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Exploring Supply Dynamics in Competitive Markets

By

**Bill Golden, Department of Agricultural Economics
bgolden@agecon.ksu.edu**

**Frieda Golden, Department of Education
fjgolden@ksu.edu**

and

**Leah Tsoodle, Department of Agricultural Economics
ltsoodle@ksu.edu**

Kansas State University

Waters Hall

Manhattan, KS 66506

785-532-1462

**Selected Paper prepared for presentation at the Southern Agricultural
Economics Association Annual Meeting, Mobile, Alabama, February
1-5, 2003**

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Introduction

Understanding the ebb and flow of competitive markets is essential for students pursuing a variety of undergraduate degrees. Competitive markets, in the academic setting, are central to all types of economic and business majors, but are most generally studied in a static setting. Competitive markets are not limited to the academic setting, but are integral in the daily life of anyone who is a consumer or producer. The objective of this paper is to develop a dynamic simulation model, with curriculum materials, that introduces users to interactions occurring in the supply side of competitive markets.

This model is geared toward, but by no means limited to, undergraduate economic courses. The model shows specific relationships graphically and mathematically, so it appeals to different learning styles. It allows users to easily make changes to any aspect of the market and immediately see how those changes affect all other aspects of the market. This model brings tangibility and simplicity to an intangible, complex concept of the competitive market. It could easily be used alone, or in conjunction with other methods, to introduce students to the dynamics of a competitive market and simulation modeling.

It is important for students to learn about conceptual models because the conceptual model is the link between theory and empirical models. Conceptual models allow students to apply economic theory to investigate a research question. The conceptual model is not limited by the data available. It is important for students to mentally develop an ideal model. The conceptual model can contain all elements that students believe need to be included in it. The conceptual model is the ideal, and the

empirical model is as close as economists can get with the data available. Often the economic models rely on complex mathematics and statistics. The system dynamic approach allows students to be introduced to modeling without the potential barrier of the mathematics. System dynamic models allow the students to focus on the economic aspects of the subject rather than the mathematical techniques.

This simulation model uses a System Dynamics framework. A simulation model attempts to simulate economic interactions in different markets to examine policy and theoretical impacts. System Dynamics models can be easily changed and “what if” scenarios can be easily created by modelers. In simulation modeling, variables can be classified as either endogenous or exogenous. Exogenous variables are those variables that are determined outside the model, usually through assumptions. Endogenous variables are determined within the model using interactions built into the model and are generally the focus of interest.

This model is designed using a visual system dynamics framework (Appendix I - Figure 1), and is based on the sample problem located in Appendix II. While there are certainly mathematical formulas underlying and driving the model, the visual format allows students to develop a mental model of the system’s structure and see market interactions through the causal loops. Within a system dynamics framework, the competitive market is dynamic where prices, the number of firms, firm output, and other elements of the system are all changing over time. These changes are the result of interactions among the elements that constitute the system. To understand the changes, we should understand the related system. Elements of the system interact through feedback loops, as the building blocks of all dynamic systems. Feedback loops consist of accumulations, or level variables (the number of firms and their output), rate variables that drive level changes (firm entry and exit rate, rate of firm output adjustment), and information levels connecting level to rate variables (profitability and price levels). Simultaneous

active feedback loops create the dynamics in this situation. Generally, the human mind is not capable of perceiving the dynamic consequences of a number of simultaneously active feedback loops. However with the interactive software, students are capable of isolating feedback loops and freezing time to enhance understanding.

This particular model has two feedback loops. The *Price-Output per Firm* loop allows students to explore the interaction between price, marginal cost, and output per firm with the ability to easily alter marginal cost and the rates of increasing or decreasing output. The *Profitability-Number of Firms* loop allows the student to explore the relationships between price, fixed and variable costs, profitability, and firm entry or exit rate, with the ability to quickly alter these parameters. The simplicity of the model allows users that are unfamiliar with system dynamics models an easy introduction to this area of modeling. This model eases the introduction of system dynamics into the economic arena by focusing on a basic economic concept, the supply side of a competitive market. The included curriculum materials give instructors several activities for each aspect of the model, focusing on how the structure of the market can generate either dynamically stable, equilibrating markets or dynamic disequilibria.

