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STUDENT VERSION
SPREAD OF TECHNOLOGY

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Abstract: We examine plots on the spread of technologies and ask students to estimate and extract data from the plots and then model several of these spread of technologies phenomena with a logistic differential equation model.

SCENARIO DESCRIPTION

Spread of variety of technologies in the United States and in Hungary

We consider two studies [1, 4] and resulting plots (Figures 1 and 2) of the spread of technology in Hungary and United States, respectively. Examine the information in Figure 2 about the spread of technology in the United States [4]. What we see are a number of possible logistic curves, indeed, if we let $P(t)$ be the percentage of users of a given technology at time t then what we have is data which could be modeled by the logistic curve. While not accepting the fact that the logistic curve is the only answer and suggesting that there are deep factors which cause people and organizations to accept new technologies, the authors of this lecture at the United Nations Open Courseware [4] do suggest that as a first model the logistic equation is a good model for describing the spread of technology.

> Recent work on diffusion has focused on trying to explain the prevalence of the S-shaped diffusion curve - the epidemic model. The epidemic model considers information to be the key to diffusion. As more people adopt the technology, information of it spreads quickly, leading to a period of rapid adoption. The epidemic model models technology as a "contagious disease." Adoption occurs as potential adopters learn about the new technology. Adoption is slow at first, as few people (or firms) know about the technology. The more people "infected" (that is, those that have adopted), the more likely others will also be "infected." Thus, as information spreads, a period of rapid adoption follows.[4]

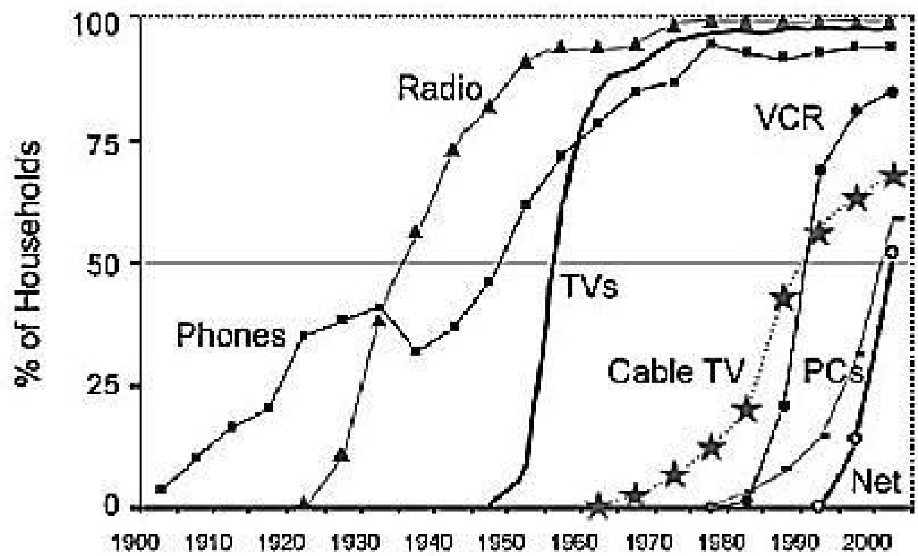

Figure 1. Plot of Diffusion of Major Inventions in Hungary.[1]

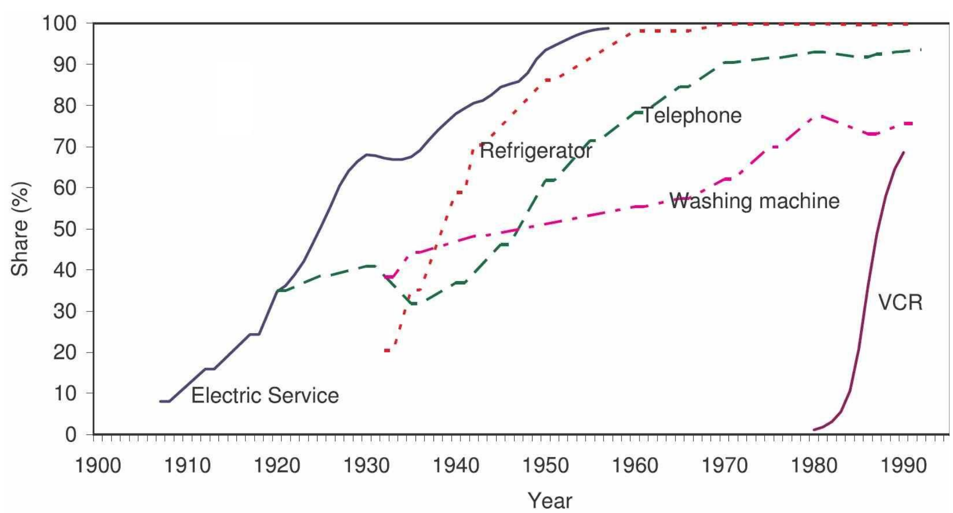

Figure 2. Plot of Diffusion of Major Inventions in the United States.[4]

Indeed, those that have the technology may share with, parade before, make envious, etc. those that do not have the technology and in some sense it is that interaction or visibility between the haves and the have-nots that causes the technology to spread. That is why the logistic differential equation is a natural model for the spread of technology.

