# Exploring Easter Island Economics with Excel

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**Abstract:** *Students learn far more from doing than from viewing. By seeing relationships that they have developed themselves, by diagraming those relationships themselves, students learn far more than merely reading over what someone else has done. It is argued that especially for the dynamic problems encountered in environmental and resource economics, Excel has a comparative advantage as a learning aid. We develop a simple, flexible excel assignment to illustrate the Brander and Taylor (1998) model of the Easter Island economy. Brander and Taylor argue that on Easter Island a crucial natural resource, the island's palm forest, was an open-access (res nullius) resource, leading to over harvesting and eventual societal collapse. That open access institutional protection of renewable resources is illustrated by a simple diagram of population and resource stock over centuries, a model much like ordinary predator-prey models in biology.*

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**Key words:** active learning; pedagogy, Easter Island; tragedy of the commons – Excel Assignments

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Figure 1. Malthus

*Though the barriers to a further increase of population be not so well defined, and so open to common observation, on continents as on islands, yet they still present obstacles that are nearly as insurmountable; and the emigrant, impatient of the distresses which he feels in his own country, is by no means secure of finding relief in another. There is probably no island yet known, the produce of which could not be further increased. This is all that can be said of the whole earth.... The question that is asked in Captain Cook's first Voyage, with respect to the thinly scattered savages of New Holland, "By what means the inhabitants of this country are reduced to such a number as it can subsist?" may be asked with equal propriety respecting the most populous islands in the South Sea, or the best peopled countries in Europe and Asia. The question, applied generally, appears to me to be highly curious, and to lead to the elucidation of some of the most obscure, yet important points, in the history of human society.*[1]

Reverend Thomas Robert Malthus

## 1 Introduction

Malthus, in the quote above, suggests that the economics of a small island or of entire continents or even the whole world, bear close resemblances and much can be learned from islands to apply to the world as a whole. The island metaphor is especially useful in gloomy warnings of societal collapse. One such warning of collapse was a seminal work in environmental economics, the Club of Rome's (Meadows, et al, 1972) *The Limits to Growth,* at the heart of which was a very complex, long-run, computer simulation, a model of worldwide ecological collapse. While there were certainly problems with their model, it illustrated the importance of the dynamic interaction of resource use and the potential for disastrous collapse.

Many of the issues in environmental economics are dynamic issues, particularly issues of both renewable and depletable resources. In addition, both stock and fund pollutants involve dynamic problems. The very problem of sustainability is dynamic, and, much like most good science fiction, asks the question, "what happens if we stay on this path?" By choosing alternative

[1] This photograph is from an engraving of an 1833 portrait of Malthus by John Linnell (1792-1882), the original of which is at Haileybury College, Hertford, UK. The photo is in the public domain as the copyright has expired. Quote is from Malthus 6th ed 1826 Chapter V in paragraph I.V.1

parameters to dynamic “what if” problems, basic spreadsheet programs offer a great deal of power to explore the effects of alternatives, using tools that are available both at school and at many work places, a tool that many employers expect a college-educated person to be able to use.

In this paper, we present a lesson on population dynamics and over-harvesting of a renewable resource using an user-friendly computer program, Excel, though other spreadsheet programs should be substitutable. We also provide a brief history of a “real world” case study of eco-collapse, Easter Island, or Rapa Nui, which instructors can use to motivate a lesson and stimulate interest in the assignment. Assignments that employ Excel provide a way to move economics instruction away from the still prevalent method of “chalk and talk” (Becker and Watts, 2001). Levie and Lentz (1982), in a literature review of educational research, mention that when students actively participate in creating pictures they learn, on average, 30% more that students who did not. Breece (1988) notes that researchers learn computers via discovery and that a discovery orientation can be recreated for students with models and simulation. Breece (p. 498) quotes Crookall (1988, p.3), who proffers “first-hand experience, active linvolvement, and enjoyment are at the base of all effective learning. A simulation, by creating a rich and challenging environment, provides that experience and allows participants to become actively involved.” As we discuss below, instructors can incorporate this lesson into classes in a variety of ways. We hope to inspire some instructors to experiment with alternate teaching techniques and, as Welbert McKeachie says, ‘break the deadly routine of lectures day after day” (McKeachie and Svinicki, 2006).

A spreadsheet program, Excel in particular, can be an effective method to break this routine of the “chalk and talk” instructional mode. Blecha (1999) argues that “chalk and talk” has dominated economics because early computer technology did not duplicate the degree of student understanding achieved through traditional lectures in a cost-effective manner. Much has changed concerning student familiarity with computers and computer access since Microsoft introduced the Windows operating system in 1995. It is our experience that most, if not all, students have a rudimentary understanding of Excel (though they are far more familiar with Word and Powerpoint, which have similar structures), and the program is available in most collegiate computer labs. As we explain below, a simulation of population and resource dynamics requires students to enter and copy formulae. In a review of the effectiveness of computer-based simulations in classroom settings, Grimes and Ray (1993) find that simulations not only enhance student learning,m but also improve student attitudes towards the economics discipline.

While economic dynamics are particularly important to environmental and resource economists, spreadsheets allow economists, and their students, to more easily explore these dynamic issues. For instance, Shone (2002) states

> *Economic dynamics has not been investigated for a long time because of the mathematical and computational requirements. But with the development of computers, especially ready-made software packages, economists can now fairly easily handle complex dynamic systems.*
>
> *Each software package has its comparative advantage. This is not surprising. But for this reason I would not use one package to do everything. Spreadsheets – whether Excel, QuattroPro, Lotus 1-2-3, etc. – are all good at manipulating data and are particularly good at displaying sequential data. For this reason they are especially useful at computing and displaying difference equations. This should not be surprising. Difference equations involve recursive formulae, but recursion is the basis of the* ***copy*** *command in spreadsheets, where entries in the cells being copied have relative (and possibly absolute) cell addresses. (p. 17)*

Advocating the use of spreadsheets in teaching economics is certainly not new (Yohe, 1989). Cahill and Kosicki (2000, p. 771) suggest the use of spreadsheets in teaching economics on rather practical grounds: spreadsheets are widely available to college students, easy to use, flexible, will be used in most careers an economics student will pursue, and calculations and commands are transparent. In addition, students have usually been introduced to spreadsheets before they come to our classes, perhaps being exposed to them in high school or before. Still, students often struggle with manipulating and presenting data with spreadsheets, with some preferring to make calculations by hand and then use the spreadsheet as a table formatting program, rather than a calculating program.