Finally, the model contributes significantly to the economic literature. System dynamics has been widely used in business fields, but is fairly new to the economic arena. Although, competitive markets are studied in business fields, the structure generally takes on more of an accounting rather than economic approach. This model is a unique merger of business and economics, using platforms familiar to both areas. The teaching activities can be adapted to any content. This flexibility and global perspective enables the model to be extremely educational to a wide variety of disciplines.

This paper has been organized so that an instructor can provide this document as a class handout. Directions for downloading and using the software are included in the next section, “Becoming Familiar with Vensim PLE”. An overview of the model, with a discussion of the dynamic components, is summarized in “Understanding the Model”. To familiarize users with Vensim, a “Sample Simulation” section is included. The last section is comprised of example exercises. The first exercise focuses on “Dynamic Stability in Competitive Markets”, while the second exercise explores “Equilibration in Competitive Markets”. In the third exercise, factors contributing to “Dynamic Instability in Competitive Markets” are discussed.

Becoming Familiar with Vensim[®] PLE

Vensim[®] Personal Learning Edition (PLE) is simulation software used to develop and analyze dynamic feedback systems. It is available, free of charge from Ventana Systems, Inc., and can be downloaded from their website at <http://www.vensim.com/download.html>. The student should download and install the software as per the instructions on the website. Be sure to download and save all six disks prior to running the executable file on Disk 1. After installation go to Start → Programs → Vensim, and open Vensim[®] PLE. Then go to Help → Vensim Manuals → User’s Guide → 2, The Vensim User’s Interface, and review the topics listed. It will be convenient to print the topics Tool Bars, Sketch Tools, and Analysis Tools for future reference. While it is not required to complete the following exercises, the student is encouraged to work through topic 3, A Hands on Example, in the User’s guide.

Understanding the Model

The system dynamic model (Appendix I - Figure 1) is based on the sample problem located in Appendix II. Prior to examining the structure of the model, the student should work through the sample

problem. After becoming familiar with the math associated with the problem, open Vensim® PLE.

Using File → Open Model command, open the file “simple S&D.mdl”. This file is available from your instructor and will run better if loaded from your hard drive. Occasionally, the model is too large to see on one screen. In this case, then use the View → Zoom → Fit to Screen command to resize the model. Your screen should now look like Figure 2.

The model is composed of many variables. The *Number of Firms*, *Aggregate Supply*, and *Profit* are a few examples of model variables. The model is composed of two causal feedback loops. The right loop is named the *Price-Output per Firm* loop, and it models how firms adjust their output depending on the market price. The left loop is the *Profit-Number of Firms* loop, and it models how firms enter and exit the market depending on the profitability of the industry. Within a system dynamics framework, the arrows portray the direction of causality between variables. As an example, you can see that *Aggregate Supply* is caused by both *Number of Firms* and *Production per Firm*. While this tells us what causes *Aggregate Supply*, it does not specify how it is caused. To see the specifics of how *Number of Firms* and *Production per Firm* interact, select the **equation** tool on the **sketch tool toolbar** (one left click of the mouse), and then select the variable *Aggregate Supply* (one left click of the mouse). This procedure opens the **equation editor** (Figure 3). We can now see that the mathematical specification is $AggregateSupply = Numberof\ Firms * ProductionperFirm$. Click **OK** to close the **equation editor** window.

Price is simultaneously determined by the interaction between demand and supply. In this model aggregate demand is assumed to be fixed and constant primarily to isolate the supply side interactions. The demand curve is composed of two variables, *Demand Curve-Intercept* and *Demand Curve-Slope*. On the **sketch tool toolbar** select the **equation** tool (one left click of the mouse), and then

select the variable *Demand Curve-Intercept* (one left click of the mouse). This procedure opens the **equation editor**. We can now see that the mathematical specification is *Demand Curve-Intercept=22*. Click **OK** to close the **equation editor** window. Use the **equation editor** to verify the mathematical specification for *Demand Curve-Slope* is *Demand Curve-Slope = .0001*. Now, use the **equation editor** to verify the mathematical specification for *Price* is *Price = max((Demand Curve - Intercept-Aggregate Supply*Demand Curve - Slope),0)*. The use of the max-min function insures that price will never go below zero. This is exactly the same specification as given in equation #1 of the sample problem (Appendix II).