Thus if we let $x(t)$ be the percentage of people who possess a technology with a maximum number of people or percent (the latter being 100%) in the population to whom the technology is available being K then the term $x(t)(K - x(t))$ represents the total number of possible interactions or sightings(!) between those who have the technology and those that do not have the technology. r is a proportionality constant that says what percentage per unit time of the meetings result in an adoption and hence an increase in the size of the "have" the technology population (and an accompanying decrease in the "have not" population). Thus a good differential equation model for the spread of technology would be the logistic differential equation (1):

$$x'(t) = rx(t)(K - x(t)) \tag{1}$$

1) a) Use the plot in Figure 1 to estimate the percentage of users who have used Cable TV or Radio as a function of time. Hint: The year ticks are in five year increments so some estimating in reading data will be necessary and you might want to magnify the graph to read more accurately.

   b) How could business folks take advantage of the logistic growth curve and what it shows them, say, in rolling out new models or some other means?

   c) How early do you think you could "get in" on the groundswell and know how high it is going to go with the logistic curve as a predictor of the future of any technology? What could you predict early on in the growth of the use of a technology?

2) a) Use the plot in Figure 2 to estimate the percentage of users who have used the Refrigerator or Washing Machine as a function of time. Hint: The decades tick mark on the plot begins over the first 9 in 1900, 1910, 1920, etc. and you might want to magnify the graph to read more accurately.

   c) With the advent of the Internet how do you think the number r has changed for most technology spread models?

Spread of ISO Standards use

In [2, p. 141] we read in the abstract:

> In an economic environment characterized in recent years by globalization and the integration of economic processes, standardization in management systems has had a high growth. In this context, there has been a remarkable increase in certain standards, or norms, issued by international organizations. Among these standards, two main groups stand out, both issued by the International Organization for Standardization (ISO): one for quality management systems – the family of ISO 9000 standards – and the other for environmental management systems – the ISO 14000 standards. This paper aims to analyze the world wide diffusion process of these two standards, using data provided by the ISO itself.

Figure 3 shows a plot of the percentage of saturation level (100%) in the use of two ISO Standards in four countries: United States, United Kingdom, Japan, and Spain. This is the first paper where it can be demonstrated that, world-wide, both the ISO 14000 and the ISO 9000 standards have followed very similar patterns of diffusion in their expansion.

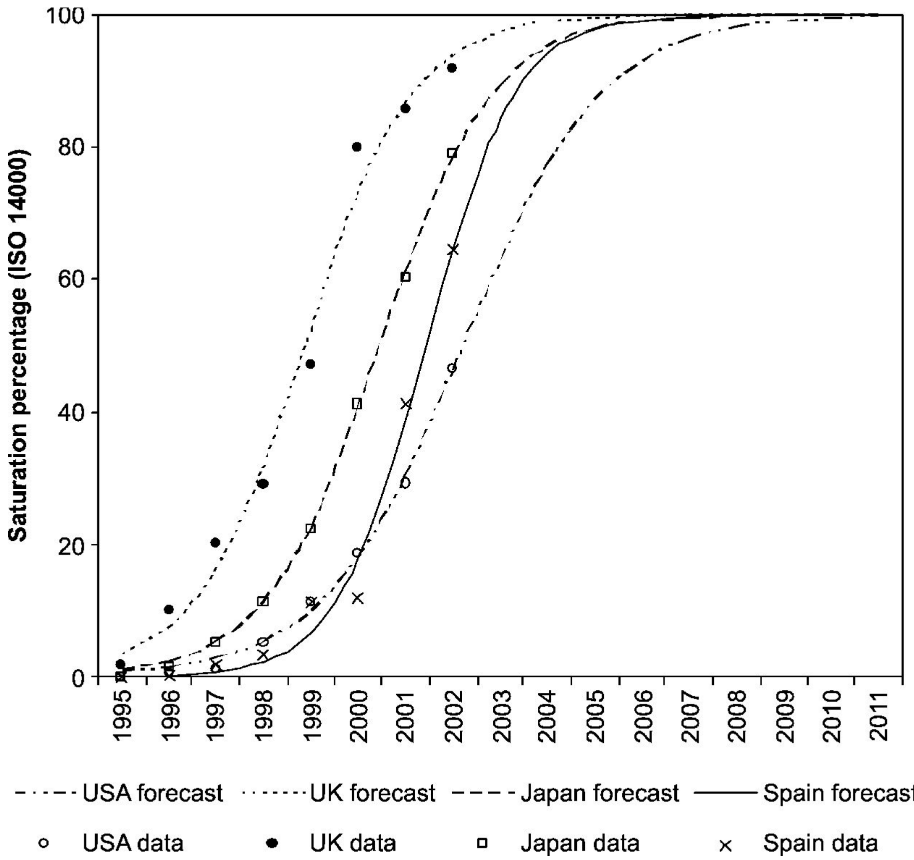

Figure 3. Plot of the percentage of saturation level (100%) in the use of ISO Standard 1400 in four countries: United States, United Kingdom, Japan, and Spain.[2]

3) a) Use the plot in Figure 3 to estimate the saturation percentages for ISO 14000 adoption for the United States and Spain percentage of users who have used the Cable TV or Radio as a function of time. Hint: You might want to magnify the graph to read more accurately.

   b) Compare the two growth rates?

