Tennis Balls in Economics

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The law of diminishing marginal returns is one of the key concepts taught in an introductory economics course. It underlies many of the concepts covered later in the course and has ongoing relevance to advanced level courses in both microeconomics and macroeconomics. It is also a concept that students perceive as particularly abstract and difficult to develop any deep understanding of. This clearly has implications for their ability to grasp applications of the concept later in their studies.

At the same time we must consider the nature of the vast majority of students enrolled in an introductory economics course, be that at school level, first year university or within an MBA programme. Ninety-nine percent of the students enrolled in introductory level economics are not going to go on and become economists (Colander, David 2001:76) They are often enrolled in the course because it is a compulsory component of the programme that they are enrolled in and also often have significant mathematical phobias built up through the schooling system. (note 1)

In view of these, any effort to develop a deep conceptual understanding of the law of diminishing marginal returns requires some approach that enables students to grasp the basic tenets of the concept, develop an intuitive understanding of the extensions and variations to this concept while not terrifying them with the mathematics or abstract nature of the concept. This kinaesthetic approach to teaching the concept is one answer. It develops an intuitive understanding of the concept while at the same time developing the model building skills, critical thinking skills and basic maths skills in the student. It also seems to have a number of less tangible benefits toward creating a positive learning environment, encouraging discussion and the participation by a wider range of class members (Becker, E. W. and M. Watts 1995; Fleming, G. 1996; Siegfried, J. and R. Fels 1979)

The history of this methodology dates back to my own days as a senior high school student studying economics for the first time in the late 1970s. I still remember running tennis balls up and down the corridor outside our school library during an economics class. It was not until I became a lecturer myself and realised that my students found this concept difficult to deal with that I reflected on why I had found it easy and the tennis ball game came back to me. Clearly, during the intervening twenty years I had forgotten much of the fine detail I am sure we were told at that the time but trial and error with a number of classes reconstructed the case provided below into a process that appears to quickly and consistently provide logical results while also leaving room for the application of the same game to a number of other theoretical areas. In preparing this case for publication I have also discovered a number of other academics who have developed their own versions that involve the production of such varied goods as books, peanut butter and jelly sandwiches, trail mix, widgets and paper airplanes (Anderson, Donna, T. J. Brooks, and Lisa Giddings 2004; Broder, Josef 2002; Neral, John 1993; Pluta, Joseph 2002; Rubin, Rose 2002).

The Game

This experiment teaches the concept of diminishing marginal returns using simple equipment and with students as interacting participants. Their participation leads to the discovery of the concept in the course of the experiment. At the beginning of an experiment, students are told that they are part of the inputs required to generate a factory's short-run production function. Equipment used includes two buckets, a number of tennis balls and a whiteboard (or an OHP or a computer connected to a data-show) to record results of the exercise. Practical experience has demonstrated this setup works equally well in small classes (less than 30 students) and also large lectures (more than 250 students). This feature of the game appears to differentiate it from many others.

One student becomes the timekeeper and a second the output recorder. All other students that participate become workers on the 'production line'. For best results I have found it useful to be very prescriptive with the rules of the game in the first instance. Flexibility can then be introduced for later rounds or played as imaginary discussion starters - "what would have happened if...?"

The buckets are set up approximately 16-20 feet apart (note 2). The first 'volunteer' is told they need to pick up one ball at a time and run to the other bucket, place it in the bucket and then return to the first bucket to collect the next ball. The goal is for them to transfer as many tennis balls as possible from Bucket One to Bucket Two in 30-seconds (note 3). A worker can only handle one ball at a time and they must treat them a little like eggs in that if they drop a ball it is broken and not worth attempting to pick up. At the end of this time the total number of balls transferred from Bucket One to Bucket Two are counted and recorded on the schedule. The balls are then all returned to Bucket One ready for the next round. A second worker is then added. I have found it useful to tell them they must use the production technology of 'handing' the ball to the other worker. In this way, when there are two workers, they each only have to take the ball half the distance. This first worker will pick up the ball from Bucket One, meet the second worker halfway and pass the ball on to that worker. As soon as this handover is made the first worker is able to return to Bucket One to get another ball while the second worker takes the first ball to Bucket Two and delivers it. As further workers join the production line, each worker has less distance to travel and very quickly they are able to stand still and just pass the balls from one worker to the next. Each student must handle every ball on each run. At the end of each thirty second period the balls are counted and returned to the first bucket. The work that each successive group of workers completes constitutes one point of the production function.

