Assignment 10 - Commodity Cycles

Motivation

Most of the poorer nations in the world have economies based on the production and sale of commodities — agricultural commodities (food and raw materials), non-agricultural raw materials, and petroleum. The persistent instability and severe oscillatory behavior in commodity prices, supply, and demand have serious adverse effects on these developing economies and on the commodity sectors of developed nations as well.

This exercise involves recreating and exploring a dynamic model of commodity cycles formulated by Dennis Meadows in 1970.[1] The model is interesting because it passes a difficult validity test: merely by changing parameters in the model representing the particular biological and economic characteristics of hogs, cattle, and chickens, the model is able to reproduce the periodicities of those different commodity cycles. This test suggests that Meadows has captured something of the essential structure underlying commodity cycles.

Tasks

1) Download the Meadows commodity cycle model excerpted from *Dynamics of Commodity Cycles*.

Simulate the model and investigate the graphs of various variables. Tell the story of the oscillatory behavior the model produces. [See Meadows's Figure 5-22 at the end of this assignment.]

2) Change the parameters in the model to represent the cattle system, as outlined in the two tables below (pp. 2 and 3). Save this version of the model under a new name (COWS.MDL?) and simulate it, trying to reproduce the behavior Meadows shows in his Figure 5.23, shown at the end of this assignment. [I had to reduce the Time Step to 0.125 to avoid spurious time step oscillations.] (No need to change "hogs" and "pork" to "cattle" and "beef.")

Hand in a documented equation listing with the parameter changes highlighted somehow, graphs of important variables, and any observations or comments you have. [I was unable to reproduce Meadows's graphs.]

[1] Dennis L. Meadows, *Dynamics of Commodity Production cycles,* Cambridge, MA: Wright-Allen Press, 1970; reprinted by Productivity Press, Portland, Oregon.

Quantity	Hog model	Cattle model
Initial value of inventory of pork (hogs)	200*10^6	400*10^6
Live weight of slaughtered hogs (lbs)	240	850
Hog-dressing yield (dimless)	0.58	0.58
Expected-consumption rate (lbs/month)	.99*10^9	1.854*10^9
Desired inventory coverage (months)	0.36	0.216
Initial farmers expected hog price ($/100lb	21.2	20
Farmers expected hog price adjustment dela	6	24
Farmers expected corn price	1	1
Initial value of breeding stock (hogs)	8.2*10^6	40*10^6
Breeding stock acquisition delay	5	24
Fraction of sows in breeding stock (dimless	0.6	1
Average productive life of sows	36	30
Litters per hog month	0.17	0.1
Pigs saved per litter (pigs/litter)	7	1
Weaning survival factor	0.7	0.94
Gestation maturation delay	10	30
Initial value of mature hogs	13*10^6	45.15*10^6
Mature stock feeding period (moths)	2	12
Marketing margin ($/100lbs)	28	24
Population of consumers	200*10^6	206*10^6
Final Time (months)	150	600
Saveper	1	1

(Graphical functions on next page.)

3) Experiment with "noise" runs of each of your two models. In the Simulate menu, select Constants, set the SH to zero, and set RANGE equal to 0.5. This will introduce random disturbances into the Consumption Rate that will range within plus-or-minus 25% of the base consumption rate determined by the Population and the Per Capita Consumption of Pork which comes from the Retail Price.

Simulate your models with this sort of random disturbance or "noise" in consumption. If a RANGE of is too small to see interesting dynamics, or too large and results in overly dramatic oscillatory or extreme behavior, adjust your value until you produce a reasonably realistic run. Do this for both models. Hand in representative graphs and comment on what you observe here and in comparison with the step-induced behavior.

Graphical functions				
LHP f	Hog model		Cattle model	
	Rel inv cov	Live hog price	Rel inv cov	Live hog price
	0	35	0	40
	0.25	26.5	0.25	37.5
	0.5	21.7	0.5	33.5
	0.75	18.7	0.75	27.5
	1	16.5	1	20
	1.25	13	1.25	12.5
	1.5	9.5	1.5	6.5
	1.75	5.5	1.75	5.5
	2	0	2	0
DBS f	Hog model		Cattle model	
	Exp hog-corn ratio	Des Breed stock	Exp hog-corn ratio	Des Breed stock
	10	5000000	10	22000000
	15	7000000	15	32000000
	20	9000000	20	40000000
	25	10600000	25	50000000
			30	60000000
PCCP f	Hog model		Cattle model	
	Retail price	Per cap cons of pork	Retail price	Per cap cons of pork
	40	6.4	0	16
	60	5	30	15
	80	3.7	60	9
			90	3
			120	2

4) There is an important *major negative* feedback loop in this oscillatory structure which is primarily responsible for the oscillatory behavior. Identify that loop and trace its effects in the ups and downs of, say, the inventory of pork.