We contribute to this literature by providing background history and motivation for an assignment using Excel to enhance student learning of populations dynamics and overharvesting of renewable resources. The remainder of the paper is organized as follows. Section 2 provides a history of Easter Island. Section 3 presents the dynamic model of population growth and resource changes. Section 4 discusses the Excel simulation based on this dynamic model. Section 5 provides suggestions for instructions for the assignment along with possible variations and some cautionary notes about Excel homework. Section 6 provides an analysis of the simulation using a predator –prey model and Section 7 concludes.

## 2 A History of Easter Island[2]

Easter Island is well known for the *moai* (see Figure 2), the stone statues that were carved by an advanced Polynesian culture about a thousand years ago. Yet when Dutch ships first came to the island in 1722, they found only about 2000 poor islanders and a relatively primitive society, with no warfare and its many *moai* standing. However, by the time Captain James Cook visited the island in 1774, the situation was similar, but many of its *moai* had been toppled. Apparently, between the time humans first landed on the island, around 400 AD, and Europeans first visited, an amazingly creative society had arisen, decayed and disappeared from the historical record, leaving only the giant stone artifacts to mark its passing.

Figure 2. Stone Moai Monoliths of Easter Island

Notes: The photo on the left is a close up of the *moai* at Ahu Tahai, restored with coral eyes by the American archaeologist William Mullo. Photo taken by Bjarte Sorenson. The photo on the right of various moai in the qauarry at Rano Raraku, Easter Island, Chile, was taken by Artemio Urbina.

Easter Island poses an intriguing mystery. The *moai*, weighing up to 80 tons, were definitely produced by a technologically advanced civilization. Also, when a society is barely subsisting, their existence is so tied to providing food, grand works of art are too costly to

[2] This section is drawn from Brander and Taylor (1998).

produce—there is no time for doing anything other than providing nutrition. Yet at the time of the first recorded encounter with the western world, a subsistence-level, stone-age culture inhabited the largely treeless island.

The mystery of the island led Thor Heyerdahl, speculating that the islanders originally sailed from Peru to the island, to replicate the journey in a balsa raft, the Kon-Tiki. He wrote about the experience, with the book becoming a best seller and, using film produced on the journey, made the book into an Academy Award winning documentary. Similarly, Erich von Daniken speculated that the Easter Islanders and its *moai* originated with alien space travelers in his popular book and movie, "Chariots of the Gods."

During the last thirty years, the central mystery of Easter Island has been unraveled through careful archeological and biological research. DNA testing of the existing population has revealed that the current inhabitants are Polynesian and has confirmed archaeological work which indicates that a small group of these people, between 40 and 100, settled the island around 400 AD (Van Tilberg, 1994). Pollen samples show that a large palm forest of about 12,000 trees, the island's carrying capacity, existed at this time (Flenley, King, Teller, Prentice, Jackson and Chew, 1991). The palm forest was a critical resource for early Polynesians because it provided raw material for homes, boats and clothing and was a source of fuel. The problem facing the Polynesians when they arrived on Easter Island was that the indigenous palm forest, while large, had a very low inherent growth rate of four percent per decade due to the southern latitude of the island, the quality of the soil and the amount of annual rainfall. This problem meant that, in the absence of harvesting, the soil and climate of the island could support only a four-percent-per-decade expansion of the forest until congestion effects set in. A high density of fish bones, wood used for tools, canoes and firewood indicated that the population grew and prospered between 400 AD and 900 AD, giving rise to the possibility of an artisan class (Bahn and Flenley, 1992). The pollen record shows that noticeable deforestation had occurred by 1000 AD.

*Moai* carving began around 1100 AD, and the next three hundred years comprised the golden age of Easter Island civilization. The palm forest was driven to extinction around 1400 AD when the population had reached approximately 10,000 persons. Deforestation led to soil erosion and falling agricultural yields between 1400 AD and the arrival of the first Europeans in the eighteenth century.

Consequently, the diet deteriorated, cannibalism ensued, and internecine warfare broke out. Moai carving ceased about 1500 AD, and the tools of the artisan were replaced with tools of war, such as the mataa (apparently a dagger or spearhead). The precipitous decline in food at the height of the human population brought about a complete devolution of the civilization to a treeless Hobbesian jungle, where there were

> *. . . no instruments of moving and removing such things as require much force; no knowledge of the face of the earth; no account of time; no arts; no letters; no society; and which is worst of all, continual fear, and danger of violent death; and the life of man, solitary, poor, nasty, brutish and short (Hobbes, 1982, p. 85).*

Brander and Taylor (1998) examine the archaeological evidence from Easter Island and present a formal model that simulates the likely evolution of this ancient civilization. The pattern that emerges is one of an initial period of sustained prosperity from the 5th to the 14th centuries followed by rapid decline with falling welfare as the resource base of the island was depleted. They conclude that unregulated resource exploitation caused a feast-and-famine cycle on Easter Island that eventually led to the collapse of its sophisticated society.

The innovation in the Brander and Taylor analysis is that the renewable resource stock sustains the human population of the island and influences the size of the human population. The large palm forest on the island encouraged population growth after settlement, and it was the rising population that, beginning in the 9th century, provided the labor resources needed to produce the *moai*. Over time, the islanders overharvested the forest, causing economic decline and, eventually, a reduction in the island's population. The size of the forest not only affected the size of the human population but also contributed to the welfare of the island's inhabitants and the stability of the society.