Focusing on the *Price-Output per Firm* loop lets the instructor review the concept of marginal cost. Within competitive markets, firms are assumed to be price takers. This means that firms take their input and output prices as given, and maximize profit by choosing their quantity of production (equation #2 of the sample problem). In perfectly competitive markets, the quantity that will maximize profit is when output price = marginal cost. Now use the **equation editor** to verify the mathematical specification for *Marginal Cost = .04* and *Desired Production = Price/Marginal Cost*. This is exactly the same specification as given in equation #3 of the sample problem (Appendix II).

We used economic theory to guide the model development; however theory only tells us how to arrive at a firm's optimal production quantity to maximize profits. Theory does not specify the mechanics of moving from one production level to another. If a firm is underproducing, then time is required to add equipment and people, as well as to obtain the financial requirements for increased production. On the other hand if a firm is overproducing, then asset reduction is equally difficult. From this perspective we need to recognize that production quantities are 'sticky', and explicitly incorporate into the model the rates at which production can change. This requires assumptions that by their nature

are abstractions from reality. It will be these assumptions that will create the dynamics of our competitive model. Use the **equation editor** to review the mathematical specifications for *Rate of Increasing Production* and *Rate of Decreasing Production*. Using the **equation editor** we see that *Feasible Change in Production = IF THEN ELSE(Production per firm < Desired production, (Desired production - Production per firm) * Rate of increasing output, (Desired production - Production per firm) * Rate of decreasing output*. This simply indicates that a firm can increase or decrease production based on 10% of the difference between current production and desired production. Use the **equation editor** to review the mathematical specification for *Change in Production* and *Maximum Output Capacity*. This specification indicates that the *Change in Production* will equal the *Feasible Change in Production*, unless that change will cause the firm to exceed its *Maximum Output Capacity*.

To complete the *Price-Output per Firm* loop use the **equation editor** to review the mathematical specification for *Production per Firm*. We started our simulation model, in the first time period, with an initial value for *Production per Firm*, and saw how this quantity impacted the price. Based on our assumptions and the current market price, the firm decided how to change their production quantity. One can now simulate the second period where *Production per Firm = Initial Production per Firm + Change in Production*.

The left loop is the *Profit-Number of Firms* loop, and it models how firms enter and exit the market depending on profitability. Using the **equation editor** examine the mathematical specifications for *Impact of Production on Cost*, *Variable Expenses*, *Fixed Expenses*, and *Profit*. The *Variable Expenses* are the product of *Marginal Cost* and the number of units produced per firm. The *Marginal Cost* and *Fixed Expenses* are assumptions built into the model and are easily changed to be industry

specific. Notice that the specification for *Profit* is exactly the same as equation #2 in the sample problem. Economic theory implies that if profits are positive (negative), then firms will enter (exit) the market. Similar to the firm's decision to alter the quantity of output, theory does not specify exactly how, or in what quantities, firms will enter the market. Because of the need to quantify the change, we need to make assumptions to model firm entry and exit. Using the **equation editor** examine *Entry Rate* and *Exit Rate*. The specification is: *Change in the Number of Firms = IF THEN ELSE(Profit=0, 0, IF THEN ELSE(Profit>0, Entry Rate, IF THEN ELSE(Profit<0, -Exit Rate, 0)))*. This equation indicates that if profits are positive, then the change in the quantity of new firms is the *Entry Rate*, and if profits are negative, then the change in the quantity of new firms is the *Exit Rate*. These assumptions are easily changed according what the modeler believes is reasonable or chooses to test.

To complete the *Profit-Number of Firms* loop use the **equation editor** to review the mathematical specification for *Number of Firms*. We began our simulation model, in the first time period, with an initial value for *Number of Firms*, and saw how this quantity impacted the price. Based on our assumptions and the current market price, the market decided how to change this number based on profitability. We can now simulate the second period where *Number of Firms = Initial Number of Firms + Change in Number of Firms*.

The flexibility of system dynamic models is the key to their importance in teaching future economists. In 1936, Keynes said that the nature of economic thinking was not to create an infallible method of blind manipulation to furnish an answer, but to develop an organized and orderly method of thinking out particular problems (Keynes, 1936). System dynamic models are excellent tools for students to explore ways to solve economic problems. These models are easy to build and change.

