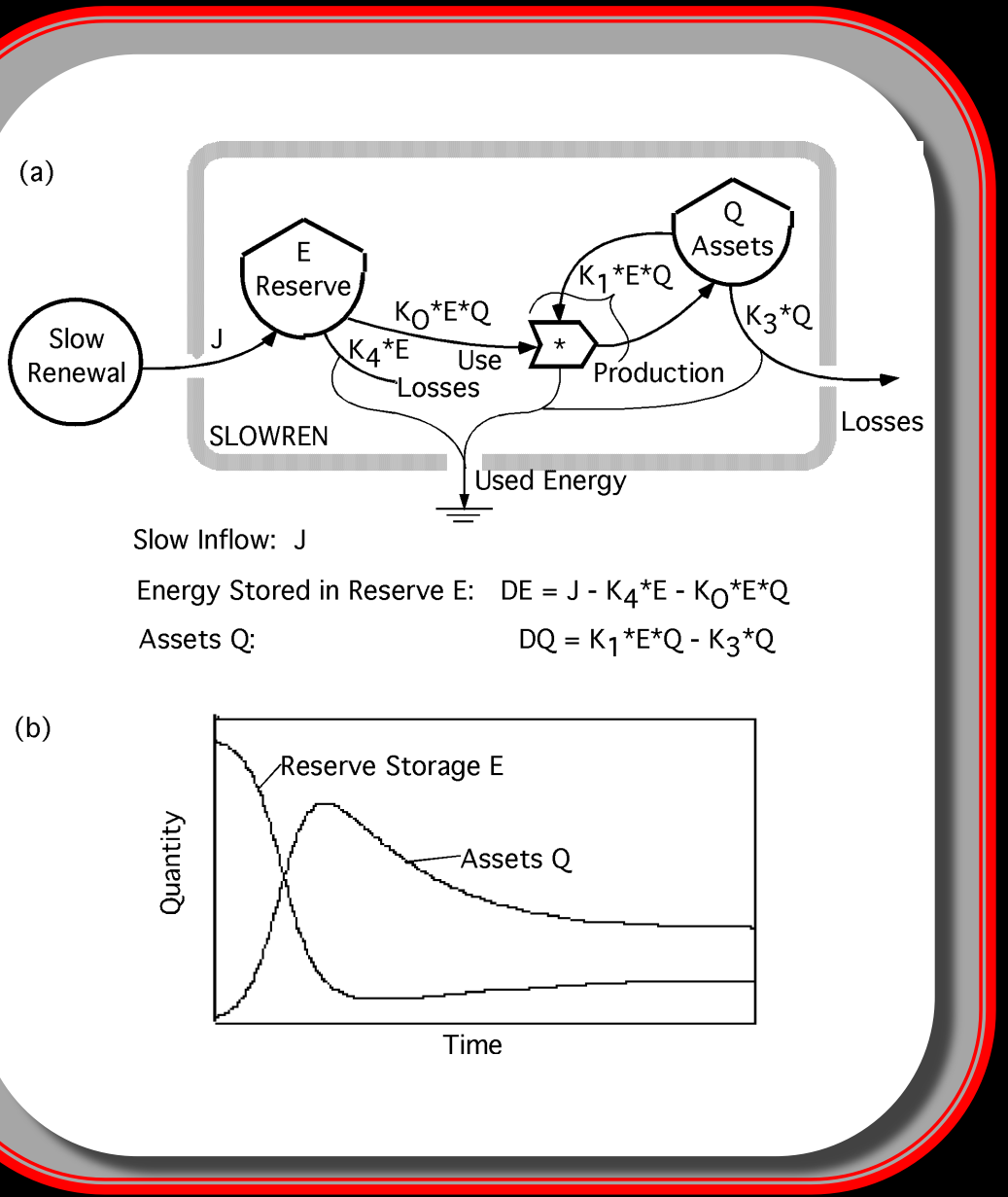
(b)



Review ...

SLOWREN: A Model of Growth on a Slowly Renewable Source

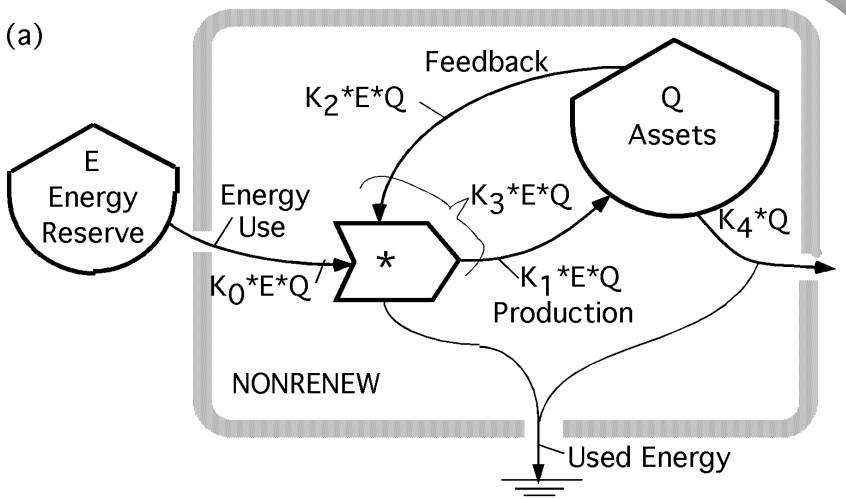
Inflows from an outside source into the system accumulate in the first storage, which becomes a reserve supply of resource for growth of the other unit, an autocatalytic consumer unit (Assets)



Review ...

NONRENEW: Growth on a Nonrenewable Source

This model represents any system with a limited source which is used up. A nonrenewable source is a storage, a limited quantity.