## 3 Examining Easter Island Economics

In 1998, James Brander and Scott Taylor published their paper, "The simple economics of Easter Island: A Ricardo-Malthus model of renewable resource use." Their version of the Easter Island story was one of key renewable, but common-property resources being harvested at above sustainable levels, leading human populations to grow to unsustainable levels and then crashing--another story of eco-collapse. Their "Ricardo-Malthus model," has been the source of quite a few derivative articles [Dalton and Coats (2000); Dalton, Coats and Asrabadi (2005); Decker and Reuveny (2005); Reuveny and Decker (2000); Pezzey and Anderies (2003); Maxwell and Reuveny (2000), among others]. Jared Diamond tells a similar story of Easter Island in his book, *Collapse: How Societies Choose to Fail or Succeed*. Tietenberg and Lewis (2011), in their popular environmental economics text, *Environmental & Natural Resource Economics,* begin their book with discussions of unsustainable growth and eventual collapse, discussing Brander and Taylor's work.

Brander and Taylor describe the growth in the resource stock *per decade* by[3]

$$dS/dt = rS(1 - S/K) - \alpha\beta SL, \tag{1}$$

where $S$ is the level of the resource stock, $r$ is the intrinsic growth rate for this resource, $K$ is the maximum size of the stock which the environment can support (called its carrying capacity), $L$ is the size of the human population, $\alpha S$ is the average and marginal productivity of a unit of labor in harvesting the resource and $\beta$ is the proportion of the population which is used to harvest the resource stock (the remainder of the population produce other goods). The first term on the right-hand side of equation 1 is the growth of the resource stock in the absence of human habitation and the second term is the level of the human harvest (both measured per decade by Brander and Taylor).

Population growth is given by

$$dL/dt = L(B - D + \varphi\alpha\beta S), \tag{2}$$

where $B - D$ is the base rate of population increase (births minus deaths in the absence of any harvest) and $\varphi$ is a fertility parameter which describes the relationship between population growth and the size of the harvest. Based on historical evidence, Brander and Taylor assume that 40 people settled the island and that the forest was at its carrying capacity when they arrived. The values of the other parameters used in the Brander and Taylor model are summarized in Table 1.

Figure 3, based on equations 1 and 2, shows simulated growth patterns for the population and resource stock using the values in Table 1.8 According to the simulation, the growth in the population is slow at first, rising to only 500 persons in the first three centuries. The rate of

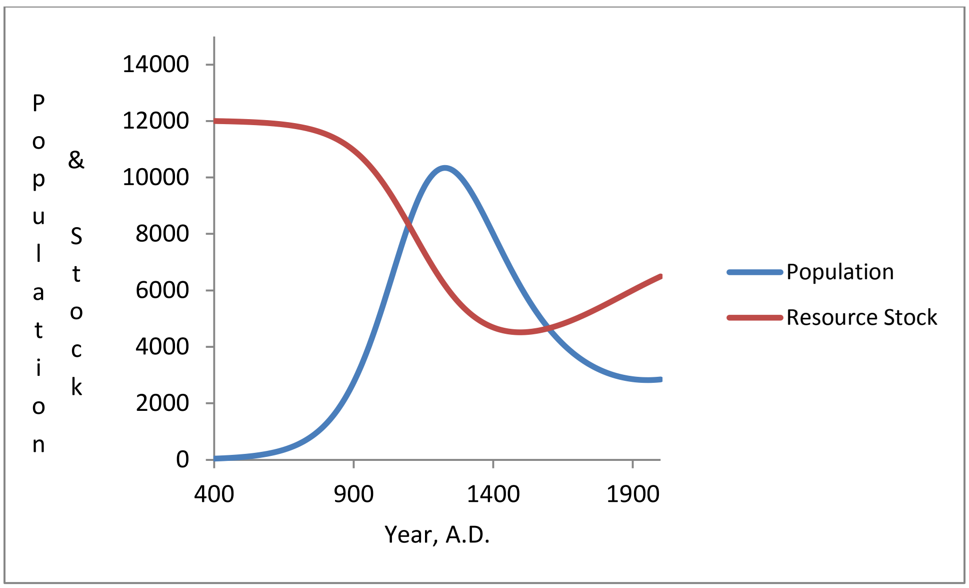
[3] See Brander and Taylor (1998) for the derivation of this equation and equation 2. Brander and Taylor also provide a detailed justification for the parametric values they use. See, in particular, pp. 128-129.

deforestation in the simulation also is slow at the beginning of human habitation, and the size of the forest fell by 200, to 11,800 trees, in the same period of time. However, the simulation

Table 1. Parameter values used in the Brander and Taylor model

| Parameter | Value |
|---|---|
| K | 12,000 |
| B – D | −0.1 |
| ϕ | 4 |
| β | 0.4 |
| r | 0.04 |
| α | 0.00001 |

Figure 3. Population and Resource Stock under Brander and Taylor's Base Case




suggests that both population growth and deforestation accelerated in the next 300 years. The population rises to 5,000 people, and the forest shrinks to 10,000 trees by 1,000 AD in the model. By 1300 AD the population peaks, and no matter what institutional change is made at that point, population declines substantially.

Equations 1 and 2 are reduced forms which Brander and Taylor (1998) derive from demand and supply functions. They derive demand by assuming that utility is a function of the consumption of the resource stock, $h$, and other goods, $m$:

$$u = h^{\beta} m^{1-\beta}, \tag{3}$$

where $0 < \beta < 1$ measures the intensity of preference for the resource good. They also derive some of their results from production functions for the resource and for a manufactured good, a numeraire good, M. For instance, Brander and Taylor's resource harvest function is a logistic function much like Schaefer's (1957), depending upon labor productivity in the harvest, the amount of labor devoted to the harvest and to the size of the stock. For those interested in the derivations of their population and resource levels or time rate of changes in those levels, we leave it to the reader to examine Brander and Taylor's (1998) original paper. While instructors and graduate students should have no problem following their math, undergraduate students may find it a bit difficult.

