CHAPTER 3

# Commodity Cycles

This workshop presents a model of the causes of commodity production cycles adapted from Goodman (1974), Exercise 10. Any raw material with the following characteristics is a commodity:

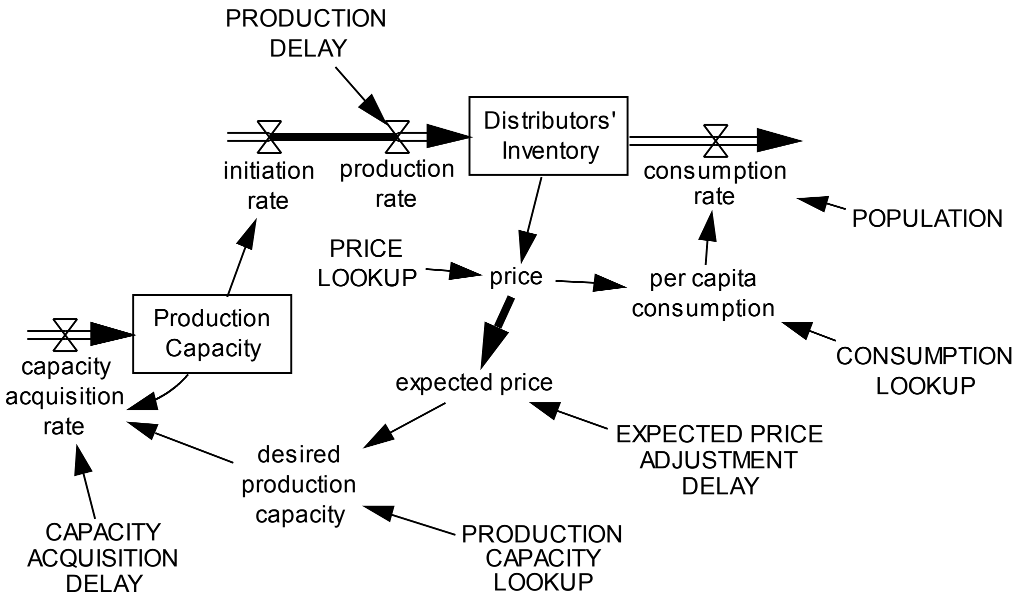
- It is undifferentiable. Thus no producer can obtain higher price or better trading terms through advertising or product modification. The producers must accept the open market price which prevails at the time of sale.
- Variable production costs (labor and materials) are small compared to fixed costs. Thus, in the short term, output of the commodity will be relatively insensitive to price changes.
- For commodity users, the commodity price is only a small fraction of the final product cost. Therefore, consumption is relatively price inelastic in the short run.

More than twenty important commodities (for example, oil, cocoa, sugar, jute, and tin) change hands in the commodity trade. This trade accounts for a large share of the foreign exchange earnings of many less economically developed countries. The price and production rate of commodities is unstable and often varies from one year to the next by five to twenty-five percent.

Commodity production cycles cause significant difficulties for producers, distributors, manufacturers, and consumers. As a result, individual countries and international agencies have invested considerable effort in various stabilization schemes. None have been totally successful, and many have been absolute failures.

## 3.1 Commodity Production Model

The following model illustrates a possible structure underlying long-term commodity fluctuations. A stock and flow diagram for this model is shown below:




This model is based on the interactions among three market sectors: production, distribution, and consumption. Price links the three sectors. Producers try to adjust their production capacity to the profit maximizing level for a given market price. Distributors try to adjust the market price by maintaining an optimal inventory. Consumers respond to the market price as they attempt to maximize their utility.

The stock and flow diagram shows a variety of features about this model. There is a delay between starting to make a change in the production rate (initiation rate) and the actual production rate change. This delay is governed by the constant PRODUCTION DELAY. The price is related to the Distributors Inventory through a lookup function PRICE LOOKUP. The per capita consumption is related to price through a lookup function CONSUMPTION LOOKUP. The desired production capacity is driven by the expected price, which is a delayed (smoothed) function of price with a smoothing constant EXPECTED PRICE ADJUSTMENT DELAY. The desired production capacity depends on the expected price through a lookup function PRODUCTION CAPACITY LOOKUP. The capacity acquisition rate depends on the desired production capacity with an impact from the constant CAPACITY ACQUISITION DELAY.