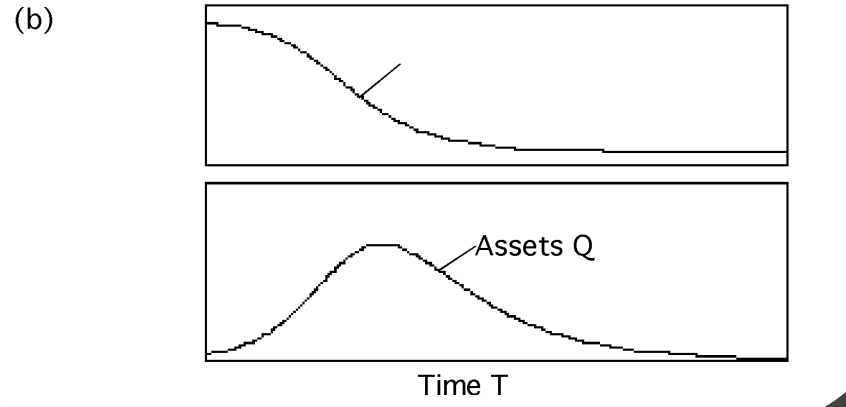


Energy Reserve E: $DE = - K0*E*Q$

Assets Q: $DQ = K_1*E*Q - K_2*E*Q - K_4*Q$

$DQ = K_3*E*Q - K_4*Q$

where $K_3 = K_1 - K_2$

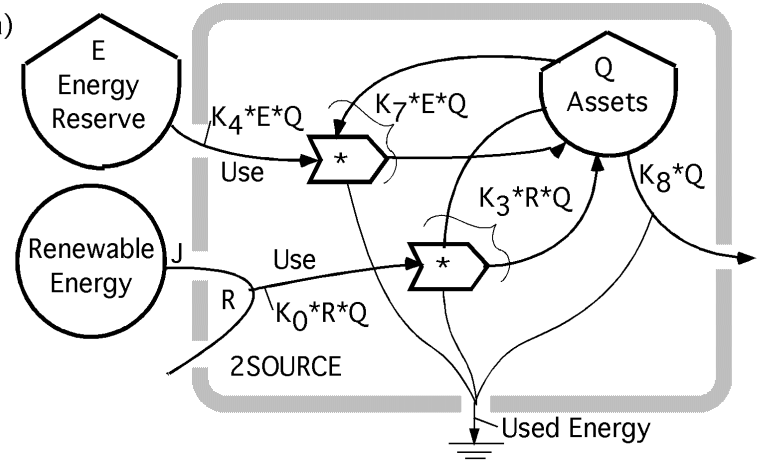


Review ...

2SOURCE : Growth On a, Renewable & Nonrenewable

The growth of this system is the result of two sources, one a steady-flowing renewable source and the other source is a temporary nonrenewable source.

(a)

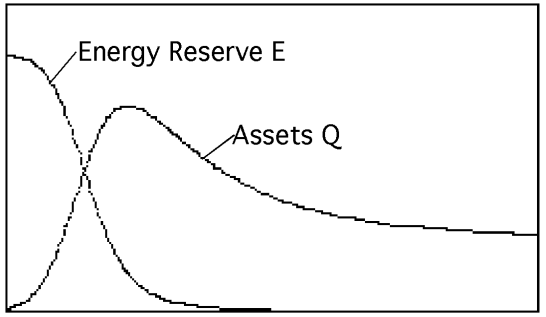


Renewable Energy Available: $R = J - K_0*R*Q$ and $R = J/(1 + K_0*Q)$

Energy Reserve E: $DE = - K_4*E*Q$

Assets Q: $DQ = K_7*E*Q + K_3*R*Q - K_8*Q$

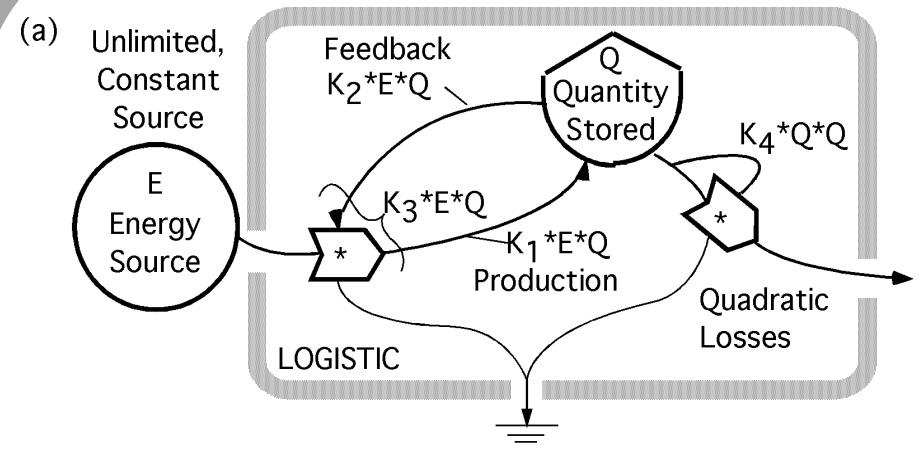
(b)



Review ...

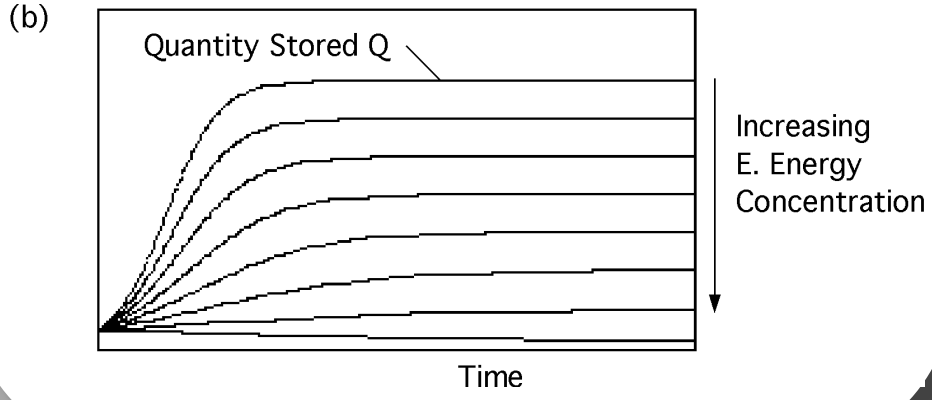
LOGISTIC: Model of Logistic Growth

Any population that grows on a constant-pressure source, increases exponentially, unless the death rate is increased because of more interactions and crowding, which cause stress and toxicity. In this case, then, the population levels off.



Quantity D: $DQ = K_3*E*Q - K_4*Q*Q$ where $K_3 = K_1 - K_2$

Quantity at Steady State: $DQ = 0$ and $Q_s = (K_3/K_4)*E$

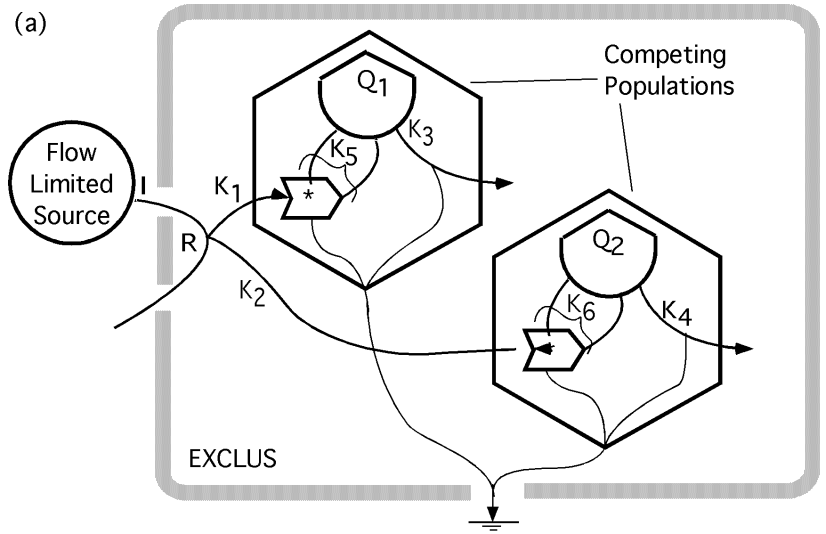


New Models...

