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Educational technology in economics instruction

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Abstract

In this paper, we will show, in the context of a "market equilibria" example, how the use of educational technology associated with system dynamics makes it possible for instructors to teach undergraduate students topics of economic structures/processes involving nonlinearity, stochasticity, non-differentiability and discontinuity. We present three submodels/subcases associated with the example. In the first model, we have continuous and continuously differentiable linear demand and nonlinear supply functions for a good. Each function involves a stochastic term. In the second model, we do not have a continuous and continuously differentiable demand function but only a demand schedule. The supply function is a continuous nonlinear function of price. In the third model, we have interrelated markets for two goods with discontinuous stochastic demand and nonlinear stochastic supply functions. In all cases, we use system dynamics to find, in a very simple and user-friendly manner, the dynamic equilibrium paths and hence dynamic equilibria in the markets in question.

Key words: economics instruction, system dynamics, market equilibria

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1. Introduction

In recent decades, information technologies have led to the development of computerized methods that have the potential of revolutionizing the economics instruction. Topics that were once outside the proper boundaries of the

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undergraduate instruction are now within the reach of even the second year students, thanks to the computerized methods in question. In this paper, we will demonstrate how proper employment of one such method, namely system dynamics, makes it possible for instructors to teach students, in a user friendly manner, topics involving economic structures/processes that are nonlinear, stochastic, non-differentiable and/or discontinuous. The example we will choose is one of the most celebrated ones in economics, namely the example of market equilibrium/equilibria. We will present three sub-models associated with the example.

2. The Models

2.1. *Model 1:* Consider the market for good A with the following linear demand and nonlinear supply functions.

$$Q_A^D = \alpha_0 + \alpha_1 p_t^A + u_t$$

$$Q_A^S = \beta_0 + \beta_1 p_t^A + \beta_2 p_{t-1}^A + \beta_3 (p_{t-1}^A)^2 + v_t$$

$$Q_A^D = Q_A^S$$

where Q_A^D, Q_A^S, p_t^A, and p_{t-1}^A represent quantity demanded for good A, quantity supplied for good A, and prices of good A at t and t-1 respectively. All prices and quantities are non-negative. u_t and v_t are stochastic terms. The last equation is the usual equilibrium condition.

We will model and simulate the equilibrium path in this model with system dynamics which is a computational method for modeling and simulating the behaviour of processes and systems over time.[†] In system dynamics terminology, a "stock" (or "level variable") is the component of the system which increases or decreases over time, and whose behaviour could be captured by differential or difference equations of non-stochastic or stochastic kinds. The rate of change of the stock is called a "flow" (a "rate variable"). By properly identifying stocks, flows, the variables affecting stocks and flows and the feedback mechanism(s) embodied in the relationships among the components of the system, one can simulate the behaviours of the systems or processes such as market processes.

In Model 1, we can take price as a stock/level variable (in the system dynamics sense). The rate of change of price is the flow. Start with an initial price level and, using the market equilibrium condition, find the new price level. Take the difference to find the change in price. Using the equations, create steps of iteration (feedback loop) through which price levels over time are determined. The diagram representing these steps and relations is created in VENSIM and is given in Figure 1. As can be seen from the diagram, "pa - pa old - pa new - change in pa - pa" represents a feedback loop, generating the values of the investigated variables over time.

[†] For a comprehensive account of system dynamics, see the classic book by Sterman (2000). The books by the inventor of system Dynamics, J. Forrester, who initiated the method at MIT, are highly informative as well (Forrester (1961, 1969).

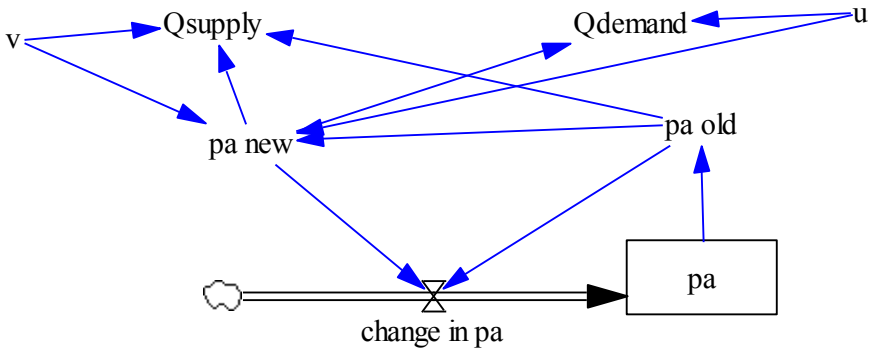


Figure 1. ”p old” is the price at t-1 and “p new” is the price at at t.

