S-curves and their Applications in Marketing, Business, and the Economy
By George P. Boretos

Forecasting product sales or market values is one of the most important and difficult endeavors for all marketing professionals. Fortunately, many forecasting tools have been developed, especially during the 20th century, which help us to model sales and produce valuable estimates about the future.
One of the most commonly used such tools is the Diffusion of Innovations Model that allows us to identify and analyze the different phases of growth, saturation, and decline of a certain product, technology, a new idea, or any innovation. It’s a valuable model that helps marketers make long-term plans and design their strategy about existing product portfolios and new product launches. It is based on the simple assumption that anything new follows a Bell-shaped curve passing through different types of users, depending on the time of the adoption. As can be seen in Fig. 1, these types are the Innovators, Early adopters, Early Majority, Late Majority, and Laggards accounting for 2.5%, 13.5%, 34%, 34%, and 16% of the target audience respectively.

Although familiar with this model, many marketing professionals are not aware of the origin and underlying rational behind the diffusion concept, or of the many applications that it has in business, the economy, and many scientific fields. Actually, there is a common misperception that the Bell curve of the Diffusion model is based on the well-known Normal Distribution, developed by the famous 19th century mathematician Carl Friedrich Gauss. If you get the value of the Normal Distribution at a distance from the mean (\(\mu\)) of one and two times the standard deviation (\(\sigma\)) you get almost the same breakpoints that you see in Fig. 1. However, this is not the case.

The Diffusion of Innovations Model was introduced by Everett Rogers, a professor of rural sociology, in his 1962 book “Diffusion of Innovations” [1].

It is based on the Logistic Growth Model, also known as the S-curve [2]. The origin of the logistic curve goes way back into the studies of population growth by Pierre-François Verhulst in 1838, who was influenced by Thomas Malthus’ “An Essay on the Principle of Population”. The underlying rational behind the construction of the logistic growth model is very simple. We assume that a given population “\(N\)” has a natural limit “\(K\)” based on geographical limitations, food or water resources scarcity, or other restrictions. As the population discovers more of these available resources (by exploring, for instance, new territories or finding new water and food sources), it grows bigger but also, at the same time, it captures an even larger part of its untapped potential (\(K-N\)), thus limiting its future growth. The evolution of the population over time (\(t\)), under the logistic growth model, can be described by the following equation:

\[
N(t) = \frac{K}{1 + e^{-\left(\frac{\ln(\beta) \cdot (t-t_m)}{Lc/2}\right)}}
\]

\(N(t)\) is the population over time, \(K\) is the maximum size that the population can reach, \(Lc\) is the life cycle of the process i.e. the time needed for the population to increase from approximately 1% to 99% of its maximum size \(K\), and \(t_m\) is the midpoint at which 50% of \(K\) is reached.

As can be seen in Fig. 2, the population growth follows a Bell-shaped curve and the population itself, on a cumulative basis, follows an S-shaped curve.

Note that although the Logistic Growth model and the Normal Distribution are based on quite different concepts and mathematical formulations, they have almost identical curvatures exhibiting the same more or less behavior (see Fig. 3).

Although s-curves started from studying natural ecosystems, it soon became apparent that they could be equally successful in modeling non-biological “populations” using the same basic principles from population ecology. Rogers was one of the first to bring s-curves into the marketing field by...
introducing the Diffusion of Innovations Model. Here, the populations are innovations of any kind; a new product, market, technology, an idea, or anything new that can be adopted by a potential audience. This is made through the word of mouth process. Take the evolution of Internet, for instance. At any time, in any given country with population "N", there are "A" persons that have adopted the new technology and use the Internet and N-A that have not. However, when users and non users meet, there is a probability that the non-user will learn about the benefits of the Internet and will eventually start using it. When the Internet penetration in the country increases more than 50% then the potential new users are fewer than the existing users, hence, growth starts to decline. This is a simplistic but valuable explanation of the evolution of the Internet, which by the way does indeed follow an s-curve pattern [3]. Since the late 70’s, Cesare Marchetti (http://cesaremarchetti.org) and afterwards Theodore Modis (www.growth-dynamics.com) described in their extended studies how various processes such as product sales, competition among products, stock prices, the use of different means of transportation, energy consumption, and even urban guerrilla activities could be approximated by using forecasting models based on logistic growth.

As the study of the Logistic Growth evolved through the years, it generated additional models based on the same principles. Frank Bass went one step further from the Diffusion of Innovations Model, in his paper “A new product growth model for consumer durables”, published in 1969 [4]. He created the famous Bass Model by incorporating another growth driver, the innovation, which describes the process of adopting something new spontaneously, either by following an innovative urge or due to the exposure to marketing communication. This is something different than the word of mouth (or imitation-process), already introduced by Rogers, which calls for physical contact with someone who has already adopted, for instance, a new technology. Marchetti and Nakicenovic introduced the Logistic Substitution Model [5] to describe the evolution of market shares among competitors passing through different phases of growth, saturation, and decline. Kondratiev waves [6], based on the difference between actual and estimated s-curve values, have also been incorporated into the study of logistic growth in order to identify embedded cyclical patterns.

**Seasons of Growth in S-curves**

Another important concept relevant to s-curves is that of “Seasons”, introduced by Theodore Modis in his book “Conquering Uncertainty” [7], representing different periods of growth, saturation, and decline. The construction of the different seasons is rather simple: we consider the Life cycle of the process (Lc in equation 1) and then divide it equally into five successive seasons: Winter, Spring, Summer, Fall, and again Winter. All seasons and their corresponding levels of penetration (% of K) can be seen in Fig.2. Those familiar with the work of Modis will recognize that the definition and penetration levels of seasons in Fig.2 are slightly different than these used by Modis. Although the concept and conclusions remain the same in both cases, the new definition is better fitted to the choice of parameters that we use in eq. 1. The seasons’ segmentation
is an alternative to the method used by Rogers (Fig. 1). However, the middle of each season is very close to the beginning of the Innovators, Early adopters, Early Majority, Late Majority, and Laggards segments, so, we can follow both segmentations at the same time, if we want to.