EXCLUS: Model of Competition for a Limited Source

If two species are using a common source of food which is in short supply, the growth of one may deprive the other of its source of food.

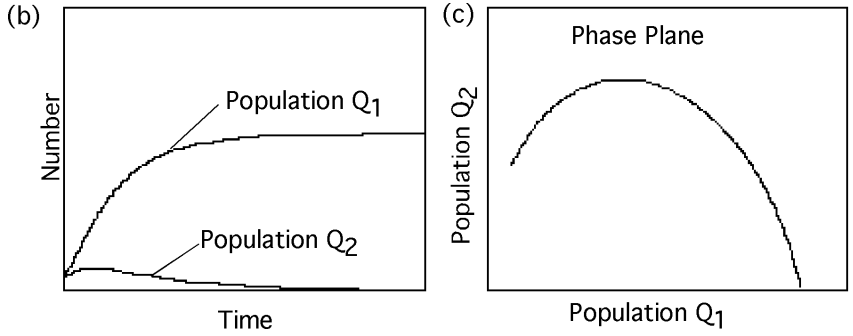
Under some conditions the species which grows faster causes the other population to die out



Available Energy: $R = I - K_1*R*Q_1 - K_2*R*Q_2$ and $R = I/(1 + K_1*Q_1 + K_2*Q_2)$

Population Q_1: $DQ_1 = K_5*R*Q_1 - K_3*Q_1$

Population Q_2: $DQ_2 = K_6*R*Q_2 - K_4*Q_2$

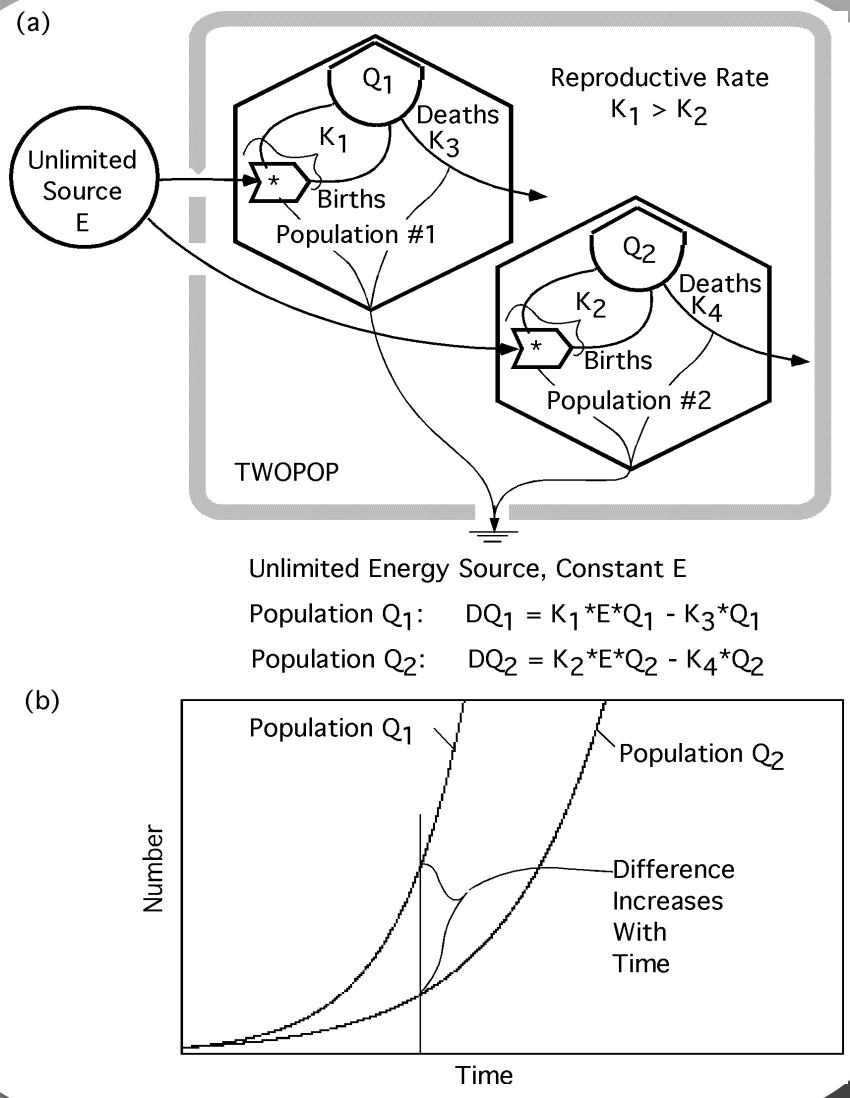


New Models...

COMPETE: Model of Two Populations in Exponential Growth

There is a natural tendency for populations with unlimited food supplies to grow increasingly rapidly with exponential growth.

Even though resources are not in short supply, and even though there are no negative interactions, one population may become increasingly dominant because it is better at acquiring the energy source.



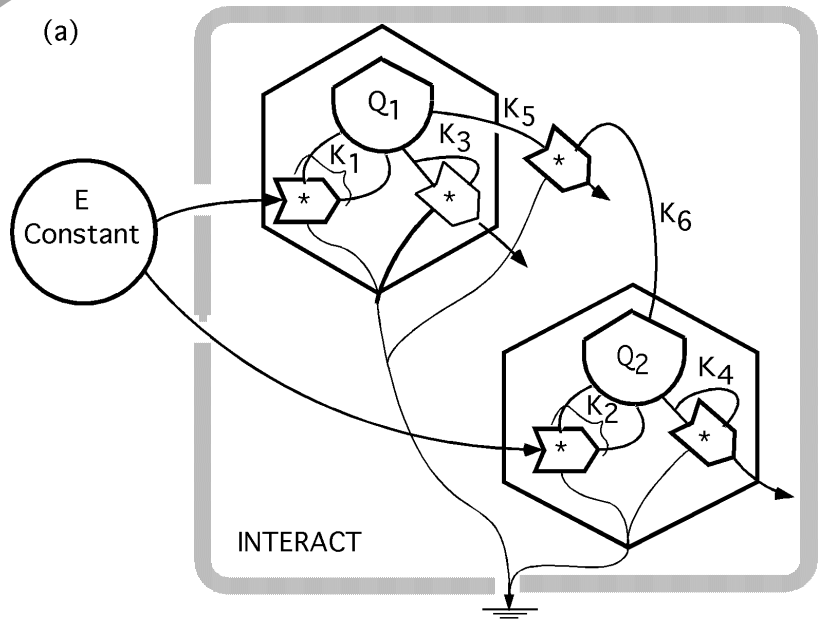
New Models...