VENSIM is a freely available, user friendly system dynamics software with which we simulate the path for price and quantity in this model for the following parameter values:‡ $\alpha_0 = 100.$, $\alpha_1 = -4$, $\beta_0 = -20$, $\beta_1 = 2$, $\beta_2 = 0.5$, $\beta_3 = 0.05$, and “initial pa” = 15.. The stochastic terms are assumed to be normally distributed with zero means and unit variances. The trajectory for “pa” is as follows:

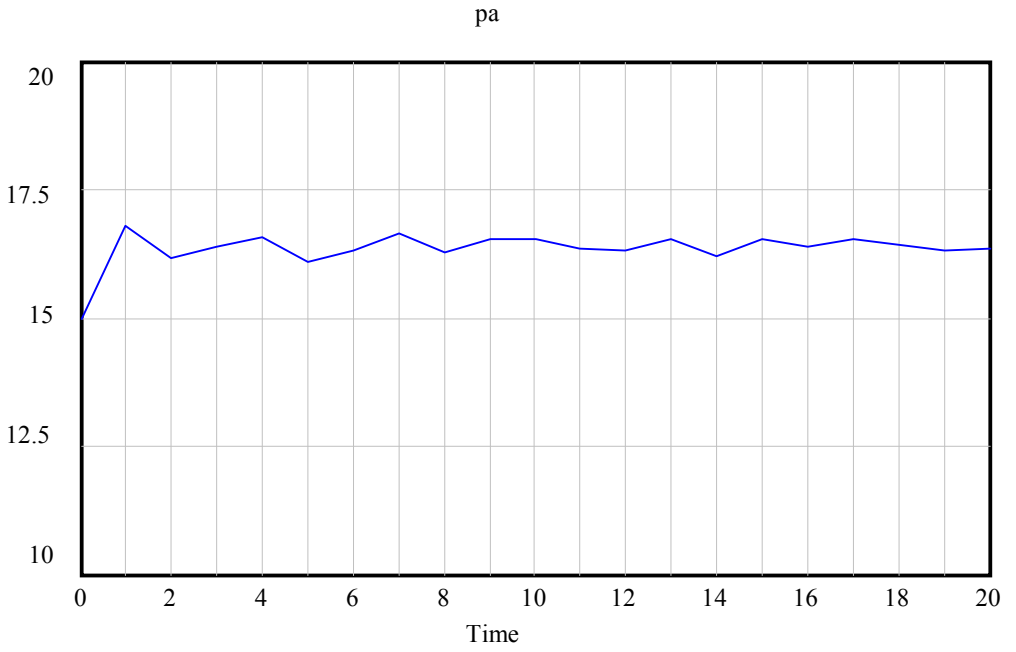


Figure 2.

‡ For detailed information about VENSIM, see http://www.vensim.com.

In the absence of stochastic terms, the equilibrium price and quantity in the dynamic context would be16.3941 and 34.4236 respectively.

Without software, the solution of this model would require solving a nonlinear stochastic difference equation, which would not normally be suitable at the undergraduate level. With easy-to-use software and a very simple system dynamics set-up, we can easily solve and simulate the model for any set of parameter values.

In model 1, we used continuous and continuously differentiable demand and supply functions. We will relax this assumption in Model 2.

2.2. *Model 2:* Suppose that we have a discontinuous mapping (f) between price and the non-stochastic part of the quantity demanded, which is represented by the demand schedule below (Table 1). The demand-supply set-up for good B is as follows:

$$Q_B^D = f(p_t^B) + u_t^B$$

$$Q_B^S = \beta_0 + \beta_1 p_t^B + \beta_2 (p_t^B)^2 + v_t^B$$

$$p_{t+1}^B - p_t^B = \sigma(Q_B^D - Q_B^S)$$

First and second equations are about demand and supply. The third equation is a dynamic adjustment equation linking price changes (adjustments) to excess demand. This way, we posit, in this example, an explicit adjustment dynamic as opposed to the implicit one embodied in the equilibration process in Model 1. Nevertheless, there is a connection between the two. At the equilibrium, $Q_B^D = Q_B^S$, the price adjustments ceases, .i.e., $p_{t+1}^B - p_t^B = 0$.