Mark Reiman at Pacific Lutheran University has recently developed a very useful flexible simulation model for teaching the economics of Easter Island that is available on the internet at http://www.plu.edu/~reimanma/easter_island/. With his simulation tool, the original Brander and Taylor model can be replicated, as well as several of the extensions of their model by various other researchers. Reiman provides one way of introducing students to simulation of these models, but another approach is to have students do these simulations with spreadsheet software.

## 4 Excel Simulation of Easter Island's Population and Natural Resource Base

Cahill and Kosicki (2000)[4] suggest that the instructions for an excel assignment can vary from the very specific, keystroke by keystroke, to the more general, and some would say, the more vague, "here, go do this." The level and sophistication of students and their familiarity with spreadsheets should guide the instructor on the level of guidance to be given in instructions or in pre-loading the spreadsheet. As with any assignment, it should challenge the student, but not be so challenging as to cause a student to give up, or worse, to resort to copying someone else's work.

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[4] Miles Cahill has an excellent "Starting Point" website, "Teaching with Spreadsheets," who had the help of Humberto Barreto, Semra Kilic-Bahi, David Schodt and George Kosicki on the project. The website can be found at **http://serc.carleton.edu/econ/spreadsheets/index.html.**

Here, we provide detailed instructions and suggestions for examining the case presented by Brander and Taylor (1998). As mentioned in the previous paragraph, the level of detail in the instructions must be guided by the instructor's familiarity with her own students at her institution. Using the original Brander and Taylor (1998) case as the baseline case, we are then able to examine variations from the baseline achieved by:

1) altering the parameters of the original Brander and Taylor article, such as the intrinsic growth rate of the stock of palms (r) per decade; the birth and death rates of the population (B & D); the carrying capacity of the island (K); the marginal productivity of labor, α; the fertility parameter, φ; and the resource preference parameter, β, from the utility function

$U = h^{\beta} * m^{1-\beta}$ or by

2) adding and manipulating parameters or imposing specific constraints into the process used by other researchers who have worked with Brander and Taylor's model [see specifically Dalton, Coats and Taylor (2006) for a literature review of Easter Island Economics].

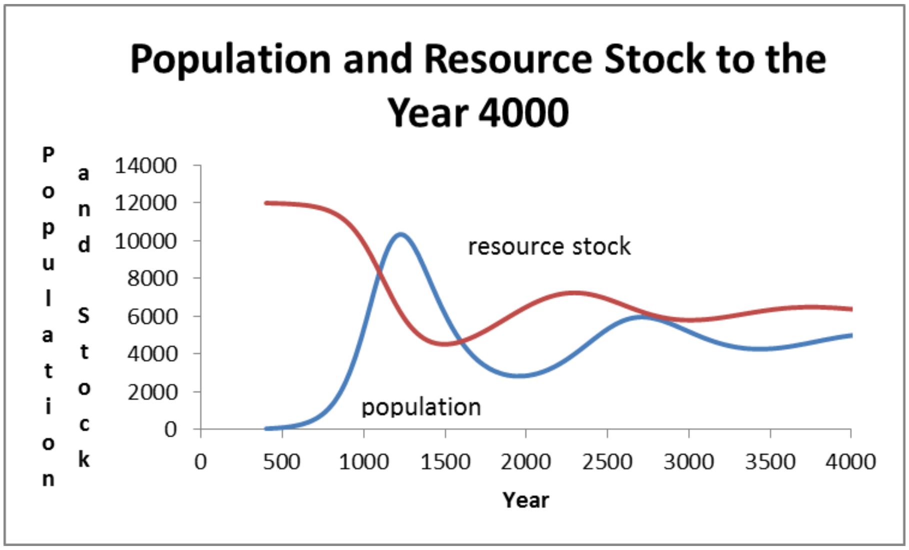
Here are some suggested steps for the assignment, recalling Cahill and Kosicki (2000) on giving students only the level of guidance that they need:

1) Copy the values from Table 1 above into the spreadsheet by simply copying and pasting the table from the PDF here or from the assignment page given to the student. These will be used in formulae or functions for computing the resource stock and the population levels for each decade. These values will be given *absolute cell addresses* (using "$"), as these values will not change. Alternatively, both instructors and students may just find it easier to enter these parameters into the cell formulae directly, as constants.
2) Under the parameter values from Table 1, label three columns of the worksheet, "Decade," "Population" and "Resource Stock." As starting values for the Brander and Taylor Base Case, use 400 (Decade), 40 (population) and 12,000 (resource stock).
3) Under the "Decade" column, on the row beneath the 400, add 10 to the cell above it (the 400) and copy that formula down until you get to the decade, "2000."
4) The formulae or functions for the values that will make up the first diagram, Figure 1 above, will start on the row for the decade, 410. The population will start with last period's value and then will add the change in the population base on birth and death rates. The value for the population in time period t will be based on equation 2), or $L_t$ =

$L_{t-1} + dL/dt = L_{t-1} + L_{t-1} (B - D + \varphi\alpha\beta S_{t-1})$. The values for $L_{t-1}$ should be in the cell above $L_t$ and the value for $S_{t-1}$ should be in the row above and in the column for the resource stock. These cells should be referenced with relative cell addresses, as they will change as you copy the formula down. The values for $(B - D)$, $\varphi$, $\alpha$, *and* $\beta$ are all constants in the models, or parameters, and the cell references should be absolute cell addresses, such as $B$3, so that the same value will be used as the formula is copied down or over.