This facet enables users to be involved in the entire model building process, rather than blindly plugging data into someone else's model. In developing one's own model, one knows all the assumptions, limitations, and strengths of the model. The ease of model building and the ease of changing the model are the major assets of using system dynamic models.

Sample Simulation

Using the **equation editor** set *Initial Number of Firms* = 400, *Initial Production per Firm* = 40, *Rate of Increasing Production* = *Rate of Decreasing Production* = 0.05, *Entry Rate* = *Exit Rate* = 0. On the Menu bar go to Model → Settings and change the Final Time to 10. On the Main Toolbar click on the Simulate button (running man with green dot). Answer yes to the question – do you want to override current data set, if the pop up screen appears. You have now successfully simulated the model. Suppose you want to know how price changed over the 10 year simulation period. On the **Sketch toolbar** click once on the **lock** button, and select the variable *Price* by clicking on it. On the **Analyses toolbar** click once on the **Graph** button. A time-series graph of price should appear on the screen (Figure 4, Appendix II). Close the graph and click once on the **Table** button on the **Analyses toolbar**. This is the same data as presented in the graph except it is in tabular form and can easily be copied to a spreadsheet package, if needed. Close the table, select the *Production per Firm* variable by clicking on it. On the **Analyses toolbar** click once on the **Graph** button, to see how *Production per Firm* changes over time. This process can be repeated for any variable that is selected.

Exercise 1: Dynamic Stability in Competitive Markets

- 1) In simulation modeling variables can be classified as either endogenous or exogenous. Exogenous variables are those variables that are determined outside the model, generally through assumptions. Endogenous variables are determined by the model and are generally the focus of interest. List the endogenous and exogenous variables in this model.
- 2) On the **toolbar** click once on the **control panel** icon. The control panel window will open and click once on the **Datasets** tab. Select *current* from the **loaded-info** window and move it to the **available-info** window. With *current* selected delete the dataset and close the window. Using the **equation editor** set *Initial Number of Firms* = 400, *Initial Production per Firm* = 40, *Rate of Increasing Production* = *Rate of Decreasing Production* = 0.05, *Entry Rate* = *Exit Rate* = 0. On the Menu bar go to Model → Settings and change the Final Time to 10. On the **toolbar** change the **runname** to Normal Marginal Cost, and simulate the model. Using the **equation editor** set *Marginal Cost* = .06, and *Impact of Production on Cost* = .03. On the **toolbar** change the **runname** to High Marginal Cost, and simulate the model. Using the **equation editor** set *Marginal Cost* = .02, and *Impact of Production on Cost* = .01. On the **toolbar** change the **runname** to Low Marginal Cost, and simulate the model. You now have three simulation datasets. Using either the **Graph** or **Table** analyses tool describe how marginal cost impacts *Profit*, *Price*, and *Production per Firm* when firms can neither enter or exit the market.
- 3) Are The three markets from question 2 stable?
- 4) On the **toolbar** click once on the **control panel** icon. The control panel window will open and click once on the **Datasets** tab. Delete the three datasets created in question 2. Using the **equation editor** set *Initial Number of Firms* = 380, *Initial Production per Firm* = 50, *Rate of Increasing Production* = *Rate of Decreasing Production* = 0, *Entry Rate* = *Exit Rate* = 2. On the Menu bar go to Model → Settings and change the Final Time to 20. On the **toolbar** change the **runname** to Normal Fixed Cost, and simulate the model. Using the **equation editor** set *Fixed Cost* = 25, on the **toolbar** change the **runname** to Low Marginal Cost, and simulate the model. Using the **equation editor** set *Fixed Cost* = 75, on the **toolbar** change the **runname** to High Fixed Cost, and simulate the model. You now have three simulation datasets. Using either the **Graph** or **Table** analyses tool describe how Fixed Costs impacts *Profit*, *Price*, and *Number of Firms* when firms can neither raise or lower the Production.
- 5) Are the three markets from question 4 stable?