Table 1:

p^B_t	$f(p^B_t)$
0	100
4	84
6	75
8	68
10	60
11	54
13	50
18	30
20	23
21	18
23	15

What VENSIM does is to transform, through extrapolation, the discontinuous mapping into a continuous but not continuously differentiable mapping before it proceeds with simulation. The simulation diagram is given in Figure 3.

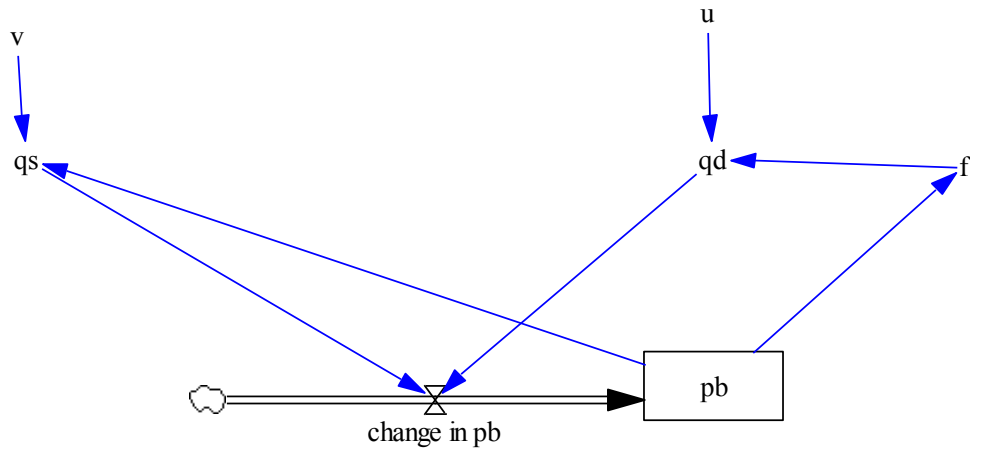


Figure 3.

We choose the following parameter values for simulation: $\beta_0 = -20,\ \beta_1 = 2,\ \beta_2 = 0.05,\ \sigma = 0.1$. The simulated trajectory for pb is as follows:

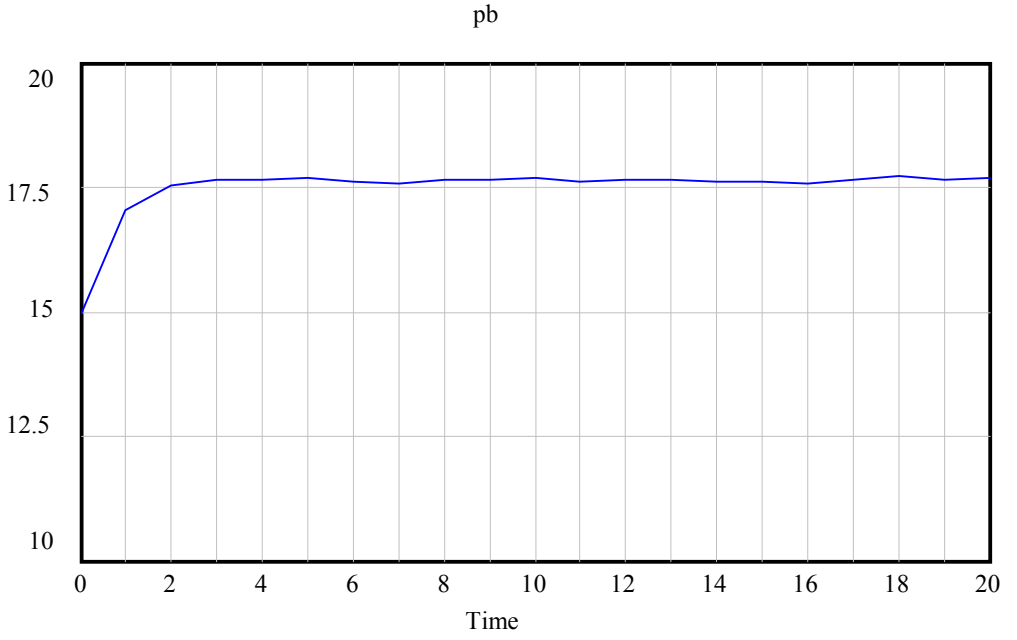


Figure 4.