To develop your simulation model of commodity production cycles, you have the following information:

- The relationship between Distributors Inventory and price (PRICE LOOKUP) is specified by the following pairs of values. Intermediate values are determined by linear interpolation.

| Distributors Inventory | 0 | 2000 | 4000 | 6000 | 8000 | 10,000 |
|---|---|---|---|---|---|---|
| price | 100 | 94 | 80 | 50 | 20 | 10 |

- The relationship between price and per capita consumption (CONSUMPTION LOOKUP) is specified by the following pairs of values. Intermediate values are determined by linear interpolation.

| | | | | | | |
|---|---|---|---|---|---|---|
| price | 0 | 20 | 40 | 60 | 80 | 100 |
| per capita consumption | 7 | 6 | 4 | 2 | 1 | 0 |

- The relationship between expected price and desired production capacity (PRODUCTION CAPACITY LOOKUP) is specified by the following pairs of values. Intermediate values are determined by linear interpolation.

| | | | | | | |
|---|---|---|---|---|---|---|
| expected price | 0 | 20 | 40 | 60 | 80 | 100 |
| desired production capacity | 0 | 40 | 200 | 1,000 | 1,200 | 1,280 |

- The consumption rate is equal to the per capita consumption multiplied by the POPULATION. The POPULATION is 200.
- The expected price is an exponentially smoothed average (SMOOTH) of price with a smoothing constant of EXPECTED PRICE ADJUSTMENT DELAY, which is 5 months.
- The capacity acquisition rate is equal to the difference between the desired production capacity and the Production Capacity divided by the CAPACITY ACQUISITION DELAY, which is 4 months.
- The initiation rate is equal to the Production Capacity.
- The production rate is a third order exponential delay (DELAY3) of the initiation rate, with a delay time of PRODUCTION DELAY, which is 12 months.
- The initial Production Capacity is 600 units per month, and the initial Distributors Inventory is 6,000 units.
- Use a time step of 0.5 months for your simulation, and run it for 240 months (20 years).

1) Develop a simulation model for commodity production and distribution cycles using the information above. Do not add any additional assumptions to your model. Hand in the stock and flow diagram, as well as the equations for your model. Also, hand in graphs of Distributors Inventory and its causes, as well as Production Capacity and its causes. (Hint: The output of this model is very boring. Everything is in equilibrium, and all the graphs are flat lines.)

## 3.2 Commodity Production Cycles

In the following question, we investigate where commodity production cycles originate. In real commodity production systems, there is usually some noise in the process. For example, weather or civil strife may cause random fluctuations in production or consumption.

2) Modify your model from Question 1 by introducing random fluctuations in per capita consumption which are twenty-five per cent above and below

the value calculated by the CONSUMPTION LOOKUP function starting at time equal to ten months. Specifically, use the Vensim equations

$$\begin{aligned}\text{per capita consumption} &= \text{CONSUMPTION LOOKUP(price)}\\ &\quad * (1 + \text{NOIse})\\ \text{NOIse} &= \text{RANDOM UNIFORM(-0.5, 0.5, 2374)}\\ &\quad * \text{STEP(0 5 10)}\end{aligned}$$

a. For this modified model, include the graphs of Distributors Inventory and its causes, as well as Production Capacity and its causes, with your solution.
b. Describe what is causing the apparent cycles (oscillations) in the commodity production system. (Hint: Think about the type of feedback structure that exists in this system and the impact of the delays in the system as the consumption rate varies.)
c. Also describe the impact of including the constant 2374 in your model. Discuss why it can be useful to include a constant like this in models that use random number generators.

## 3.3 Changes to the Model

This is a continuation of the investigation of commodity production and distribution from Question 2. Assume that all of the conditions specified in that question hold except as specified below. In this section, you investigate the impact of two changes to the model developed in Question 2.