INTERACT: Model of Active Negative Interaction

Two populations may compete by means of a negative interaction on the other population.

The competing populations are shown without food limitations (E is constant) and each population has a self-interactive crowding drain which causes logistic growth.

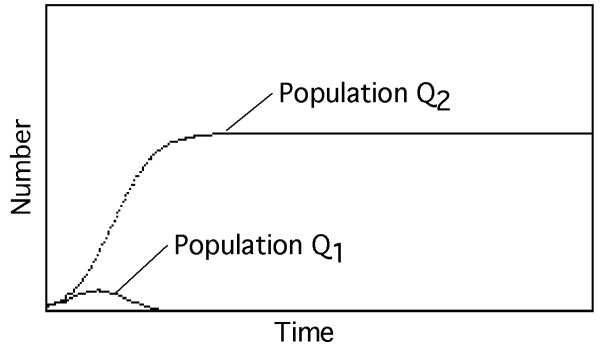
(a)



Population Q_1: $DQ_1 = K_1*E*Q_1 - K_3*Q_1*Q_1 - K_5*Q_1*Q_2$

Population Q_2: $DQ_2 = K_2*E*Q_2 - K_4*Q_2*Q_2 - K_6*Q_1*Q_2$

(b)



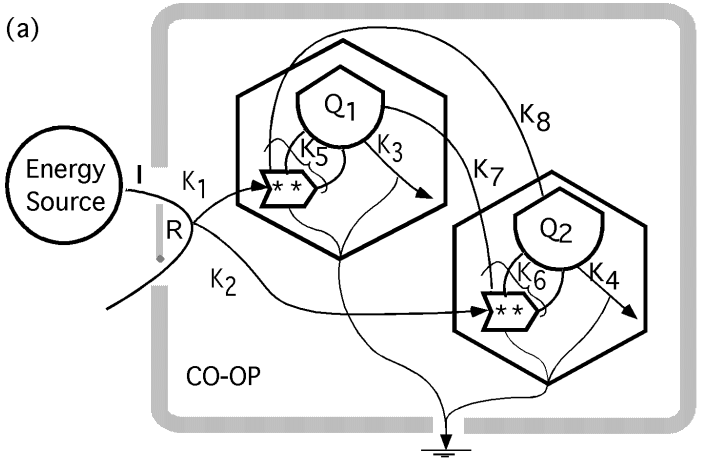
New Models...

CO-OP: Model of Two Populations which Cooperate

Two populations grow on a common renewable limited flow energy source. Part of the assets of each population is used for the growth of the other population (K7*R*Q*Q2 and K8*R*Q*Q2).

The maximum growth of each population is dependent on the other.

(a)



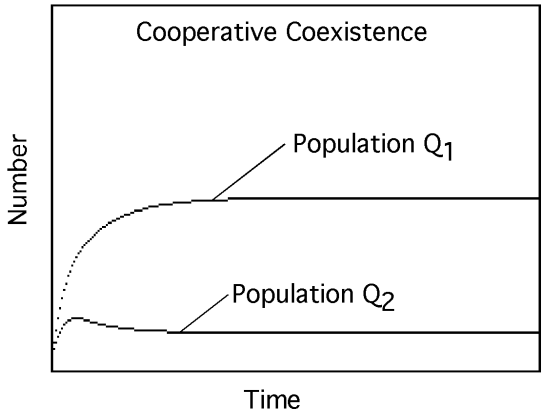
Available Energy: $R = I - K_1*R*Q_1*Q_2 - K_2*R*Q_1*Q_2$

$R = I/(1 + K_1*Q_1*Q_2 + K_2*Q_1*Q_2)$

Population Q_1: $DQ_1 = K_5*R*Q_1*Q_2 - K_3*Q_1 - K_7*R*Q_1*Q_2$

Population Q2: $DQ_2 = K_6*R*Q_1*Q_2 - K_4*Q_2 - K_8*R*Q_1*Q_2$

(b)



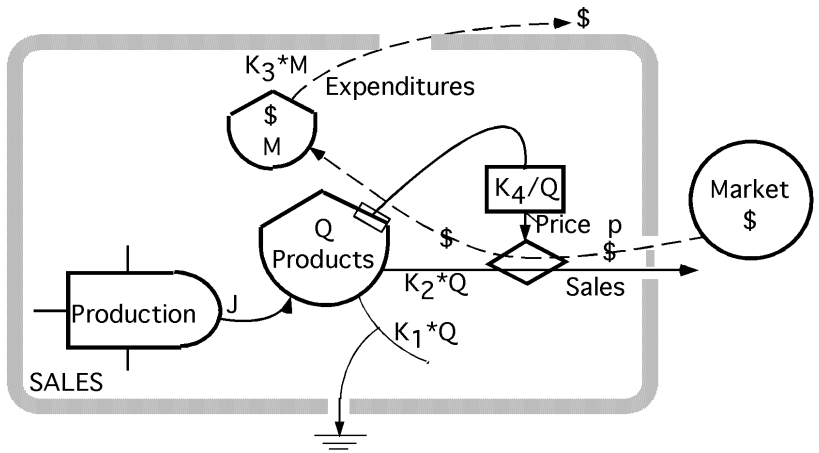
MicroEconomic Models...

SALES: Model of Sales with Price Inverse to Supply

The SALES model shows the operation of sales and money in a simple system. In the model, products Q accumulate from a process which produces J units per time. The expression for the depreciation of the products is K1*Q.

The products are sold to the market (K2*Q), and money is received in exchange. According to the economic principle of supply and demand, the price P goes up if the supply of products is less and down if the supply is greater. The expression which shows that the price is inverse to the supply of available Q is K4/Q.