The output recorder (and other students not on the production line) develop a schedule consisting of the number of Labour Units and Total Output during the experiment. A sample from an actual class is illustrated below in Table 1. A discussion takes place as to why we are able to normalize capital equal to one and effectively remove it from our graphing. From the schedule developed, average and marginal returns can then be calculated and relevant graphs constructed to illustrate the concept of diminishing marginal returns. Each series of runs constitutes a short run production function. Once the data is gathered students are asked to plot the points generated from the schedule on a graph. Students can do this individually or as a group. A sample of the graphs from the figures below are attached in Appendix 1.

Table 1: Production Schedule

Labour	Total Product	Average Product	Marginal Product
0	0		
1	9	9.00	
2	16	8.00	7
3	23	7.67	7
4	26	6.50	3
5	26	5.20	0
6	24	4.00	-2

Continue the 30-second runs of the game until negative returns can be demonstrated. I know others stop once diminishing marginal returns set in, but I have found it useful to continue until negative returns sets in because it then allows for a useful discussion on where production decisions should be taken. For example, should you stop adding workers when the marginal return starts to decrease or when it becomes negative? Often, students will decide one thing when deciding from the schedule and a different answer once they have graphed the data.

Colleagues who have used the game let the students choose their own technology when they move from one worker to more than one. The best results are gained when the process of transfer is a chain of students passing the ball along the chain. An alternative is to have a series of student runners taking each single ball to the other bucket. However, once this decision has been made it cannot be changed over the time of the game. I have found allowing the students this choice opens the discussion up to too many possibilities too early and they lose sight of the basic concept of diminishing marginal returns.

If the space available is limited in some way so the students very quickly start getting in each other's way, the students seem to grasp a range of possibilities as to the cause of falling output very quickly. For example, if the production line is reasonably tightly packed between the two buckets, the workers start knocking each other and dropping more balls which can also lead to an interesting discussion on quality issues.

Extensions to the basic game

There are several extensions to this game that may be accessed by either referring back to a game already run (and the students appear to always remember the tennis ball game) or re-running the game with a particular variation to be emphasized such as changing the production technology. This repetitive usage or reference has two benefits. First, it encourages a greater understanding of the linkages between the various ideas and the importance of these basic understandings to later ideas on production costs, growth and technology. Second, while it takes time to run the game initially, the reference back to it can save significant time later in the course. Instead of having to go back over the basic ideas because students did not really understand it the first time and have since managed to forget the idea entirely, I find that as soon as I say "remember the tennis balls", it is possible to move on to new ideas relatively quickly. They not only remember the game but also the ideas they discovered through playing the game.

If the prescriptive methodology above is used, then further discussion may include the variation of fixed inputs. For example a bigger or smaller workspace, different methods of production (technology) and then determining whether the alternative methods lead to higher output relative to the number of workers. Some examples of alternative methodologies include making all the workers run from bucket to bucket rather than handing the ball through the chain or rolling the balls along the ground.

The recording and graphing of this information can also be used as a computer lab exercise to get students working out these calculations and graphing the outcomes using a spreadsheet such as Excel. For many of the more computer literate students of today, this exercise of writing the formulae to calculate average and marginal cost is actually easier than having them calculate it by hand, and also develops a deeper understanding of the formulae. Rather than just plugging the numbers into a calculator, the students think about the relationships between the types of products and then the costs in order to write the correct formulae. This can be particularly useful if you rerun the game and do not increase the units of labour in increments of one. Many students initially assume marginal changes are from one line of the table to the next without paying attention to the actual change in quantity. This exercise can be a useful way of highlighting the error of this methodology. Often we initially give students increases of one as it makes things easier for them but many students never move beyond that to understand what "marginal" really means and this is one way of encouraging that deeper understanding. While this exercise is not a required part of the game it is useful in using the skills many of the students already have to enhance the classroom experience.

Once these product curves have been generated it is then possible to use these in order to generate cost curves and demonstrate the links between these ideas. When using the human chain production process and 30-second run times I have found appropriate costs are fixed costs of $20 and $10 per unit of labour. Samples of the actual graphs generated by a class are attached. I will concede that these results are a bit smoother and more 'ideal' than often achieved but these results were generated by a class of students who had not played this game before.