Exercise 2: Equilibration in Competitive Markets

- 1) On the **toolbar** click once on the **control panel** icon. The control panel window will open and click once on the **Datasets** tab. Delete the three datasets created in exercise 1, question 4. Using the **equation editor** set *Initial Number of Firms* = 350, *Initial Production per Firm* = 45, *Rate of Increasing Production* = *Rate of Decreasing Production* = .15, *Entry Rate* = *Exit Rate* = 1, and *Fixed Cost* = 50. On the Menu bar go to Model → Settings and change the Final Time to 100. On the **toolbar** change the **runname** to Normal Quantity Change, and simulate the model. Using the **equation editor** set *Rate of Increasing Production* = *Rate of Decreasing Production* = .10, on the **toolbar** change the **runname** to Slow Quantity Change, and simulate the model. Using the **equation editor** set *Rate of Increasing Production* = *Rate of Decreasing Production* = .175, on the **toolbar** change the **runname** to Fast Quantity Change, and simulate the model. You now have three simulation datasets. Using either the **Graph** or **Table** analyses tool describe how a firm's ability to adjust quantity produced based on price signals impacts *Profit*, *Price*, *Production per Firm* and *Number of Firms*. Note: resizing the graph will help see the impacts more clearly.
- 2) Are the three markets from question 1 stable?
- 3) Does *Price* equilibrate around the equilibrium value found in the sample problem? Why or why not?
- 4) Does *Number of Firms* equilibrate around the equilibrium value found in the sample problem? Why or why not?
- 5) Does *Production per Firm* equilibrate around the equilibrium value found in the sample problem? Why or why not?

Note: As an aid in answering questions 3 through 5, open the **control panel** window, on the **graph** tab choose 'ALL_VARIABLES' and **display**. The displayed table is the results of the last simulation for all variables.

Exercise 3: Dynamic Instability in Competitive Markets

- 1) To this point we have evaluated markets that are somewhat symmetrical in nature. We have assumed that both the starting values of *Number of Firms* and *Production per Firm* are below the market equilibrium points. Additionally we have assumed that *Rate of Increasing Production* = *Rate of Decreasing Production* and *Entry Rate* = *Exit Rate*. On the **toolbar** click once on the **control panel** icon. The control panel window will open and click once on the **Datasets** tab. Delete the three datasets created in exercise 2, question 1. Using the **equation editor** set *Initial Number of Firms* = 420, *Initial Production per Firm* = 45, *Rate of Increasing Production* = .185, *Rate of Decreasing Production* = .115, *Entry Rate* = 3, and *Exit Rate* = 1. On the Menu bar go to Model → Settings and change the Final Time to 100. On the **toolbar** change the **runname** to Unsubsidized, and simulate the model. Using either the **Graph** or **Table** analyses tool describe the results. Include comments on: Is the market stable? What is the relationship between *Number of Firms*, *Production per Firm*, and *Aggregate Supply*. Why, in general are *Profit* and *Price* always below the equilibrium level of the sample problem?
- 2) Suppose the government decides to stabilize the market by providing a lump sum subsidy to the firms in this market. To see what would happen we need to add a variable *Subsidy* to the model. On the **Sketch** toolbar click once on the **Variable** icon, and click one time on a clear space under the *Profit-Number of Firms* loop. A text box will appear, type in the variable name as *Subsidy*, and on the **Sketch** toolbar click once on the **Lock** icon on the **Sketch** toolbar. Now we need to specify the relationship between *Subsidy* and *Profit*. On the **Sketch** toolbar click once on the **Arrow**, once on *Subsidy*, once on *Profit*, and once on the **Lock** icon on the **Sketch** toolbar. An arrow should appear connecting *Subsidy* to *Profit*. Using the **equation editor**, open *Subsidy*, set it equal to 25, and set the units to 'dollars/firms'. Using the **equation editor**, open *Profit*, and add at the end of the existing equation '+subsidy'. On the **toolbar** change the **runname** to Subsidized, and simulate the model. Using either the **Graph** or **Table** analyses tool describe the results. Include comments on: Is the subsidized market stable? Is *Price* in general higher or lower in the subsidized market? Is the variability in *Price* higher or lower in the subsidized market? What happened to firm profitability in the subsidized market? Why do so many firms enter the subsidized market? Overall does the government subsidy help or hurt producers and consumers.
- 3) In order to simulate the behavior of this market we have made several assumptions about the structure of the market, and agent behavior. That is we have made assumptions about the initial *Number of Firms* and *Production per Firm*, as well as *Rate of Increasing Production*, *Rate of Decreasing Production*, *Entry Rate*, and *Exit Rate*. We have also made assumptions how these variables impact other variables. If we change these assumptions will we get the same results as we did in question 1 and 2 of exercise 3?

