Robert, Nancy et al. 1983.

CHAPTER 21

COMMODITY CYCLES: A STUDY OF HOGS*

Economic and environmental systems are subject to numerous and unexpected external shocks and disturbances. A drought, for example, can cause a sudden reduction in the harvest of corn. A strike can lead to changes in the availability of a product. A rapidly spreading disease can quickly reduce the size of a herd of cattle. And a chemical spill can affect the ecology of a coastal area.

One question to ask about an economic or environmental system is how it responds to shocks such as these. Following the disturbance, does the system smoothly return to equilibrium? If it reaches equilibrium, is the new equilibrium value the same as the equilibrium value before the disturbance? Does the system amplify disturbances?

Many systems tend to oscillate in response to external disturbances. The national economy, for example, shows cycles of high and low Gross National Product (GNP) and employment. And animal populations (such as rabbits and lynx) often exhibit oscillations.

In this chapter, a classic example of cyclical behavior will be explored—the production and consumption of pork products in the United States. While the pork example is interesting in itself, it is also important because it focuses on some general questions about the nature of oscillations and the stability of systems in response to disturbances.

The data in Figure 21.1 show the pig crop and slaughter rate in the United States from 1925 to 1960. As can be seen, there are cycles of high and low production, and the average period from peak to peak is about four years. The exercises that follow seek an explanation for why these cycles occur.

*Information in this chapter draws on material from Dennis L. Meadows, *Dynamics of Commodity Production Cycles* (Cambridge, Mass.: MIT Press, 1970).

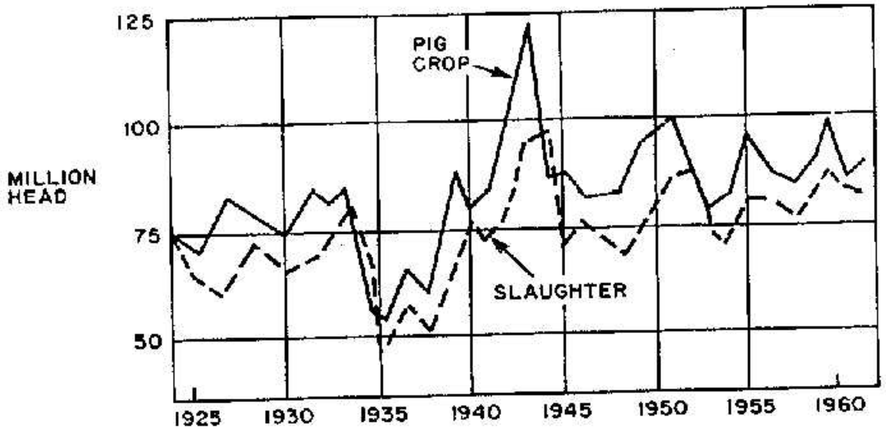


Figure 21.1 Pig crop and slaughter rate in the United States, 1925–1960

The production and consumption of pork products involve three groups of actors: farmers, butchers, and consumers. Butchers buy hogs from farmers, "dress" the hogs to obtain pork products, and then sell the pork products to consumers.

In order to understand the cycles that take place in the production and consumption of pork products, it will be helpful to build two models—one focusing on the process of breeding and fattening hogs on the farm, and the other focusing on the sale of pork products. Then the two models can be combined to generate cyclical behavior. It is easiest to begin with a model of the sale of pork products, then turn to the breeding of hogs, and finally combine the two models into one larger model and analyze the behavior the combined model generates.

Exercise 1: The Sale and Consumption of Pork

The main element in the model of the sale of pork is the inventory of pork maintained by butchers. When hogs are slaughtered on the farm, the pork products that are produced are added to the inventory kept by butchers; when pork is sold, that pork is taken from the inventory. In general, the amount of pork people buy depends on the price of pork; the price of pork, in turn, depends on the size of the pork inventory. When the inventory is high, prices fall; when the inventory is low, prices rise. (It may be helpful to sketch a rough causal-loop diagram at this point, before continuing with the exercise.)

For the initial model of the sale of pork, assume that the number of hogs slaughtered each month is an exogenous constant—4 million hogs per month. Hogs weigh about 250 pounds each, and the "dressed yield" of pork is about

60 percent. (This means that each hog produces 0.60*250 = 150 pounds of pork.) Thus a slaughter rate of 4 million hogs per month corresponds to a pork production rate of 600 million pounds of pork each month.

On the average, each person in the United States normally consumes about 3 pounds of pork each month. If a constant population of 200 million people is assumed, the total amount of pork normally consumed each month is 3*200 million = 600 million pounds of pork per month. But when the price is high relative to the normal price of pork, people usually consume somewhat less than 3 pounds each month; when the price is low, they consume somewhat more.

The price of pork depends on the price of hogs, and the price of hogs depends on supply and demand. Assume that butchers try to keep on hand about two weeks' worth of the amount of pork products they usually sell. When the available inventory of pork runs low, relative to their normal inventory, butchers are willing to pay higher prices to get hogs. When the butchers' inventory of pork is high, butchers are less willing to buy and the price of hogs falls.

Assume that the normal price of hogs at slaughter is $0.30 per pound. This means that butchers normally pay $0.30/0.6 = $0.50 for a pound of pork, since the dressed yield of pork is 0.60. Assume that butchers charge consumers a $0.50 per pound markup on pork. Thus when the price of hogs is at its normal value ($0.30/pound), the price of pork to consumers is ($0.30/0.6) + $0.50 = $1.00 per pound.

a. Draw a causal-loop diagram and flow diagram of the sale and consumption of pork.

b. Now write equations for the model. It is easiest to represent the pork consumed per person as the product of a "normal value" (3 pounds per person per month) and a TABLE function multiplier that reflects the influence of pork price on consumption. Similarly, it is easier to represent the hog price as the product of a "normal value" ($0.30/pound) and a TABLE function that reflects the influence of pork availability (relative to demand) on hog price.

c. In order to run the model, you will need to choose an initial value for the pork inventory. What value is necessary in order to place the system in equilibrium?