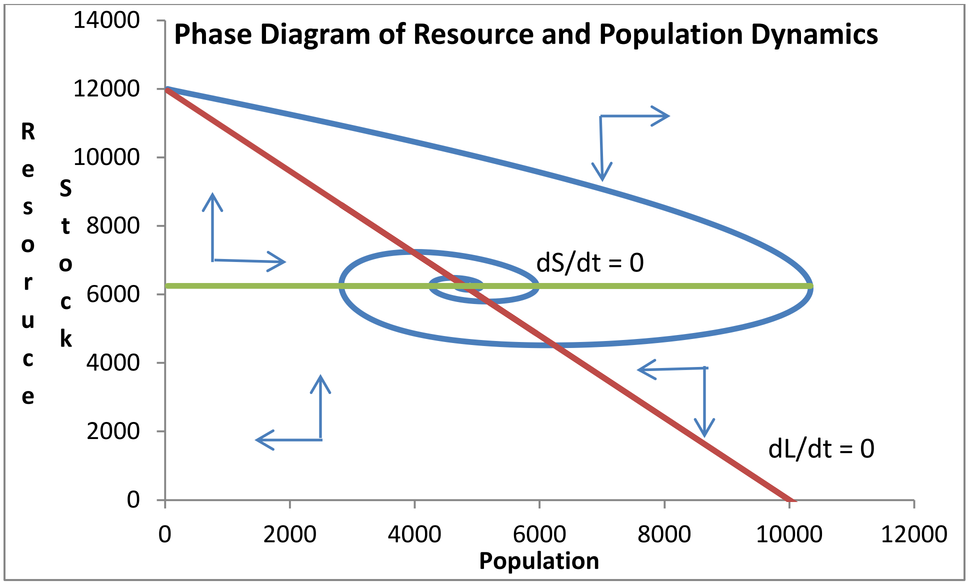
5) For the resource stock, the function will be based on the logistic function
$S_t = S_{t-1} + dS/dt = S_{t-1} + dS/dt = S_{t-1} + rS_{t-1} (1 - S_{t-1} /K) - \alpha\beta S_{t-1} L_{t-1}$
6) The values for $L_{t-1}$ should be in the cell above $L_t$ and the value for $S_{t-1}$ should be in the row above and in the column for the resource stock. These cells should be referenced with relative cell addresses, as they will change as you copy the formula down. The values for $(B - D)$, $\varphi$, $\alpha$, *and* $\beta$ are all constants in the models, or parameters, and the cell references should be absolute cell addresses, such as $B$3, so that the same value will be used as the formula is copied down or over.
7) Now, copy the values for L and S on down to the decade "2000."
8) Now. highlight the entire table, with labels for the columns on down to the decade, 2000. Next, click on Insert from the tool bar and insert a smooth scatter chart. You should have something that looks like Figure 3, above. To properly label the diagram, click on layout and then "Chart Title" to give the diagram a Title, such as we have with Figure 3, above. Then, label the axes with the "Axis Titles" option. It is important for the reader to be able to understand which variables are being shown and where.
9) Another possible step in the assignment would be to increase the time-span for consideration to about the year 4000 or even to 6000, and see how long the fluctuations persist as we do with Figure 4.

**Figure 4: Brander and Taylor Simulation Extended to Year 4000**




10) For a classroom where students are mathematically strong, an instructor might consider having them reproduce the phase diagram from Brander and Taylor (1998). This can be done by using the data for the population and the resource stock used in step 9, but without the decade variable. Instead, the students would need to solve for the phase "boundary lines" for the diagram, where dS/dt=0 and dL/dt=0, solving for S. based on equations 1) and 2). The steady-state equilibrium is where both are zero and equal, so, where they intersect. These "boundaries" should be drawn and labeled. They should also include the arrows to show the direction of change toward equilibrium from any point. Figure 5 below reproduces Brander and Taylor's phase diagram.

**Figure 5. Brander and Taylor's phase diagram**




Notes for the instructor:

1) To make sure that the students understand the importance of what they simulated and what they have drawn with Excel's graphics, the students should be required to write an accompanying paragraph or two, explaining what they did. Here, it would be advisable for the student to be asked to turn in a very short paper in Word or PDF, with their diagrams inserted from their Excel sheet. They should be required to turn in their Excel work, as well.
2) One can also track the levels of cardinal utility based on equation 3), though one would have to do a little math in order to get this value. It turns out that utility is $u_t = (1\text{-}\beta)^{(1-\beta)} * (\alpha\, \beta\, S_t)^{\beta}$, which is actually rather easy to compute.
3) The harvest and the production of the manufactured good are also easy to compute for each decade and graph out decade by decade over these 17 centuries.

## 5 A Predator-Prey Model

Better students should recognize the pattern of population versus resource stock as the same one they probably learned about in biology class as a model of predator and prey, or more specifically, a Lotka-Volterra predator-prey model, after Alfred Lotka (1925) and Vito Volterra (1931), who originated this model of non-linear difference equations, or logistic equations.

Sometimes, the model is given a name with particular animals as predator and prey, such as the fox-hare model. This model, which is additionally known as a model of feast and famine, was first introduced into economics by Richard Goodwin (1967).

We should note that animals in the wild have no means of protecting property rights other than their own power and probably have very little regard for future generations (extremely high "discount rates") or their natural wealth, the means for supplying the mouths of future generations. Similarly, a society with vital natural resource left unprotected by open-access property institutions will behave much like those animals in the wild, which could be termed a Hobbesian jungle. Ostrom (1990) and Ostrom, Gardner and Walker (1994) discuss the evolution of property institutions from open-access to other common-property institutions with limited access, this evolutionary process is often incomplete and often falls short of fully protecting these resources for future generations, falling short of dynamic efficiency. Dalton and Coats (2000) suggest that this Polynesian society on Easter Island probably used rules they call consumption-rights rules as were observed in other Polynesian societies (Melville, 1921), but these still fell short of dynamic efficiency or weak sustainability.