The eBook market

In [3] we find Figure 4 in which the growth in eBook sales in the United States is charted. There was an attempt to fit a sigmoidal curve of the form $y = \arctan(x)$ through the data. However, might the logistic curve do a better job and might it actually explain the growth and possible slowing of growth.

4) a) Use the plot in Figure 4 to estimate the monthly book share of US consumer book purchases over time. Hint: You might want to magnify the graph to read more accurately.

   b) What does this data (by continuing into the future) tell you about the future of hardback, paperback, DVD, etc. - physical - book sales in the future?

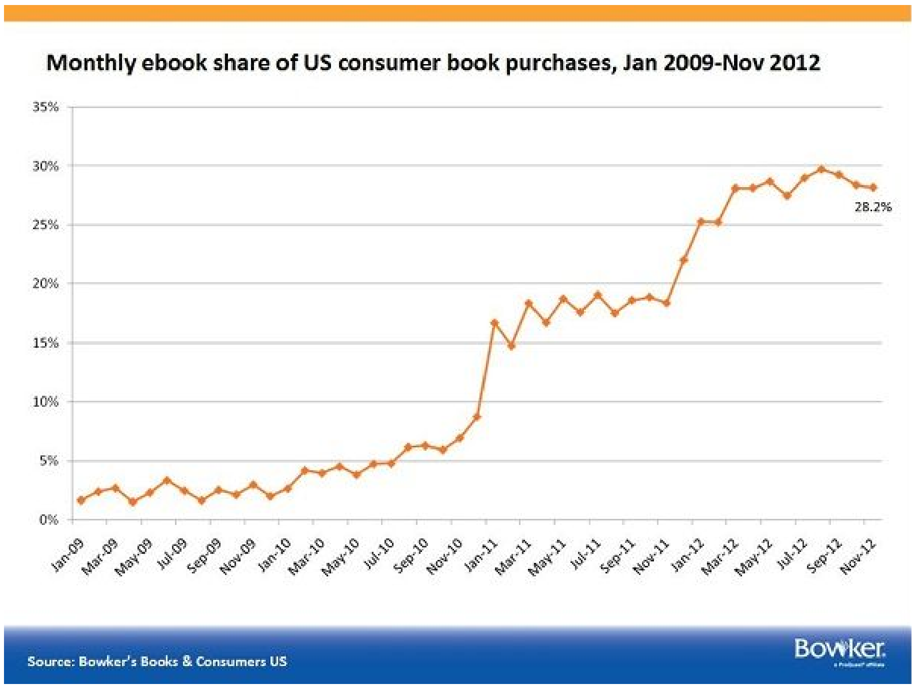

Figure 4. Plot of growth in eBook share of the United States consumer book purchases.[3]

c) Discuss compounding factors and other changes in technology which might shape the future of eBook sales.

5) Pick a current technology and see if you can find data on its use over time, e.g., laser printer, 3D printer, camera in smart phone, social media software, digital camera, etc. Then build a mathematical model of the spread of that technology.

NOTES FOR TEACHERS

We offer several instances of plots on the spread of technology from the literature. Such instances abound and can easily be found using Google Images search.

In these activities we are attempting to get students to do some estimating from a plot to get their hands on the data, to model with the logistic curve, to see the significance of the logistic model, to demonstrate the limitations of the logistic model, and to impart meaning to the parameters r and K found in the logistic model.

In a separate *Mathematica* file, 1-22-Mma-T-SpreadOftechnology-TeacherVersion.nb (and .pdf) we offer some analysis of several of these situations to gain a flavor of what can be expected in student work.

A referee suggested that the logistic equation needed defending as a mode for the spread of technology. Often the defense is that there are two groups of people related to the technology, those that use it, denoted by $x(t)$ the number of users of the technology or the percent of the base that uses the technology at time t and $K - x(t)$, the remaining (of a base total of K or total percent of $K = 100$) members of the population who do not use the technology.

In (1), repeated here without number, the product of the two terms $x(t)$ and $(K-x(t))$ represent the number of interactions or influences, e.g., conversations at professional meetings, observations of each other's sales, personnel exchanges, and r represents the percent or fraction of those possible meetings which fresult in a conversion of a member of non-users who's number is $K - x(t))$ to become a user and increase $x(t)$, and thus incorporated in $x'(t)$ as a positive term.

$$x'(t) = rx(t)(K - x(t))$$

It is clear that no product ever reaches total saturation for a number of reasons, stemming from resistance to "new" ways to the fact that a new product comes on the market and folks skip a generation of technology and move to th4e next one without actually embracing the one just before that. Nevertheless, we use K as the saturation level for the use of a technology and often it represents all available users.

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