2.3. Model 3: We will extend the first two models so as to make them interrelated and obtain a simultaneous system of markets. The equations are as follows:

Market for good A:

$$Q_A^D = \gamma_0 + \gamma_1 p_t^A + \gamma_2 p_t^B + u_t^A$$

$$Q_A^S = \delta_0 + \delta_1 p_t^A + \delta_2 p_{t-1}^A + \delta_3 (p_{t-1}^A)^2 + v_t^A$$

$$Q_A^D = Q_A^S$$

Market for good B

$$Q_B^D = f(p_t^B) + g(p_t^A) + u_t^B$$

$$Q_B^S = \beta_0 + \beta_1 p_t^B + \beta_2 (p_t^B)^2 + v_t^B$$

$$p_{t+1}^B - p_t^B = \sigma(Q_B^D - Q_B^S)$$

The quantity demanded of good A depends on the price of good B in a continuous and continuously differentiable manner. However, the quantity of good B depends on the price of good A through a discontinuous mapping ($g(p^A_t)$, which is represented in Table 2 below.

Table 2: $g(p^A_t)$

p^A_t	$g(p^A_t)$
5	0
10	1
15	3
21	6
25	7
35	10
45	12
50	13
60	15
63	16
70	18

The simulation diagram is given in Figure 5.

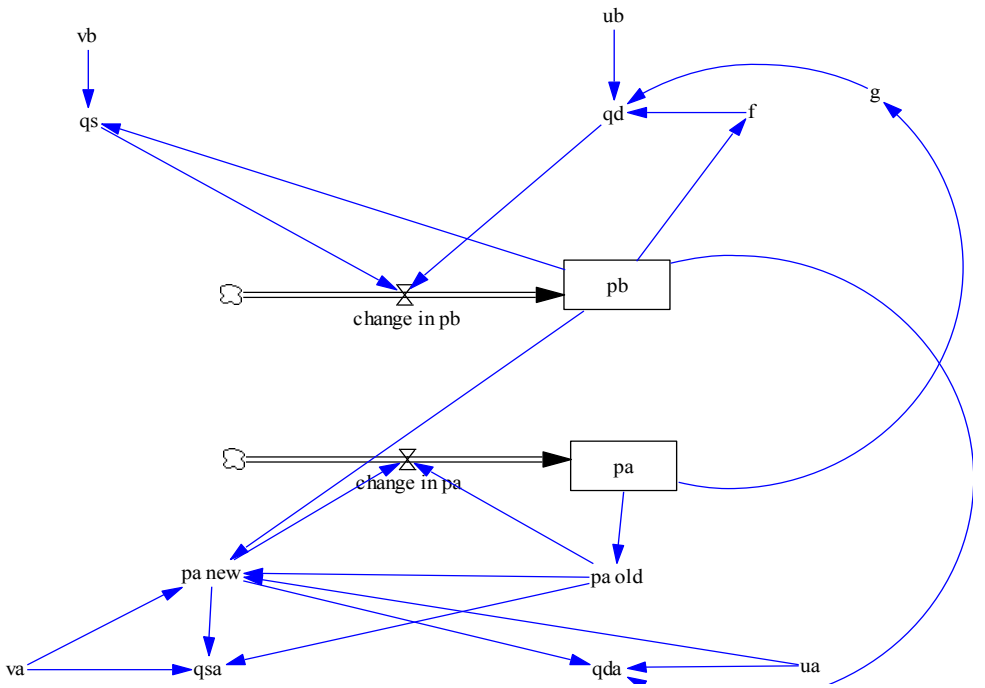


Figure 5.

We choose the following parameter values for simulation: $\gamma_0 = 100.$, $\gamma_1 = -4$, $\gamma_2 = 0.8$, $\delta_0 = -20$, $\delta_1 = 2$, $\delta_2 = 0.5$, $\delta_3 = 0.1$, "initial pa" = 10, $\beta_0 = -20$, $\beta_1 = 2$, $\beta_2 = 0.05$, $\sigma = 0.1$, "initial pb" = 15. The simulation results are as follows (only graphs will be presented):