## 6 A Cautious Word

One problem that you might encounter with a spreadsheet assignment to be done out of class and to be graded is the problem of copying. In my undergraduate years in the 1970s, copying homework took some time and a bit of effort. Copying a computer file to hand in is much less costly. Of course, it is also somewhat easy to detect, as the file's meta data contains information on author and last-modifier of the file. Identical layouts, fonts, and sometimes the same incorrect answers are other ways to detect cheating. Beyond these, there is software to detect cheating on excel assignments authored by Hellyer and Beadle at the University of Kent at Canterbury, that they call Excel-Smash (Hellyer and Beadle, 2009). It should be noted that Blackboard's SafeAssign does not accept Excel files, but TurnItIn does, but these files must first be converted to a version earlier than the 2007 version of Excel. Exactly how the conversion for TurnItIn is made (by the student before submitting or by the instructor after submission) could matter and would need a further attention.

Another approach might be to alter various parameters, individualizing the assignment to the student. Starting values for the resource stock and the population might also be varied.

Alternatively, all students could be assigned the task of replicating Brander and Taylor, adding a second part to the assignment with parameters and/or starting values varying, with the instructor then reviewing findings by compiling the various diagrams created for comparison to the Brander and Taylor baseline case and with each other. Note that this is what Reiman (2012) does on his Easter Island Economics simulation website, offering several models from the literature as possibilities to replicate. We suggest following that approach for the more advanced students, though we prefer having the students do so with spreadsheet software for reasons discussed above. For a graduate or more advanced class, not only can less detail be given in instructions, but the students can be assigned different derivative extension papers (see the review in Dalton, Coats and Taylor, 2006). Again, comparisons of the various resource stock – population diagrams or predator-prey diagrams, from different students in class could be useful.

**7 Conclusions**

After reading Brander and Taylor's paper in the AER when it came out, Dalton noticed the opportunity to extend their paper along lines Brander and Taylor suggested and he invited me along with him to explore Easter Island. Our exploration was done long distance, not as an exciting ride on a raft as Thor Heyerdahl had done in the 1940s, but only with the tools provided by Excel. While we did use Axum for publication-quality graphics, Excel did all of the heavy lifting along the way.

Just as Tietenberg and Lewis (2011) begin their book with historical cases of eco-collapse, or self-extinction, including a brief discussion of Easter Island, we have presented our work in class as part of introductions to Environmental Economics classes we have taught. As instructors who have appreciated the value of spreadsheets in our research and in teaching (and computing grades!), it only recently occurred to us that this could make a worthwhile assignment for an undergraduate class in Environmental Economics, to follow the same path we did, following the Brander and Taylor. Excel has become a vital tool in work, something many employers expect of a college graduate, a tool students have almost always used before, so they are usually already on the learning curve, and should require less instruction on the software, but the assignment should still reinforce what the student has learned elsewhere and increase their confidence in using Excel.

Now, other previous work seems to be potential assignments, particularly, potential spreadsheet assignments. For instance, in Coats, Pecquet and Sanders (2010), where the effects of a large future increase in oil supply from reductions of drilling bans are examined, based on Hotelling's (1931) work, a dynamic model of depletable resources. Such a model could be examined with Excel, as well. So a major conclusion here should be that we can turn many of our research projects, especially those with a dynamic elements as we find in environmental economics, into teaching tools that are probably worth sharing with our colleagues.

**References**

Bahn, P. and J. Flenley. (1992) *Easter Island, earth island*. Thames and Hudson, London.

Becker, W.E. and M. Watts (2001). Teaching economics at the start of the 21st century: Still Chalk-and-Talk. *American Economic Review* 91:446-51.

Blecha, B.J. (1991). Economic pedagogy and microcomputer software, *Social Science Computer Review* 9:5451-557.

Brander, J.A. and M.S. Taylor (1998). The simple economics of Easter Island: A Ricardo–Malthus model of renewable resource use. *American Economic Review* 88: 119–138.

Breece, J.H. (1988). Computerized economic modeling: From laboratory to classroom, *Social Science Computer Review* 6:498-514.

Cahill, M. and G. Kosicki (2000). Exploring economic models using Excel. *Southern Economic Journal* 66:770-92.

Cahill, M. and G. Kosicki (2000a). A framework for developing spreadsheet applications in economics, 19 *Social Science Computer Review*:186-200.

Coats, R. M., Pecquet, G.M. and S.D. Sanders (2009). "A Fallacy in the ANWR drilling debate: A lesson on scarcity rents and intertemporal pricing under different market structures," *Journal of Industrial Organization Education*: Vol. 4: Iss. 1, Article 2. URL: http://www.bepress.com/jioe/vol4/iss1/art2.

Crookall, D (1988). Computerized simulation: An overview. *Social Science Computer Review* 6:1-11.

Dalton, T.R. and R.M. Coats (2000). Could institutional reform have save Easter Island? *Journal of Evolutionary Economics* 10:489-505.

Dalton, T.R., R.M. Coats and B.R. Asrabadi (2005). Renewable resources, property-rights regimes and endogenous growth, *Ecological Economics* 52: 31-41.

Dalton, T.R., R.M. Coats, and L. Taylor (2006). Economics and the Easter Island Metaphor. *Rapa Nui Journal* 20(2):97-110.

Flenley, J, S. King, J. Teller, M. Prentice, J. Jackson, and C. Chew (1991). The late quaternary, vegetational and climatic history of Easter Island. Journal of Quaternary Science 6(1): 8–115.

Goodwin, R.M. (1967). A Growth Cycle, Socialism, Capitalism and Economic Growth, Feinstein, C.H. (ed.) Cambridge University Press, Cambridge.

Grimes, P.W. and M.A. Ray (1993). Economics: Microcomputers in the college classroom—A review of the academic literature, *Social Science Computer Review* 11:452-63.

Hellyer, L. and L. Beadle (2009). Detecting Plagiarism in Microsoft Excel Assignments. Proceedings of the10th Annual Conference of the Subject Centre for Information and Computer Sciences, University of Kent at Canterbury, ed. Hazel White. URL: http://www.ics.heacademy.ac.uk/events/10th-annual-conf/Papers/Proceedings/Proceedings_ICS_10th_Annual_Conference.pdf (downloaded 10/28/2011).