Appendix I

Figure 1

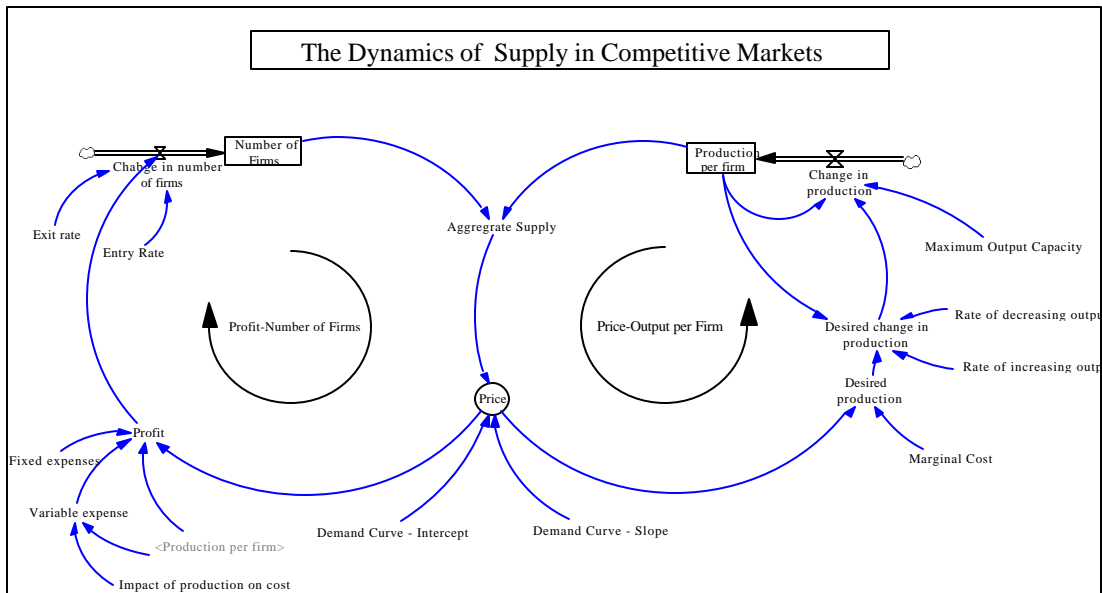


Figure 2

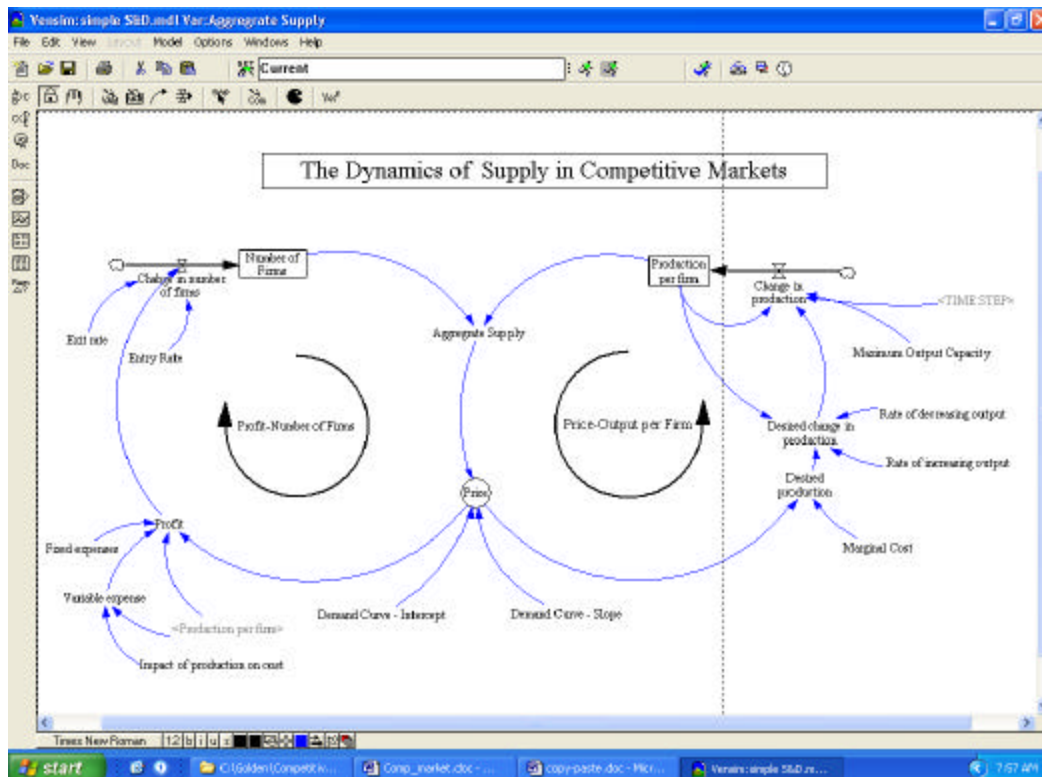


