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Numerical simulations of competition in quantities[☆]



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ABSTRACT

We present a series of numerical simulation models built in Excel that can be used to explore the properties of various models of strategic competition in quantities and their economic implications. The resources incorporate both tabular and graphical data presentation formats and are built in such a way that they provide instant or 'live' feedback on the consequences of changes in the economic system. We discuss the theory behind the models, how they can be implemented as numerical simulations in Excel, and ways in which the simulations can be used to enhance student understanding of the material.

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1. Introduction

Models of strategic competition in quantities are a mainstay of the undergraduate curriculum at multiple levels. The Cournot model of oligopoly is frequently taught in both introductory and intermediate microeconomics, and its various extensions form a core component of most courses in industrial organization. Moreover, models of competition in quantities are also commonly used in the international trade classroom when covering 'new' trade theory models of the reciprocal dumping variety. The models provide important insights into core concepts from game theory and into the implications of variations in market structure for economic outcomes. Hence, it is important that students develop a solid understanding of the properties of these models.

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There are a number of ways to teach models of strategic competition in quantities like the Cournot model. At the principles level a graphical approach is likely to be adopted, while in intermediate and senior-level industrial organization classes, simple models of competition in quantities are often used to introduce more general concepts from game theory and are typically solved algebraically for simple functional forms. A useful analog to these approaches is the use of numerical examples, which are a good mechanism for developing economic intuition. Numerical simulation makes abstract results more compelling for students, allows faster and more general demonstration of model properties, and can help connect models based on a common foundation. There are a wide range of examples in the literature, including models from microeconomics principles (Mixon and Tohamy, 2000), international trade (Gilbert and Oladi, 2011), macroeconomics (Findley, 2014) and financial economics (Guo and Gilbert, 2014).

While there are many platforms on which numerical simulations can be built, Excel has a number of advantages for pedagogical purposes.¹ It allows for both tabular and graphical presentations of information, can be used to solve quite complex problems, and is widely available on many computer platforms. It is also a program with which most students are already familiar, and it is widely used outside of the classroom.

In this paper we describe a series of numerical simulation models built in Excel that can be used to support instruction on models of strategic competition in quantities. As in Guo and Gilbert (2014), the models are built in such a way that they respond instantly to changes, have a consistent presentation across various extensions, and gradually build complexity onto a common foundation.² The paper is organized as follows. In the next section we set out the structure of the basic model and its solution, followed by a review of the geometry of the problem. We then turn to the question of how to implement the model as a numerical simulation in Excel. Next, we discuss how the resources we have built can be obtained and used, and we provide details on various extensions. Throughout we provide examples of exercises that can be used to explore the implications of differences in market structure for various economic variables of interest. We conclude with a few notes on how the approach we have taken in this paper could be extended to other topics.

2. The basic Cournot duopoly

We begin by sketching the basic Cournot duopoly model and its solution. We follow a standard, textbook approach and assume: (1) there are two firms (no entry); (2) firms have constant marginal and average costs, denoted c_i ; (3) the firms are producing a homogeneous product; (4) the overall market demand function is linear, with the inverse demand being specified as $P(Q) = a - bQ$ where $a, b > 0$ and $a > c_i$; and (5) the firms must choose their outputs simultaneously.³

The Cournot output represents a Nash equilibrium in a game where firms simultaneously choose output. Thus, the equilibrium is a list of price and output levels for each firm such that neither firm can increase their profits by changing their output given that the other firm does not change their output. Formally, the Cournot-Nash equilibrium is a triplet $\{p^c, q_1^c, q_2^c\}$ such that:

- Given $q_2 = q_2^c$; q_1^c solves $\max_{q_1} \pi_1(q_1, q_2^c)$
- Given $q_1 = q_1^c$; q_2^c solves $\max_{q_2} \pi_2(q_1^c, q_2)$
- $p^c = a - b(q_1^c + q_2^c)$

We begin by solving firm 1's maximization problem, whereby firm 1 chooses its profit maximizing quantity and takes firm 2's quantity as given. This yields firm 1's best response function, $R_1(q_2^c)$.

¹ Excel is useful in other contexts too. Wight (1999) discusses some general benefits of using spreadsheets beyond numerical simulation, while Briand and Hill (2013) consider the use of Excel for econometrics.

² While we present the models as a progression from relatively simple models to more complex ones, instructors may use the resources in the reverse order if they prefer. The model of monopolistic competition is the most general, and the others can be classed as special cases derived by adding more restrictive assumptions.

³ A more complete treatment of the model, and those that follow, can be found in typical industrial organization texts, such as Carlton and Perloff (2005).

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