Hobbes, T. (1982). *Leviathan*, in: Fuller, N. (ed) The Great Books Collection, The University of Chicago and Encyclopedia Britannica, Chicago (originally published in 1651).

Hotelling, H. (1931). The economics of exhaustible resources. *The Journal of Political Economy* 39: 137-75.

Levie, W. H. and Lentz, R. (1982). Effects of text illustrations: A review of research. *Educational and Communication Technology Journal* 30:195-232.

Linnell, J. (1833). Re. Thomas Robert Malthus. Photo is in the public domain as the copyright has expired.

Lotka, A.J. 1925. *Elements of Physical Biology.* Williams and Wilkins, Baltimore.

Malthus, T.R. (1826). *An essay on the principle of population: A view of its past and present effects on human happiness; with an inquiry into our prospects respecting the future removal or mitigation of the evils which it occasions.* 6th ed. 1826, (1st ed. 1798) John Murray, London, URL: http://www.econlikb.org/library/Malthus/malPlong1.html (downloaded 10-1-11).

Maxwell, John W. and Rafael Reuveny (May, 2000). Resource scarcity and conflict in developing countries. *Journal of Peace Research* 37(3):301-322.

McKeachie, D.H. and Svincki, M. (2006). *McKeachie's teaching tips: Strategiew, research, and theory for college and university teachers.* Houghton Mifflin, Boston.

Meadows, D.H., D.L. Meadows, J. Randers, and W.W. Behrens, III (1972). *Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind*, Universe Books, New York.

Melville H. (1921) *Typee*. The Page Company, Boston.

Ostrom, E. 1990. *Governing the commons: The evolution of institutions for collective action.* Cambridge University Press, Cambridge.

Ostrom, E. R. Gardner and J. Walker. 1994. *Rules, games and common-pool resources.* The University of Michigan Press, Ann Arbor.

Pezzey, John C.V. and John M. Anderies. 2003. The effect of subsistence on collapse and institutional adaptation in population-resource societies. *Journal of Development Economics* 72: 299-320.

Reiman, Mark (2012). The Economics of Easter Island: Modeling Resource Sustainability in Flash, URL:
http://www.plu.edu/~reimanma/easter_island/#intro (first accessed June 9, 2012).

Reuveny, Rafael and Christopher S. Decker (2000). Easter Island: Historical anecdote or warning for the future? *Ecological Economics* 35 (2): 271-87, doi:10.1016/S0921-8009(00)00202-0.

Ripoli, F.J., J. Feurer and R. Wilkens (2010). Teaching the logistic growth difference equation using spreadsheets. Spreadsheets in Educaiton (eJSiE) 3(3) Article 3. URL: http://epublications.bond.edu.au/ejsie/vol3/iss3/3/ (downloaded 10-3-11).

Schaefer, M.B. (1957). Some considerations of population dynamics and economics in relation to the management of marine fisheries. *Journal of the Fisheries Research Board of Canada* 14: 669–681.

Shone, R. (2002). Economic dynamics: Phase diagrams and the economic application, 2nd ed. Cambridge University Press, Cambridge.

Sorenson, B. (2003). Photograph of *moai* at Ahu Tahai, Easter Island, Chile, URL: http://en.wikipedia.org/wiki/File:Ahu_Tahai.jpg (downloaded 11-1-11), license to use through Wikimedia Commons http://en.wikipedia.org/wiki/GNU_Free_Documentation_License (downloaded 10-1-11).

Tietenberg, T. and L. Lewis (2011). *Environmental Economics & Natural Resource Economics*, 9th ed. Pearson, Boston.

Urbina, Artemio. Photograpgh of *moai* at Rano Raraku, Easter Island, Chile. URL: http://en.wikipedia.org/wiki/File:Moai_Rano_raraku.jpg#file
(downloaded 11-1-11), released into public domain by author, Urbina.

Van Tilberg, J.A. (1994). *Easter Island: Archaeology, ecology, and culture*. British Museum Press, London.

Verhulst, Pierre-Francois. 1838. *Notice sur la loi que la population suti dans son accroissement, Correspondence Mathematique et Physique*, 10, pp. 113-121 URL: http://books.google.com/books?id=8GsEAAAAYAAJ&pg=PA114&vq=%22la+suppose+proportionnelle+au+carr%C3%A9+de+la+vitesse+avec+laquelle+la+population+tend+%C3%A0+cro%C3%AEtre+(*.+C'est+assimiler+le+mouvement%22&source=gbs_quotes_r&cad=7#v=onepage&q&f=false (downloaded 10/28/2011).

Volterra, V. 1931. *Lecons sur la Theorie Mathematique de la Lutte Pour la Vie*. Paris: Gauthier-Villars.

von Daniken, E. (1968). *Chariots of the gods: Unsolved mysteries of the past*. Putnam Publishing, New York.

Williamson, O.E. (1985) *The economic institutions of capitalism*. The Free Press, New York.

Yohe, W.P. (1989). Spreadsheets in Teaching Economics, *Social Science Computer Review* 7:431-445.

Appendix: Population Dynamics

Logistics equations were first discovered by Pierre Verhulst in 1838, but they did not become important in describing population change until Robert May explored them with simulations in the 1970s. May simulated change with several models, but the equation of interest to us is the one that described change in a population, relative to the capacity population for its habitat as

$$\left(\frac{\mathrm{L}}{\mathrm{K_L}}\right)_{t+1} = \kappa\left(\frac{\mathrm{L}}{\mathrm{K_L}}\right)_t - \kappa\left(\frac{\mathrm{L}}{\mathrm{K_L}}\right)_t^2 \tag{A1}$$

In this equation L is population, $K_L$ is capacity population and κ is an adjustment parameter.[6]

Milner Schaefer's population growth equation is similar to the logistics equations explored by Robert May. Schaefer described the change in fish populations over time, ΔS, with the following equation,

$$\Delta S = S_{t+1} - S_t = r_s S_t (1 - \frac{S_t}{K_s}) \tag{A2}$$

where $S_{t+1}$ is the fish (stock) population in period t+1, $r_s$ is an inherent growth parameter and $K_S$ is the maximum size of the fish population that the habitat can support.

