WHITE PAPER

MODELLING DIFFUSION OF INNOVATION

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Estimating the Potential of New Therapy

How Important Is It?

The answer to this question lies in the cost of inaccuracy in the forecasts that we are currently seeing. The price of bringing pharmaceutical innovation to market is $2.7B[1] and marketing expense represents about 30% of total revenue[2], arriving at an inflated forecast that results in wasted R&D and manufacturing capacity, licensing, and marketing costs for only marginally viable products. Additionally, underestimating potential further results in supply challenges, possible project termination, and missed licensing opportunities.

One typically utilizes historical data, time series forecasting, and other extrapolation methods for marketed products forecast. Usually, the focus of extrapolation methodology is to understand the short-term future. However, new drug development and launch take years, sometimes even decades, and are long and complex processes, with often no data for extrapolation. *Then how should we predict the potential of a new therapy before its launch?*

Historical data suggests that new product adoption follows the S-shape curve. Figure 1 represents cumulative adoption, the S-curve, and period-by-period adoption (Roger's bell curve). Why new product follows the S-curve is explained by Everett Roger's diffusion of innovation theory3, which attributes it to the heterogeneous nature of the population. In 1969, Frank M. Bass published a quantitative tool for modeling the new product potential, famously known as Bass Diffusion[3].

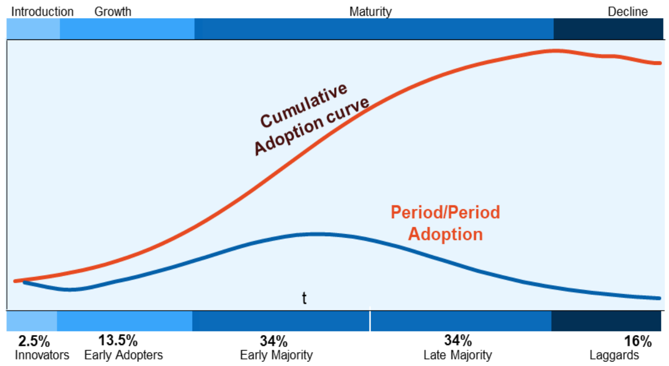

Figure 1 Schematics of New Product Adoption

What is Bass Diffusion?

In Simple Words-

It is a mathematical expression that models Everett Roger's diffusion of innovation theory, i.e., once the product is introduced, its initial market growth is due to innovators, then they are followed by imitators; as more people adopt innovation, more imitators start using the product. Eventually, potential new user size dwindles, the market becomes saturated, and then the adoption pace levels off and goes down. Here, the chance of new product adoption by those who are yet to adopt is a linear function of those who have already adopted it.

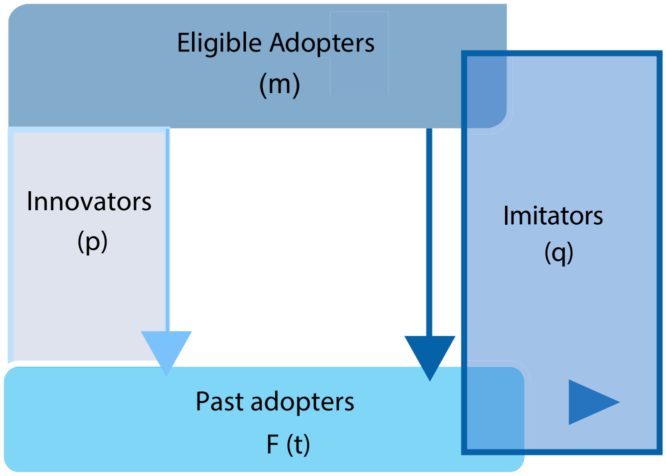

Figure 2 Graphical representation of Bass diffusion model4

In Mathematical Terms-

$$f(t) = p + \frac{q}{m} F(t) \; [m - F(t)]$$

Equation 1

Cumulative number of adopters at time t =

[p (Remaining Potential)] (+) [q (Remaining Potential) (Past adopters)]

Equation 2

Equation 1 is a mathematical expression of Bass diffusion5. Here 'p' and 'q' are the innovation and imitation coefficient, f(t) is cumulative sales at time 't', and 'm' is total market potential. The constant 'm' describes the height of the adoption curve while two coefficients (p, q) govern the shape of the curve. The total market potential can be estimated from the epidemiological study as an eligible patient pool, employing conjoint analysis for physician preference measurement based on new and established therapy attributes. Usually, innovation and imitation parameters are taken as a rule of thumb (p 0.03 |q 0.38) based on a meta-analysis of large databases of empirically observed 'p' and 'q' parameters6 or by estimation using analogies. Typically, Bass Diffusion initial period output is an overestimation (~year one), and after the point of inflection (take-off point) will tend to be an underestimation and approaches accuracy towards the peak.