Graph for pa

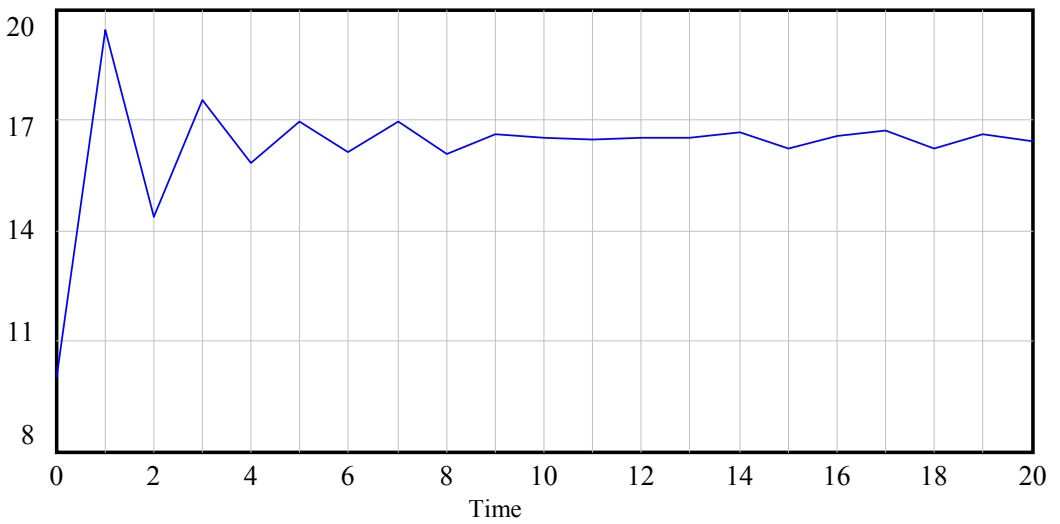


Figure 6

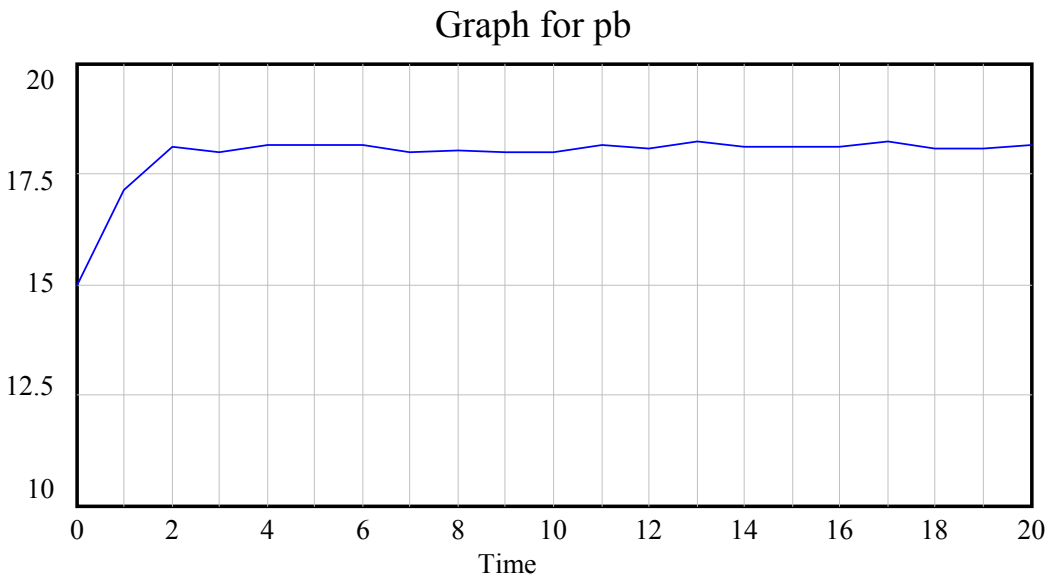


Figure 7

3. Concluding Remarks

In this paper, we have demonstrated, with the help of some models associated with a market example, how the proper use of system dynamics enables instructors to teach students dynamic analysis in the presence of nonlinearity, stochasticity, discontinuity and non-differentiability. Solutions to the models above would normally involve solving either a nonlinear stochastic difference equation or a system of nonlinear stochastic difference equations, which may involve discontinuity or non-differentiability. The method of system dynamics makes it possible to obtain numerical solutions to these models without having to analytically solve them. The method could also be used for the numerical solutions of the problems that are analytically intractable. It can be applied to a wide range of topics including issues of strategic interactions and even chaos.[§]

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[§] For an example of the treatment of strategic thinking with system Dynamics, see Kunc (2012).