Figure 3

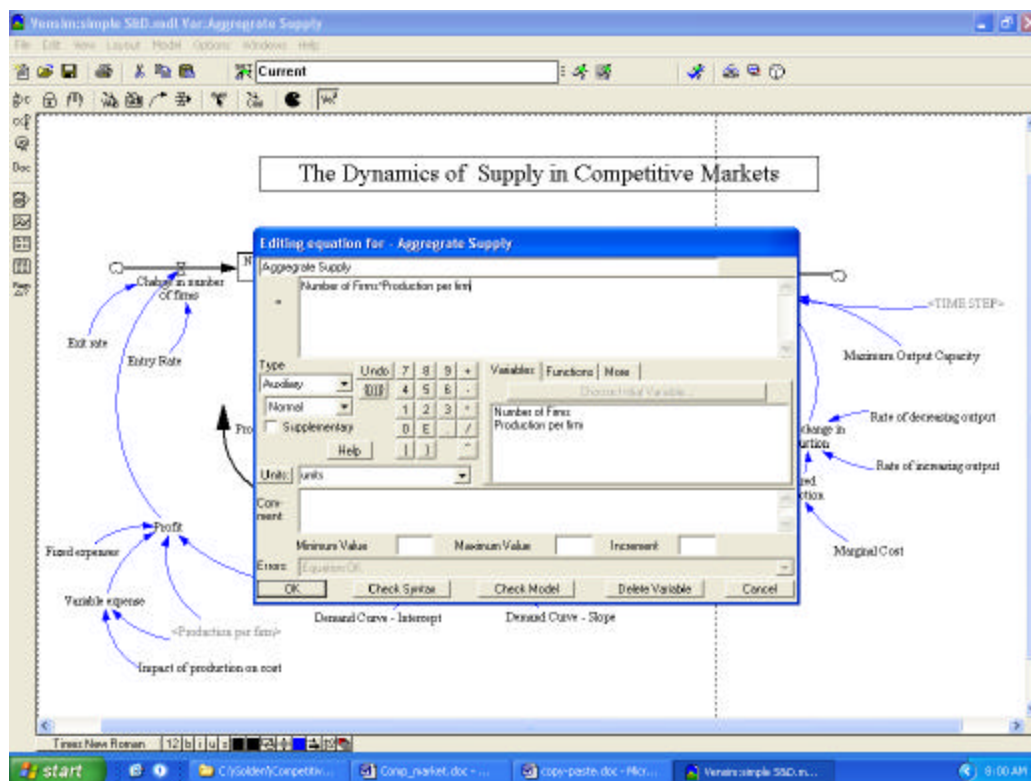
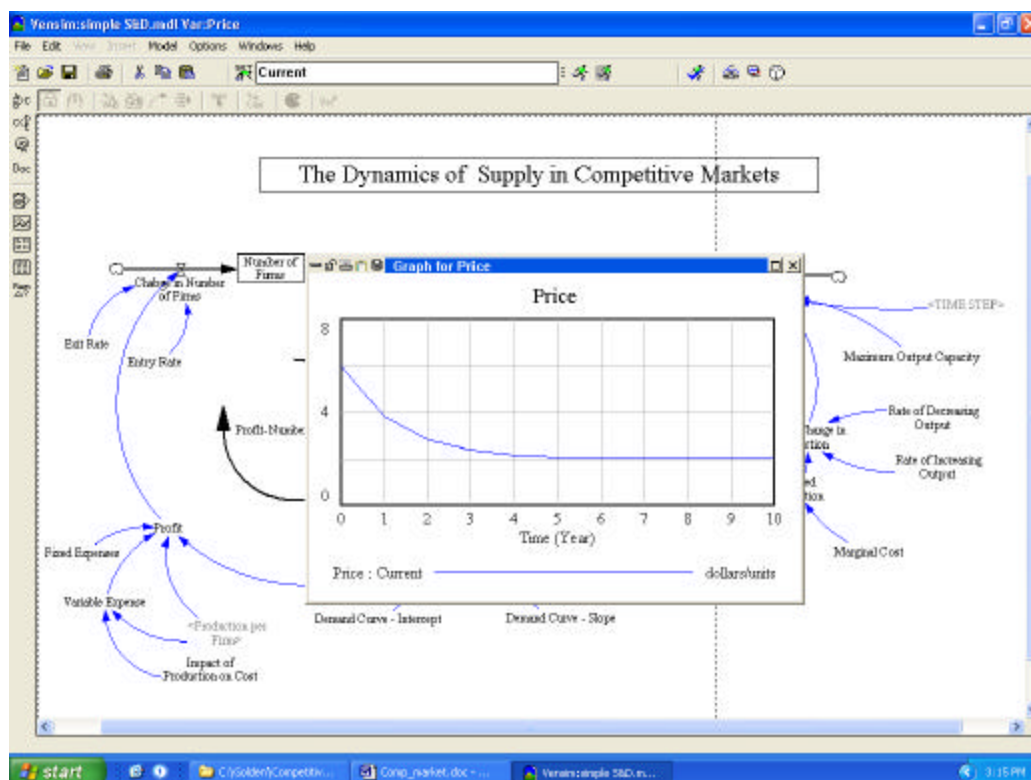