3) The population consuming most commodities does not remain constant. Assume that population grows exponentially with a constant of 0.5 percent (0.005 fraction) per month. Add the structure and equations to your model from Question 2 to represent population growth, and explain how this impacts the results from Question 2. Include the equations that are modified from Question 2 with your answer, and also show curves for some variables to support your explanation. Discuss the reasons, in terms of the system structure, for the impact, or lack of impact, that you see from making this change. (Hint: Remember the basic feedback structure that generates exponential growth. This is a simple question! Specifically, it is not necessary to put in any exponential functions to answer this question.)
4) For most commodities, Production Capacity does not last indefinitely, but wears out gradually until it is no longer useful. Assume that Production Capacity wears out as an exponential decay process with a constant of 10 years (120 months). Add the structure and equations to your model from Question 2 (**not** Question 3) to represent this process, and explain how this impacts the results from Question 2. Include the equations that are modified from Question 2 with your answer, and also show curves for some variables to support your explanation. Discuss the reasons, in terms of the system structure, for the impact, or lack of impact, that you see

from making this change. (Hint: Remember that exponential decay is the same as goal seeking behavior with a goal of zero. As in Question 3, it is not necessary in answering this question to put in any exponential functions.)

## 3.4 Recycling

This is a continuation of the investigation of commodity production and distribution from Question 2. Assume that all of the conditions specified in that question (**not** Questions 3 and 4) hold except as specified below.

For some commodities, such as metals, a significant amount of the consumed commodity is recovered into a scrap inventory. As price increases, more and more of this scrap is recycled into the Distributors Inventory. To build the model of recycling, assume the following:

- Forty percent of consumption is recovered into the scrap inventory.
- There is a third-order exponential delay (DELAY3) in this recovery with a delay time of 20 years (240 months).
- The relationship between price (**not** expected price) and the scrap recycling rate (RECYCLING LOOKUP) is specified by the following pairs of values. Intermediate values are determined by linear interpolation. (The scrap recycling rate is the fraction of the scrap inventory that is sold into the Distributors Inventory per month at a specified price.)

| price | 0 | 25 | 50 | 75 | 100 |
|---|---|---|---|---|---|
| scrap recycling rate | 0 | 0 | 0.1 | 0.2 | 0.4 |

- Since the introduction of recycling provides an additional source of the commodity, the initial values of the various stocks which result in equilibrium are different from those in part a. For this part, assume the initial scrap inventory is 3,396 units, the initial Distributor s Inventory is 6307 units, and the initial Production Capacity is 415.39 units.

5) Add the structure and equations to your model from Question 2 (**not** Questions 3 or 4) to represent recycling, and determine how this impacts the results from Question 2. Specifically, provide the following:
   a. The stock and flow diagram for the modified model.
   b. The equations for the modified model.
   c. The graphs of Distributors Inventory and its causes, and Production Capacity and its causes
   d. A brief explanation for the reasons for the change in behavior from Question 2.

   (Hint: Carefully read the definition of the scrap recycling rate which is given above. Also, be sure that the flows into Distributors Inventory are correct. Recycling **does** improve the behavior of this process. Carefully examine the vertical scales on the graphs when you are comparing the results you obtain in this exercise with those in Question 2.)

6) For the model in Question 5, examine the behavior over time of the rate at which the recovered commodity actually flows *into* the scrap inventory after taking into account the delay in the recovery. To see this behavior more clearly, you should extend the duration of the simulation run to fifty years (600 months). Specifically, answer the following questions:
   a. Explain this behavior in terms of the properties of the third-order exponential delay (DELAY3).
   b. Compare the behavior of the flow into the scrap inventory with the consumption rate, and explain why the patterns of behavior for these two variables are so different.

   (Hint: This question asks about the behavior of the flow into the scrap inventory, and **not** about the flow into the Distributors Inventory.)

## 3.5 Reference

M. R. Goodman, *Study Notes in System Dynamics*, The MIT Press, Cambridge, Massachusetts, 1974.