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![Graph of five seasons (Winter, Spring, Summer, Fall, Winter) showing GDP growth over time.](image)


modeling the global economy with the logistic growth model

Through my personal research, I had the opportunity to use s-curves extensively. I soon discovered that many phenomena from completely different fields, such as social media networks like Facebook and LinkedIn, global warming, and the global economy could be approximated with the logistic growth model. The reader can find more details about these cases in the site www.forecastingnet.com. Perhaps, the most interesting finding is that by using such a simple model, we can produce valuable insights and predict even major economic events like the current global crisis.

We all know that after the 2008 credit crunch, the global economy entered a serious recession that was characterized by uncertainty, low liquidity, and reduced business activity in almost every sector. The initial efforts of the G20 to reinitiate the economy by the deployment of extensive fiscal stimulus packages, although successful in the beginning, resulted in the significant rise of public debts challenging the credibility of even the largest economies. This is definitely an important turning point testing the structural integrity and defenses of the global economy. But was this a random incident in our history or could we have predicted it and taken the necessary steps to minimize losses? In an article [8] published just a few days prior to the collapse of the Lehman Brothers, evidence was presented about an upcoming economic downfall, near the end of the first decade of the millennium. The analysis was based on a simple logistic growth fit against actual real GDP data.

According to this model, the global economy follows a two-century growth wave, spanning from 1917 to 2112 around the midpoint tm at 2015, attributed to globalization (Fig 4). This period is equally divided into five seasons that last nearly 40 years and constitute successive periods of growth, saturation, and decline.

**Winter** (1917–1956), as expected according to the seasons’ concept, was a difficult period including both the struggle for survival and innovation. To begin with, it includes the last part of World War I, World War II, and the Great Depression. But this period also includes many great inventions and technological advancements: the first television set, the first large scale digital computer-ENIAC, the invention of the transistor, the patent for cellular technology for mobile phones, and...
the invention of the liquid-propelled rocket, the first jet engine, and the discovery of the DNA structure.

Also as expected, Spring (1956–1995), was a period of considerable economic growth based on the novelties of the previous season. Space age began, following the invention of liquid-propelled rocket, with the launch of the first communication satellite, Sputnik, and the first manned mission to the moon in 1969. The information technology and telecommunications industry expanded rapidly based on a series of transistor-enabled innovations (such as the first personal computer), the World Wide Web, the first cellular phone, and the launch of the GSM system. Following the discovery of the DNA, genetics studies became popular leading to the launch of the Human Genome Project in 1990.

We are now approaching the middle of Summer (1995–2034), supposedly the period when we harvest the fruits of previous seasons’ innovations and investments. Indeed, we are now into the age of globalization and the world seems more united than ever. The Cold War has ended, the EU reached 27 members, and China, following Deng Xiaoping’s reforms, entered the free market and became one of the biggest international economic powers. All high technology sectors have peaked, involving billions of users of the Internet, PCs, mobile phones, smartphones, and social media. The Human Genome was finally decoded within only ten years from the launch of this important project. The living standards of the average person on Earth, as expressed by GDP per capita and all the available conveniences of our times that the technology and modern science can offer, have never been better.

However, there is a catch. First, as we approach the midpoint tm (2015) of the process, we should expect the first mild symptoms of saturation, as growth will first decelerate and afterwards will start declining. Most important, though, is the cyclical pattern that the economy follows, presented in Fig 5. Almost every 40 years, near the middle of each season, there is a peak point that initiates a cyclical slowdown of the global economy. This occurs when the economy “overshoots” i.e. when the ratio between actual and estimated GDP is at maximum. This cyclical trend is actually a Kondratiev wave of the economy.

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The first two cyclical slowdowns occurred in 1937, near the start of World War II, and in 1975, near the outburst of the Oil Crisis. The next cyclical peak point occurs in 2013, very close to the 2009 global economic recession. There are two options concerning this forecast: either the cyclical downturn occurred at 2009, an acceptable four year error in the two century growth process, or we haven’t seen the worst of the recession yet. We will by 2013. Based on what we’ve seen happening in the economy during the last three years, the latter option still remains a strong possibility.

To conclude, both the two century growth wave and the cyclical 40 year trend have been saturating as we are approaching their peak points, in 2015 and 2013 respectively. Therefore, we should have expected a deceleration of the economy near the end of the first decade of the millennium and the beginning of the second. The first signs where there all along and we could have started preparing early on instead of trying to find a last minute solution.

Conclusion
Although this case study is about the economy, it’s equally useful for marketing professionals and everyone involved in business, as it demonstrates the significance of forecasting and s-curve modeling. After all, the Global GDP is an aggregation of all business activity in the world. We should continuously observe our markets for evidence of growth, saturation, or decline. And to do so, we should choose the right model, look for alert signs of changing market behavior, and act accordingly. S-curves proved to be an excellent forecasting tool, offering valuable insights in so many different cases regarding the economy, business, product management, or other areas. Surely, it’s not the only available forecasting tool and obviously it does not stand as a substitute for human judgment. It’s merely a tool that helps improve our visibility about the future. The rest is up to us, to look for the right signs, make the right decisions, and better prepare ourselves for what is coming in the future.

References

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