Figure 4



Appendix II - Sample Problem

Consider a competitive market composed of n identical firms and 1000 identical consumers. Each firm has a cost function: $C(q_i) = .02q_i^2 + 50$, $i = 1, 2, 3, \dots, n$. Each consumer has an inverse demand function: $p(q_i) = 22 - q_i$, $i = 1, 2, 3, \dots, 1000$.

- 1) Find the individual firm's supply, the market supply, the market demand, equilibrium price and equilibrium quantity.
- 2) Firms enter and exit the market according to the level of profit. Find the equilibrium price, quantity, and the equilibrium number of firms.

Answer:

$$1) \quad Q_D = \sum_{i=1}^{1000} q_i = \sum_{i=1}^{1000} (22 - p) \Rightarrow Q_D = 22000 - 1000p \Rightarrow p = 22 - .001Q \quad [eq \#1]$$

$$\text{Firms solve the problem: } \text{Max } \mathbf{p} = pq_i - .02q_i^2 - 50 \quad [eq \#2]$$

$$\Rightarrow p = .04q_i = MC$$

$$\Rightarrow q_i = p / .04 = 25p \quad [eq \#3]$$

$$Q_S = \sum_{i=1}^n q_i = \sum_{i=1}^n 25p_i \Rightarrow Q_S = 25np$$

At equilibrium

$$Q_S = Q_D \Rightarrow p^* = \frac{22000}{(1000 + 25n)} \quad \& \quad Q^* = \frac{550000n}{(1000 + 25n)} \quad \& \quad q_i^* = \frac{550000}{(1000 + 25n)}$$

Firms will enter the market until economic profits are zero: $\mathbf{p} = (p^*)(q_i) - .02q_i^2 - 50 = 0$ which yields

$$n = 400 \quad p^* = 2 \quad q_i = 50$$

References

Keynes, M. *The General Theory of Employment, Interest, and Money*. New York: McMillan Press, 1936.