There is also an important *major positive* feedback loop in this structure which exacerbates the oscillatory tendencies of the system. Identify that loop. Use that loop to argue that it is responsible for the interesting behavior that farmers respond initially to shortages in pork at the retail level in a way that initially *increases* rather than counteracts such shortages. This is a "first response in the wrong direction" loop.

5) Meadows's model has a flaw (a number of them, actually). In equilibrium -- where the

inflows to each stock equal the outflows from each stock, the Breeding Stock does not equal its Desired Breeding Stock value — the model has a "stressed equilibrium." One can see that by working with the inflow and outflow to the Breeding Stock level. Do the simple algebra in the HOG model necessary to show that in equilibrium, when Breed Stock Acquisition Rate = Old Sow Slaughter Rate, the Breeding Stock does not equal the Desired Breeding Stock. What does it equal?

Now reformulate the Breeding Stock Acquisition Rate in the HOG model to correct this flaw. [What would farmers actually do? What would you do here if you wanted to keep your breeding stock at some desired level? Hint: Think what you'd want to be doing if the Breed Stock is just the size you want it, and you don't want it to decline.] Explain how your fix solves the problem. Save your new model under yet another name (HOGFIX.MDL?). When you are satisfied, simulate your revised model with the original 15% step in consumption and then again with the step turned off and randomness turned on, as above. Hand in your equation revisions, graphs of behavior over time, and comments on what you observe.

<u>Extra for would-be experts</u> (Part (a) is easy; part (b) is potentially hard): Meadows claimed his model was in equilibrium, until it was disturbed by the STEP in the INPUT variable in the consumption rate. But he was wrong.

a) Show that the hog model is not in equilibrium, even when the step is turned off (SH = 0).

b) Put the hog model into equilibrium. This should require changing only the initial values of some (maybe all) of the stocks -- nothing else. Show the initial values of the stocks that do the job, and explain briefly how you found them.

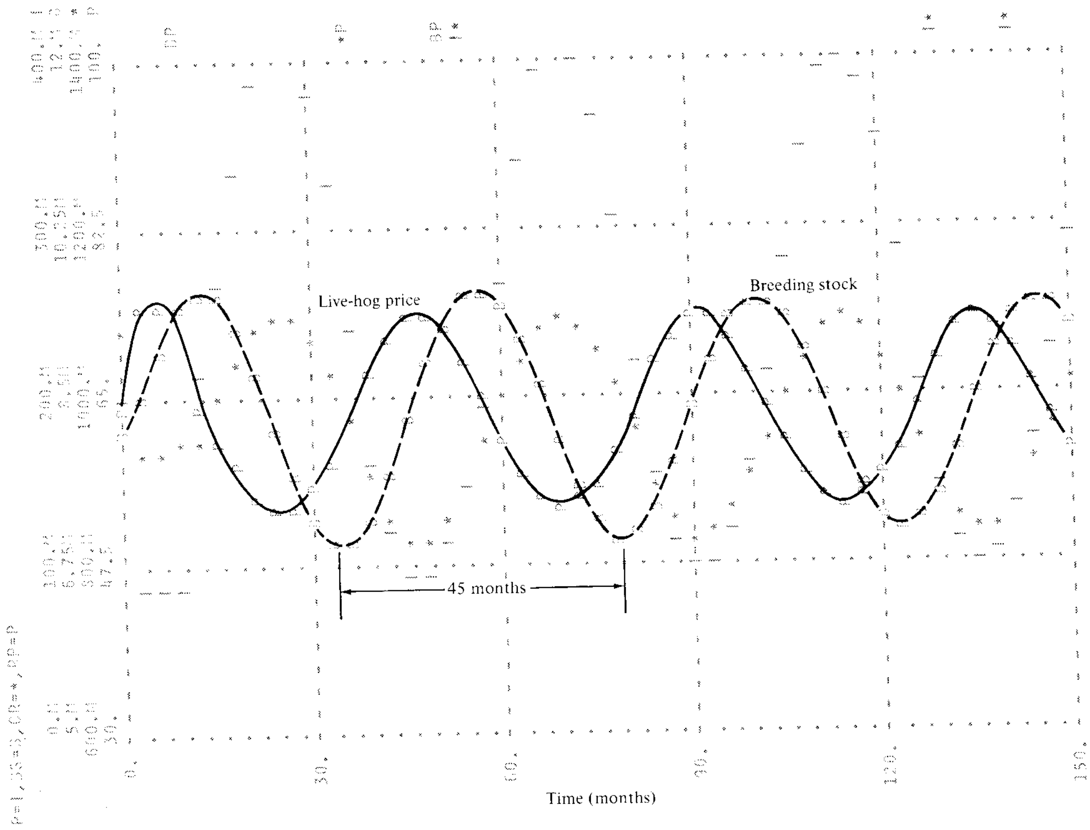

Figure 5-22. Behavior of the Dynamic Hog Cycle Model.