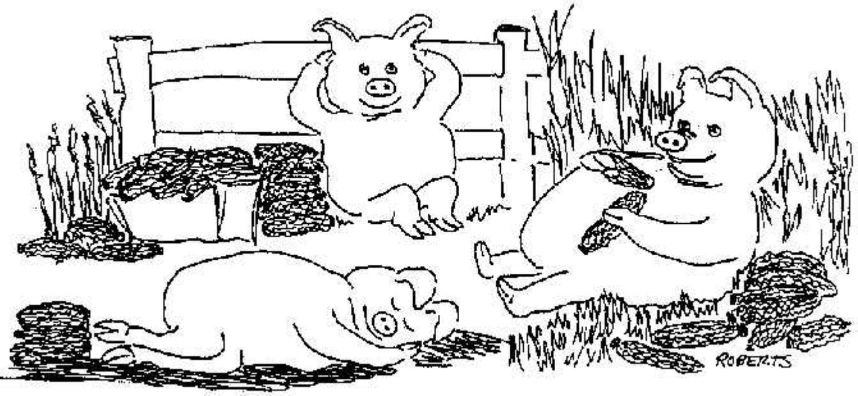
d. Once you have obtained a model that runs in equilibrium, try testing its response to exogenous disturbances. For example, how does the system respond to a year-long 10-percent reduction in the hog slaughter rate? (This might represent the impact of a drought or a disease. You can use two STEP functions to represent the year-long reduction in the slaughter rate.)

e. How does the system respond to a year-long 10-percent increase in the normal consumption of pork per person? (This might represent a change in buying habits, or a change in the availability or price of other kinds of meat.)

Exercise 2: The Breeding and Maturation of Hogs

In Exercise 1 we assumed the hog slaughter rate was an exogenous constant. Now let's develop a model of the breeding and maturation of hogs to simulate the slaughter rate. For this model, we will assume that the price of hogs is an exogenous constant. In Exercise 3, we will combine the two models to simulate both the hog price and the slaughter rate.

Farmers distinguish between two kinds of hogs: hogs for market and hogs for breeding stock. Hogs for market (which can be either male or female) are fattened for about a year after they are born, and then they are slaughtered. Females intended for market are not bred. Females to be bred (called sows) are raised separately as "breeding stock," and they are used entirely for breeding. They are not slaughtered for pork.[1]



Farmers change the size of their hog herd by adjusting the number of sows in their breeding stock. When the price of hogs is higher than normal, farmers generally desire to increase the size of the breeding stock, and when the price of hogs is lower than normal, they desire to decrease the size of the breeding stock.

a. Draw a flow diagram and write equations for a model of the breeding and maturation of hogs. Assume that each sow gives birth to 24 hogs per year (2 per month). Also, assume that hogs must be fattened for 12 months before they are ready for market. (The most difficult part of the model is the "breeding stock adjustment rate." One way to formulate this is to use a TABLE function to represent a "desired breeding stock size" as a function of hog price. This desired size can be expressed most easily as a percentage of the actual breeding stock size. The breeding stock adjustment rate can then be formulated as the difference between the "desired size" and the "actual size," divided by an adjustment time.)

Set the exogenous hog price at $0.30 per pound. You will also need to choose an initial value for the breeding stock and an initial value for the number of hogs. Choose values that will produce an equilibrium slaughter rate of 4 million hogs per month (the value we assumed in Exercise 1.)

b. Once you have obtained a model that runs in equilibrium try testing its response to a year-long 10 percent increase in the price of hogs. What happens? Why?

Exercise 3: Combining the Two Models

a. Now let's merge the models developed in Exercises 1 and 2. To do this, all that is necessary is to use the hog price from model 1 in place of the exogenous hog price in model 2, and the slaughter rate from model 2 in place of the exogenous slaughter rate in model 1. Run the model and examine the results. If you use the same initial values as those you chose in Exercises 1 and 2, the model should be in equilibrium.

b. Once you have obtained an equilibrium run, you can test the model's response to external disturbances. For example, test the model's response to a year-long 10-percent increase in the pork consumed per person. What happens? Can you explain why the cycles occur?

Two features of cyclical behavior are particularly important: period and damping. The period of a cycle is the time that elapses from one peak to the next. For the parameter values we have chosen, the hog model produces cycles with a period of about 48 months. Damping refers to the degree to which oscillations fade away over time. For the parameter values we have chosen, the hog model produces oscillations that are slightly damped. (Some models produce oscillations that grow over time. These are sometimes called "explosive" oscillations.)[2]

c. (Optional) See if you can determine which parameters in the hog model influence the period and damping. (This will take some investigation.) Once you have discovered which parameters influence the damping of the system, you may wish to explore some policies that might reduce the degree to which the system oscillates in response to external disturbances.

ENDNOTES

1. This is a somewhat simplified description of the process of breeding and fattening hogs. For a more detailed description, see Dennis L. Meadows, *Dynamics of Commodity Production Cycles* (Cambridge, Mass.: MIT Press, 1970).
2. One measure of the degree of damping is the "damping ratio," which is defined as "one minus the ratio of the amplitude of two successive peaks." If the oscillations are fading, the damping ratio will have a value between zero and one. If the oscillations are steady, the damping ratio will have a value of zero; if the oscillations are growing, the damping ratio will have a negative value.