(a)

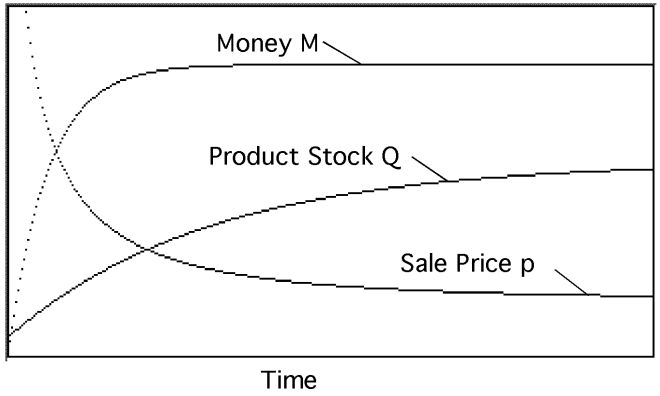


Price of Products $p = K_4/Q$

Money: $DM = p*K_2*Q - K_3*M$

Stock of Products: $DQ = J - K_2*Q - K_1*Q$

(b)



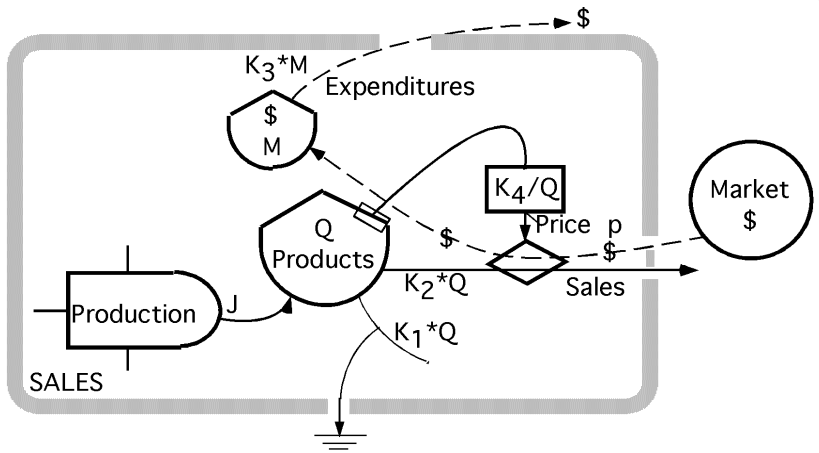
MicroEconomic Models...

SALES: Model of Sales with Price Inverse to Supply

…..The money received is stored in a bank account M, and then paid out in proportion to the amount in the account (K3*M). The small rectangle on the Q tank and the line from it to the price box indicate a sensor: it is recording Q, but not using it.

When the program is simulated, products accumulate and level off, prices go down, and money increases and levels as a steady state is reached. In this model income is a product of sales and price (K2*Q)*(K4/Q) = K2*K4, a constant. Prices vary, but income to the producer is steady.

(a)



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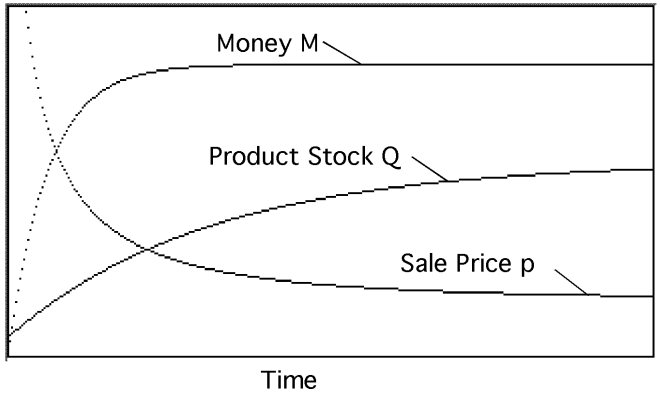
(b)

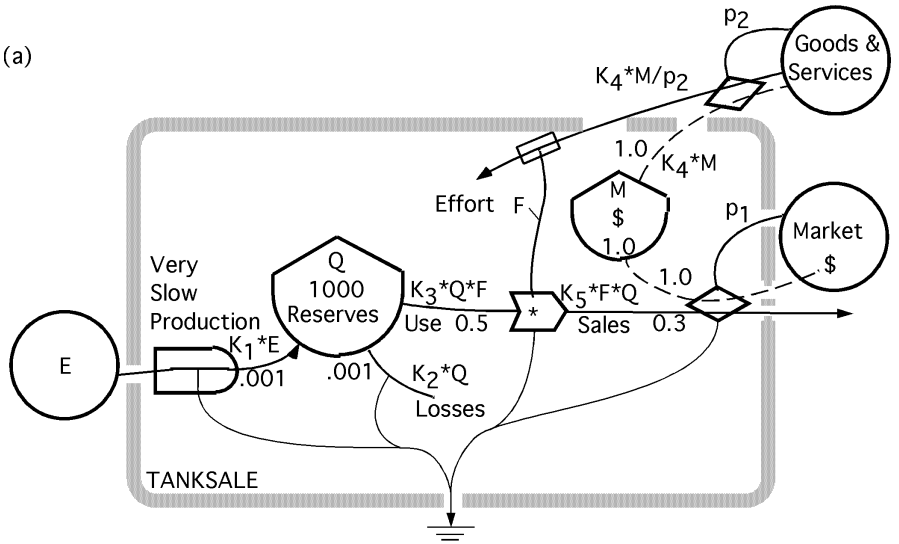


MicroEconomic Models...

TANKSALE : Model of Economic Use of Mined Resources

TANKSALE is a model of mining and use of a nonrenewable source Q, like coal, oil, or copper. Money received for the product is used to pay for necessary inputs, profits, costs, etc. The mining company uses purchased goods and services F to mine, sort, store, and transport the product. The reserve in the ground Q is slowly renewed by the geological processes (K1*E). Since use is much faster than its renewal, we call it a "non-renewable" resource.

(a)

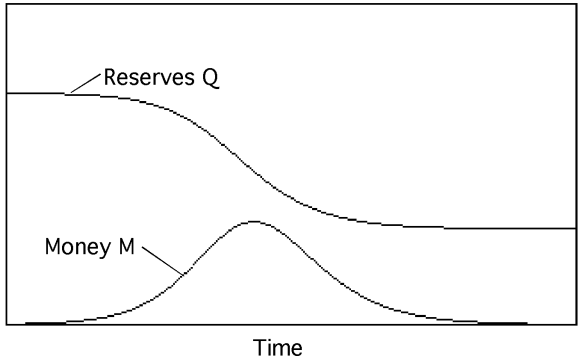


Mining Effort: $F = K_4*M/p_2$

Reserves: $DQ = K_1*E - K_2*Q - K_3*Q*F$

Money: $DM = p_1*K_5*F*Q - K_4*M$

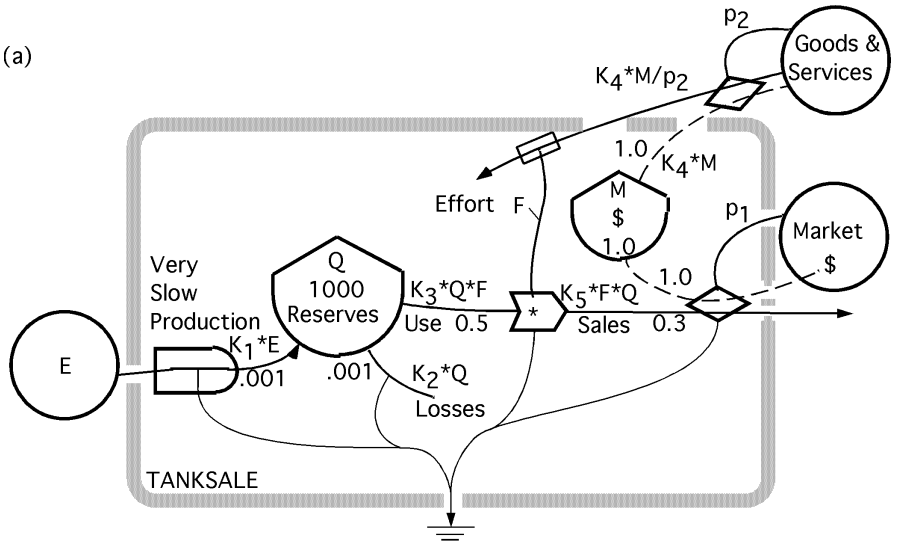
(b)



MicroEconomic Models...