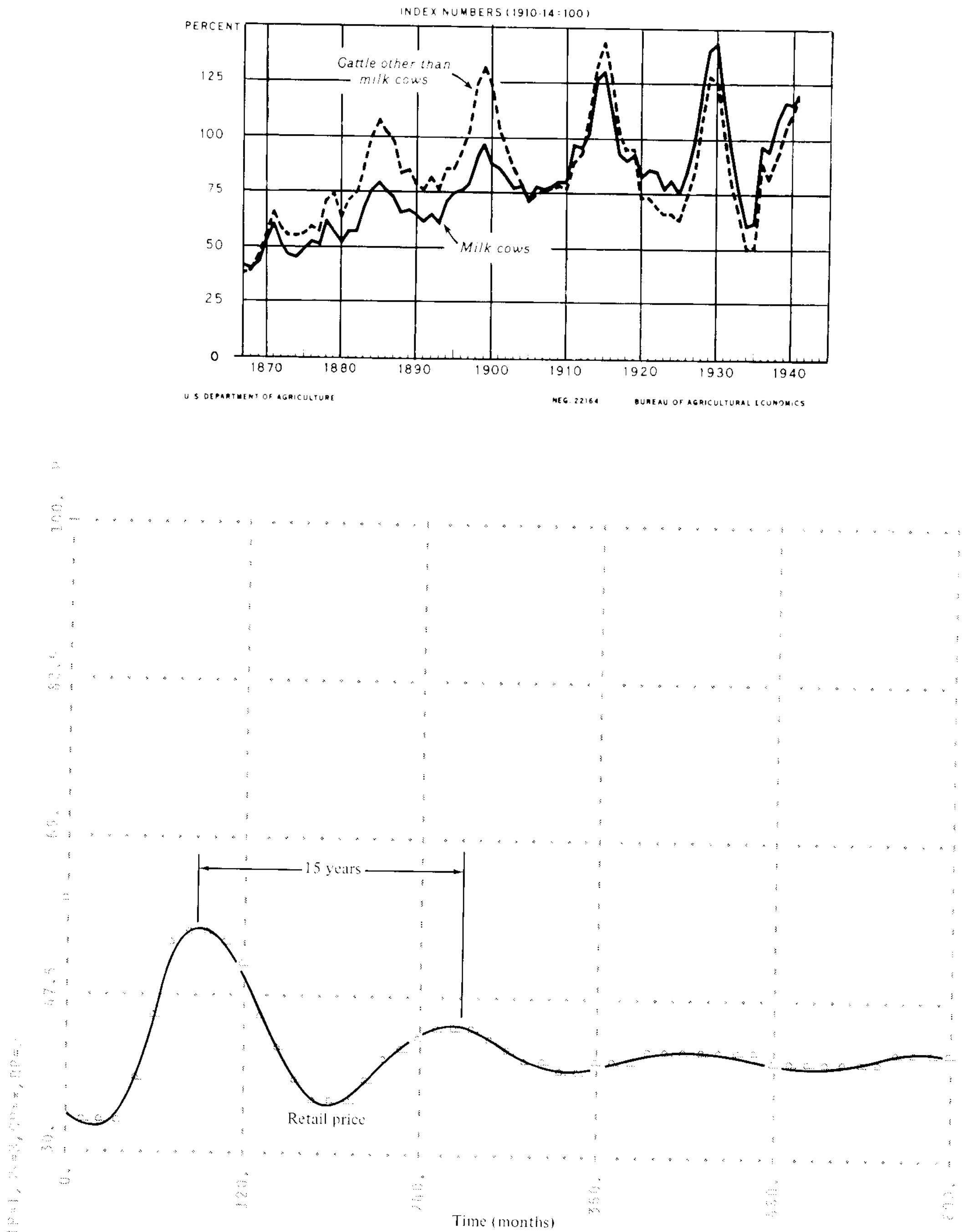

Figure 5-23. Actual and simulated cattle cycle.