Schaefer's biological growth model looks very much like the Robert May's logistics equation. In fact, the two are closely related mathematically. We see this by solving for $S_{t+1}$.

$$S_{t+1} = S_t + K_s S_t (1 - \frac{S_t}{K_s}) \tag{A3}$$

Dividing through by $K_S$ and defining $s_t = \frac{S_t}{K_S}$ gives us

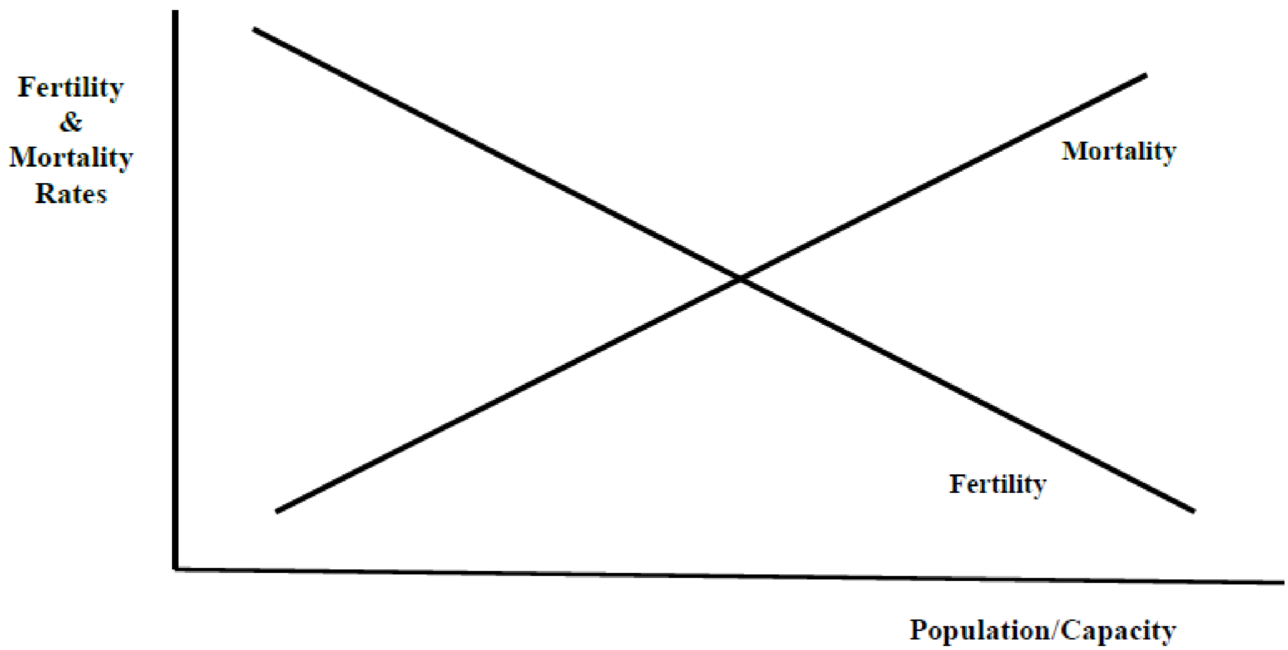
[6] Ripoli, Feuer and Wilkens (2010) offer an interesting discussion of the use of spreadsheets to teach logistic growth difference equations, demonstrating the population dynamics of a single population, the dynamics without a predator-prey relationship with another species, much as we see in equation (A1)..

$$s_{t+1} = (K_s + 1)s_t - K_s s_t^2 \tag{A4}$$

which is a logistics equation with separate coefficients for $s_t$ and $s_t^2$.

Population dynamics occur when disequilibrium between fertility and mortality prompts a change. Both Schaefer's and May's equations are reduced forms that describe this process. The process can be explored further by considering the underlying fertility and mortality functions as in the figure below. Mortality is shown as a linear function that increases in value as the habitat becomes more densely populated. Fertility is shown falling when the habitat is more densely populated but this is not a necessary condition. The equilibrium level of population for the habitat occurs at the intersection of the fertility and mortality functions.

**Figure A1. Population Equilibrium**




*Fertility declines and mortality increases as the population rises relative to its capacity level. The equilibrium population occurs where the two functions intersect.*

The dynamic process is revealed by examining the change initiated in disequilibrium. Population change is given by

$$\left(\frac{L}{K}\right)_{t+1} = \left(\frac{L}{K}\right)_t + \Delta\left(\frac{L}{K}\right) \tag{A5}$$

Where L is once again population, and K is still the capacity population.

Fertility, $f_t$, is

$$f_t = a - b\left(\frac{L}{K}\right)_t \tag{A6}$$

and mortality $m_t$, is given by

$$m_t = c + d\left(\frac{L}{K}\right)_t \tag{A7}$$

Change is shown by

$$\Delta\left(\frac{L}{K}\right) = \left(\frac{L}{K}\right)_t (f - m)_t \tag{A8}$$

Substituting for fertility and mortality we get

$$\Delta\left(\frac{L}{K}\right) = (a\text{-}c)\left(\frac{L}{K}\right)_t - (b+d)\left(\frac{L}{K}\right)_t^2 \tag{A9}$$

Define $\kappa_1 = 1 + a - c$, $\kappa_2 = b + d$, and substitute into the first equation above to get the general form of the logistics equation:

$$\left(\frac{L}{K}\right)_{t+1} = \kappa_1\left(\frac{L}{K}\right)_t - \kappa_2\left(\frac{L}{K}\right)_t^2 \tag{A10}$$

From this equation it is apparent that May's and Schaefer's formulations are special cases. May's equation is a reduced form when b + d = 1 + a – c, and Schaefer's equation applies when b + d = a – c.