TANKSALE - 2: Model of Economic Use of Mined Resources

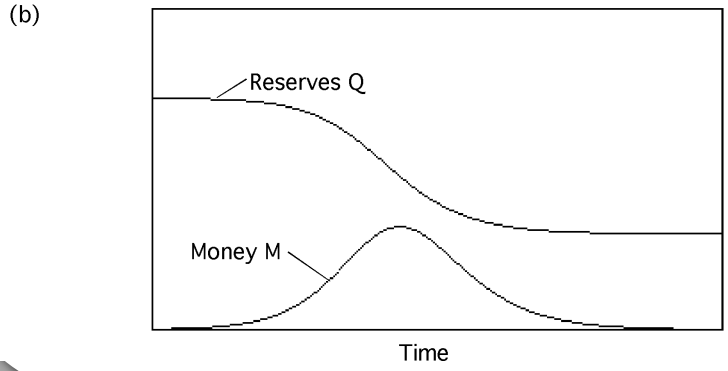
….At first with an abundant supply of source reserves, large quantities are mined with little effort, not using many goods and services. With set prices for the yield P1 and for necessary goods and services P2, the company makes money. Later when reserves are less available, yield is less since sales are less than what is required to maintain the mining process. The operation stops; some ore may be left in the ground.



Mining Effort: $F = K_4*M/p_2$

Reserves: $DQ = K_1*E - K_2*Q - K_3*Q*F$

Money: $DM = p_1*K_5*F*Q - K_4*M$



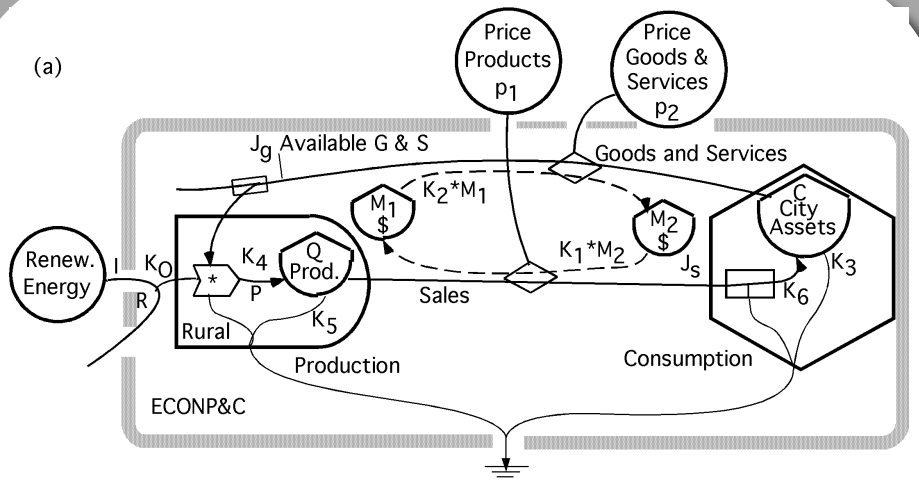
Micro Economic Models...

ECONP&C : Model of Money Counter-currents in an Economy

In the model ECONP&C, economic production generates products from environmental resources and human goods and services. These are sold to consumers who use the products to generate services which they sell to the producers.

The energy source is a renewable inflow, limited at its source to a regular inflow. Thus, the model is appropriate for a segment of an agrarian economy before the industrial revolution

(a)



Renewable Energy: $R = I - K_0*R*J_g$

Rural Production: $P = K_4*R*J_g$

Rural Products: $DQ = P - K_5*Q - J_s$

City Assets: $DC = K_6*J_s - K_3*C - J_g$

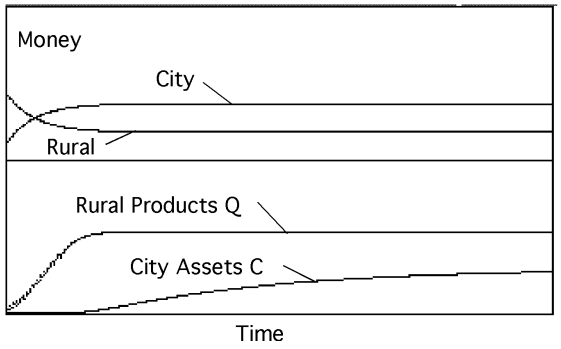
City Money: $DM_2 = K_2*M_1 - K_1*M_2$

Rural Money: $M_1 = T_m - M_2$

$J_g = (K_2*M_1)/p_2$

Sale to City: $J_s = (K_1*M_2)/p_1$

(b)



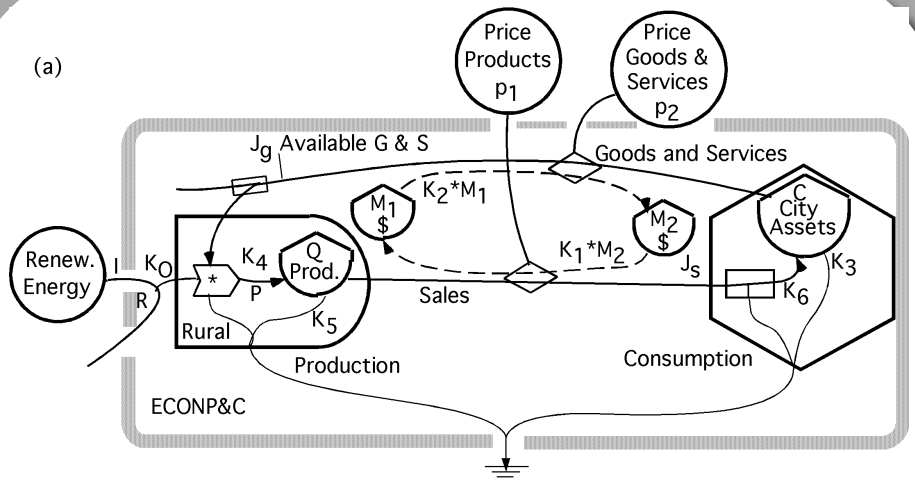
MicroEconomic Models...