This type of discussion on production methodology can also be very useful for extending the game into an introduction to growth theory in macroeconomics. The production function generated can provide an to introduction to the Solow model and practical ideas on what would shift a production function, eg. more workers, more capital (more buckets and balls or other additions to 'aid' production).

A re-run of the game can be used to illustrate the different points of labour additions where diminishing returns set in or the law of large numbers. Running the same game with the same class several times offers surprisingly similar results. While there will be some variation, most noticeably the second time through when the students all understand what they are doing, the actual results are very consistent and, if averaged out, do provide relatively smooth lines.

Video from a session at at Oxford Brookes University, June 2006

Real Player format (29 secs, 1.7MB)

Windows Media format (29 secs, 2.1MB)

Conclusion

Since using this game in my introductory classes and some intermediate classes, I have found the student's grasp of the core concepts behind models has been greatly improved. For example, the conceptual grasp of Solow growth theory has been enhanced through the use of this game as a starting point and allowing the students to discuss what is likely to lead to growth in the short-run and then the long-run.

The game has an additional benefit, particularly if used early in a course, in that it provides a common focal point for the class. While running the game, students who are not actively involved in it become involved by cheering the 'workers' on. They quickly start volunteering themselves or their friends. Even in large lectures this works so long as you choose students from around the lecture theatre rather than just those in the front or at the end of rows. The students also continue to talk about the exercise and how they would have done it differently after class. Discussions held in the next class often offer quite different ideas to those discussed on the day of the exercise. This is another reason to revisit the game in later topics.

In smaller classes, this game seems to act extremely well as an ice-breaker for the class and leads to far better participation in class activities and discussions for the rest of the course. Even for students who are often quiet in class, this game seems to encourage their greater participation. Often, these students volunteer to be the timer or recorder, so still gain a sense of belonging, participation and contribution to the class. As an economist the best side effect is when I hear students telling other students or academic staff that they enjoyed economics or had fun in class. This type of response frequently turns up on lecturer and course evaluations, often connected to a statement like 'much to my surprise' or "I expected economics to be boring but..."

In conclusion, there is no question that running this game does take time. However, experience has taught me that I more than make this time up later in the course by not having to repeat key concepts. Instead it serves as a reminder of the link backwards in the course - 'remember when we did the tennis balls and how'. Furthermore, students demonstrate a far deeper understanding of the law of diminishing marginal returns, cost functions and concepts of growth than by teaching through 'chalk and talk' only. For many of the students who only ever take introductory level economics, they leave the course with a good grasp of these concepts and a realisation that economics can be fun, relevant and interesting.

Notes

1. This is a common complaint from economics lecturers in Europe, North America and Australasia and has been supported by research into the attitudes of students to mathematics as they enter tertiary institutions.

2. This distance will vary dependent on the space available and the time available to run the game. If in a large lecture theatre it is worth taking the entire one hour lecture time, placing the buckets further apart, and involving more students.

3. Time used is also variable. If the buckets are further apart it is useful to use a longer time period but this set up is ideal in a small classroom for approximately 30 students. It also prevents the game becoming too tedious and repetitive.

Bibliography

Anderson, Donna, T. J. Brooks, and Lisa Giddings. 2004. "Economics Research Lesson on Diminishing Returns and Increasing Marginal Cost."

Becker, E. W. and M. Watts. 1995. "Teaching Tools: Teaching Methods in Undergraduate Economics." *Economic Inquiry*, 33, pp. 692-700. DOI: 10.1111/j.1465-7295.1995.tb01889.x

Broder, Josef. 2002. "A Frat's Production Function." *Resources for Economics Teaching*, Vol. 2004: Chapel Hill.

Colander, David. 2001. *The Lost Art of Economics*. Northampton, MA: Edward Elgar. ISBN: 9781840646948

Fleming, G. 1996. "Australian Economics and the 'Educative Ideal'." *Journal of Economic and Social Policy*, 2:1, pp. 24-34.

Neral, John. 1993. "Widget production in the Classroom." *Classroom Expernomics*, Spring.

Pluta, Joseph. 2002. "Diminishing Returns and Fixed Inputs." *Resources for Economics Teaching*, Vol. 2004: Chapel Hill.

Rubin, Rose. 2002. "Diminishing Marginal Productivity in Class." *Resources for Economics Teaching*, Vol. 2004: Chapel Hill.

Siegfried, J. and R. Fels. 1979. "Research on Teaching College Economics: A Survey." *Journal of Economic Literature*, 17:3, pp. 197-224. JSTOR: 2723388