ECONP&C - 2: Model of Money Counter-currents in an Economy

Money that is used to buy and sell products and goods and services flows as a circular counter-current in the opposite direction. As shown by the diamond-shaped symbols, the flow of products and goods and services are linked to the flow of money by the prices.

The prices are determined by the larger systems markets outside this system's boundary.

(a)



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Rural Production: $P = K_4*R*J_g$

Rural Products: $DQ = P - K_5*Q - J_s$

City Assets: $DC = K_6*J_s - K_3*C - J_g$

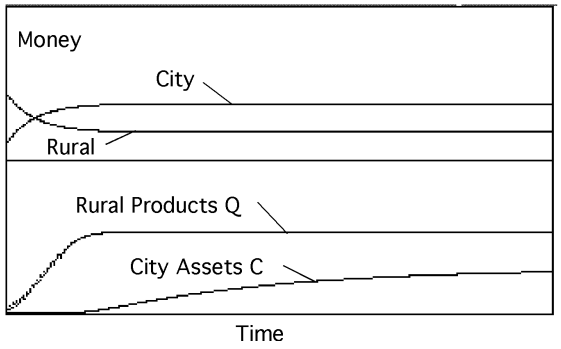
City Money: $DM_2 = K_2*M_1 - K_1*M_2$

Rural Money: $M_1 = T_m - M_2$

$J_g = (K_2*M_1)/p_2$

Sale to City: $J_s = (K_1*M_2)/p_1$

(b)



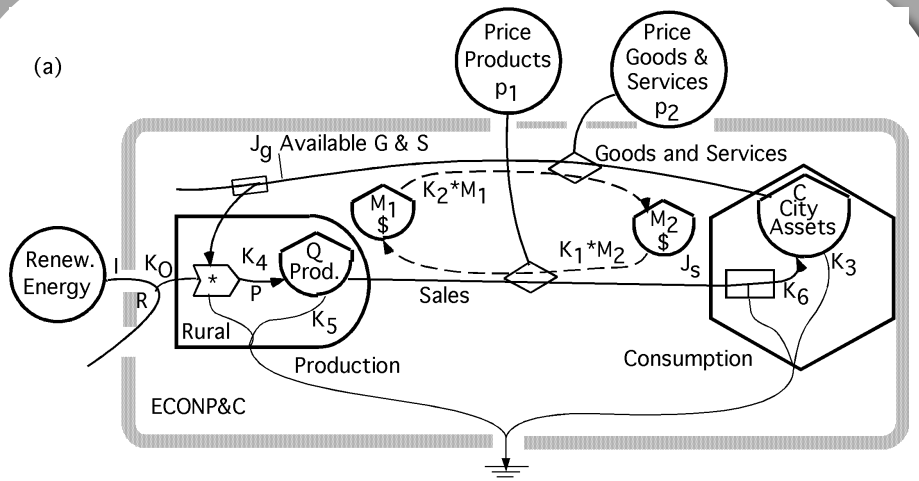
MicroEconomic Models...

ECONP&C - 3: Model of Money Counter-currents in an Economy

The working capital in the bank accounts of the producers and consumers are the small tanks indicated with $ signs. The spending of money in this model is proportional to the money in the bank accounts--the more money, the more spending.

If the initial conditions are started with small storages of products Q or consumer assets C, simulation shows a growth as money goes round and round. If the money supply Mt is not changed, the same money buys more as production increases until the growth is limited by the source.

(a)



Renewable Energy: $R = I - K_0*R*J_g$

Rural Production: $P = K_4*R*J_g$

Rural Products: $DQ = P - K_5*Q - J_s$

City Assets: $DC = K_6*J_s - K_3*C - J_g$

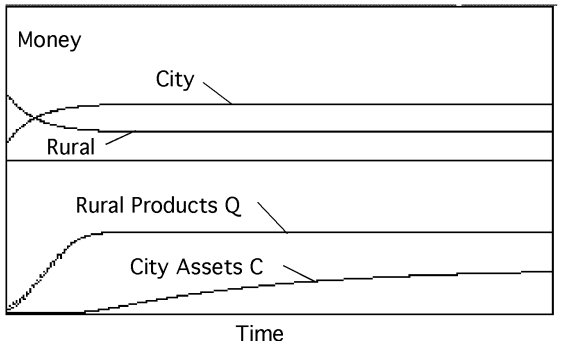
City Money: $DM_2 = K_2*M_1 - K_1*M_2$

Rural Money: $M_1 = T_m - M_2$

$J_g = (K_2*M_1)/p_2$

Sale to City: $J_s = (K_1*M_2)/p_1$

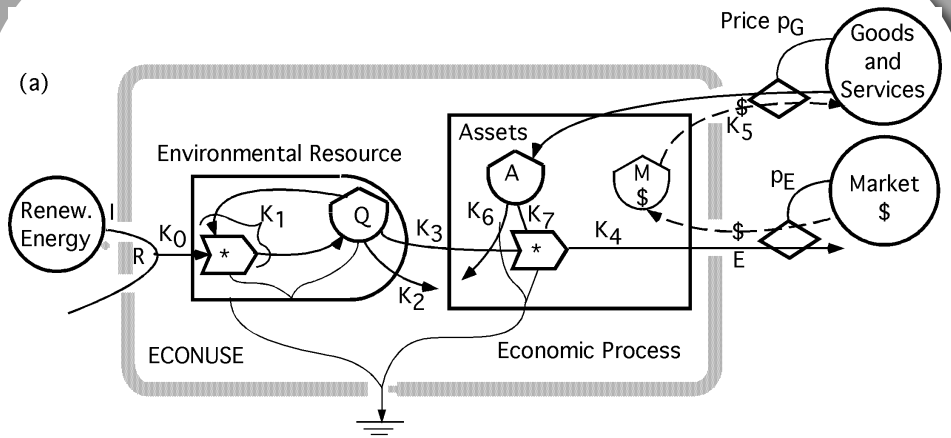
(b)



MicroEconomic Models...

ECONUSE : Model of Economic Use of Environmental Resource

The model ECONUSE is an example of an environmental product being used in an economic process. The product Q--forest wood, fish, or nuts--is produced by the renewable energies of sun, rain, and wind. The product accumulates (tank Q). To process the product for sale, money is needed to buy and sustain equipment and labor. As the product is sold, the money received is used to buy goods and services needed to continue the processing.

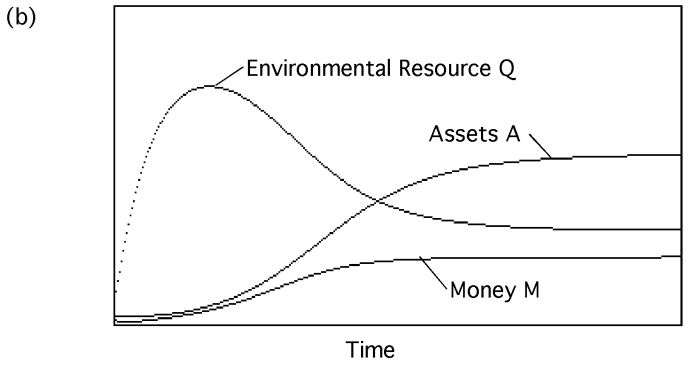


Unused Renwable Energy: $R = I/(1 + K_0*Q)$

Environmental Resources: $DQ = K_1*R*Q - K_2*Q - K_3*A*Q$

Assets: $DA = K_5*M/p_G - K_6*A - K_7*Q*A$

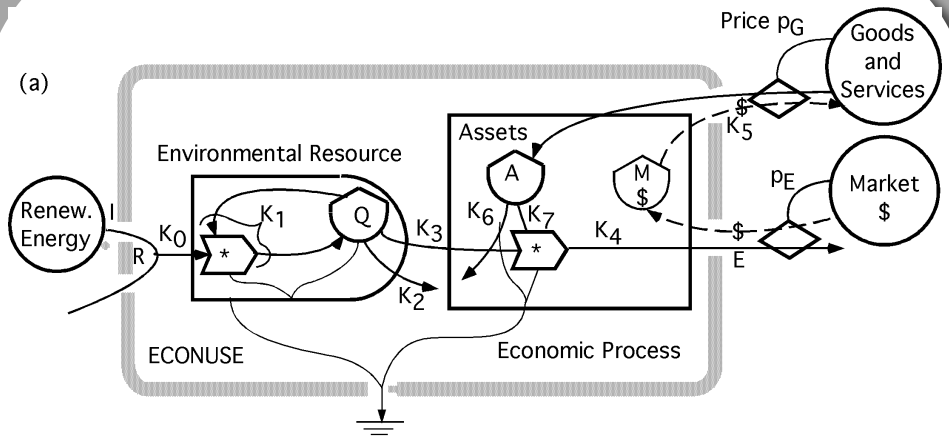
Exports: $E = K_4*A*Q$ Money: $DM = p_E*E - K_5*M$



MicroEconomic Models...

ECONUSE - 2: Model of Economic Use of Environmental Resource

The yield of product ready for sale E depends on both the quantity of original product Q and the amount of processing equipment and labor A. The amount of money which accumulates M is the money brought in from the sale of the product (pE*E) minus the money paid out for goods and services (K5*M).

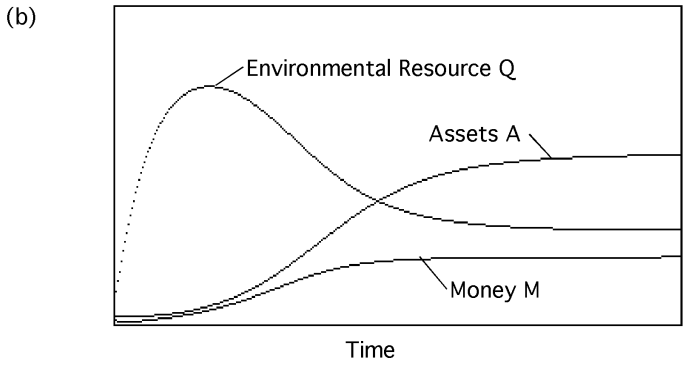


Unused Renwable Energy: $R = I/(1 + K_0*Q)$

Environmental Resources: $DQ = K_1*R*Q - K_2*Q - K_3*A*Q$

Assets: $DA = K_5*M/p_G - K_6*A - K_7*Q*A$

Exports: $E = K_4*A*Q$ Money: $DM = p_E*E - K_5*M$



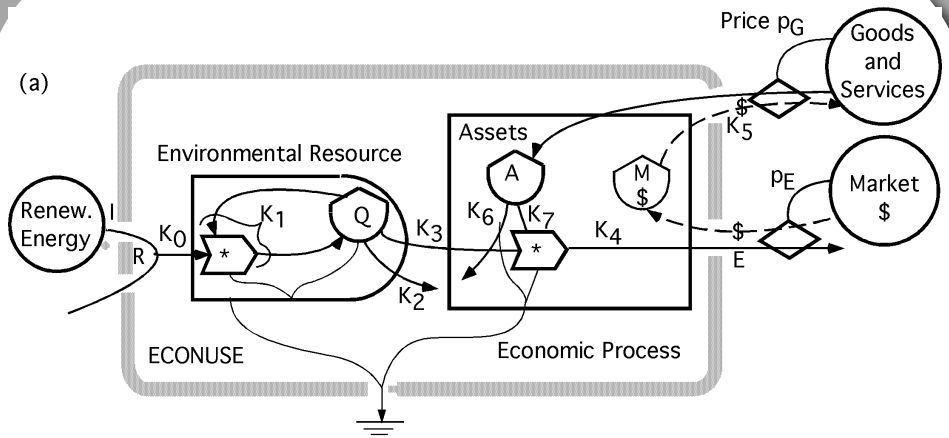
MicroEconomic Models...

ECONUSE - 3: Model of Economic Use of Environmental Resource

The simulation starts with low quantities of product (Q), equipment assets (A), and money (M).

If this is a wood products operation, first the quantity of wood (Q) grows before the development of assets (A). Then assets and sales increase, and more money (M) becomes available to buy more goods and services to build up economic assets (A).

This economic growth uses up some of the of wood (Q). Later, a balance of production and use is reached at a lower rate of use based on the natural limitation of tree growth.

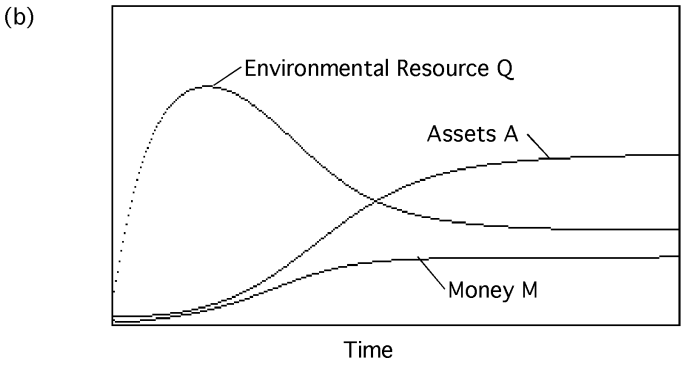


Unused Renwable Energy: $R = I/(1 + K_0*Q)$

Environmental Resources: $DQ = K_1*R*Q - K_2*Q - K_3*A*Q$

Assets: $DA = K_5*M/p_G - K_6*A - K_7*Q*A$

Exports: $E = K_4*A*Q$ Money: $DM = p_E*E - K_5*M$



Questions?