Are There Other Diffusion Models?

The other most notable models are the Fourt and Woodlock model, that considers the innovation effect in adoption7, and the Fisher and Pry model, that considers only imitative effect8.

The Bass Diffusion model is an aggregate model that considers both innovation and imitation effect and is a particular case of the Gompertz function. It is discussed in literature to a great extent and many extensions and improvements have been published which incorporates the impact of the Marketing Mix variable. You can read more about Bass Diffusion on www.bassbasement.org9. Following are the notable extension of Bass Diffusion:

- Generalized Bass Diffusion model incorporating price variable10
- Replacement and Repeat purchase model 11
- Modeling marketing mix variables and next-generation substitution12
- Modeling competition among product13

Why is Bass Model Preferred Over Other Advanced Models?

Before answering Why Bass model? Let us start with understanding what the model is. According to John D. C. Little, father of marketing science, "Model is a preconceived idea of how the world works and therefore of what is interesting and worthwhile in the data" 14. To create a good model, one should select interesting and worthwhile assumptions. The same idea resonates in the principle of parsimony that one should select the hypothetical solution that requires the least number of assumptions. This principle acts as a heuristic guide in the model building in marketing science.

The original Bass Diffusion model requires only three parameters, 'p', 'q', and 'm', to build a growth curve. If we know 'm' (market potential), then complexity is reduced to two parameters.

Bass model's parsimonious nature is what makes it ideal for use15. The Bass Diffusion model allows decomposing the complicated problem of new product adoption into two components: time to peak and peak sales. These are two crucial benchmarks that are easy to estimate and predict even before launch.

Some Applications of the Bass Diffusion Model

Forecast Calibration Using Early Year's Sales Data

The Bass model can calibrate forecasts using early-year sales data. In the following case, we have utilized the first two years' sales and Product D's estimated peak potential of $2B. Post-calibration with a two-year data model predicts third-year revenue with -10% error, closer to third-year actuals than other extrapolation models triple exponential smoothing where prediction error was -16%.

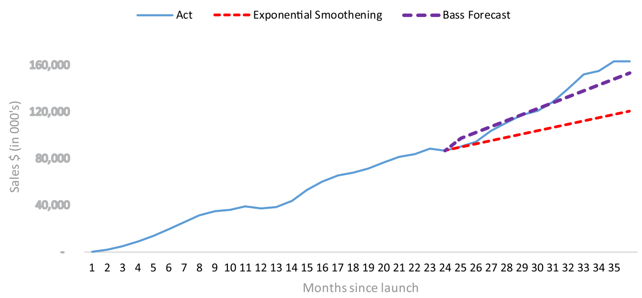

Figure 3 Bass Model vs. Exponential Smooth

The Shape of Uptake Curve Using Analogies

There are very few examples in literature that discuss the methodology of establishing the shape of the uptake curve based on analogies. All publications on uptake curve estimation using analogies emphasize analog selection based on product attributes and market characteristics. Product attribute suitability of a particular analog should be assessed using factors like market behavior, launch timeframe, market-mix parameter, and pricing strategy.

Suppose a new product in development mimics most of the attributes of one analog. In that case, we can use nonlinear least-squares curve fitting of historical sales data to estimate the 'p', 'q' parameters and create the model. However, if the new product draws analogies from multiple products, we can take a weighted average of analog parameter16–19. Here, weight can be assigned to analogs based on attribute importance and attribute score, order of entry, launch time period17. Following is one hypothetical scenario for illustration.

- A new biological Product A for atopic dermatitis is under development. Unmet clinical need and market dynamics mimic psoriasis indication. Product A's likely peak potential is determined based on conjoint. Product A draws an analogy with Product B and Product c attributes.

	Innovation Rate p	Imitation Rate q	Pdt weight
Product c	**0.02**	**0.10**	**63%**
Product B	**0.05**	**0**	**37%**

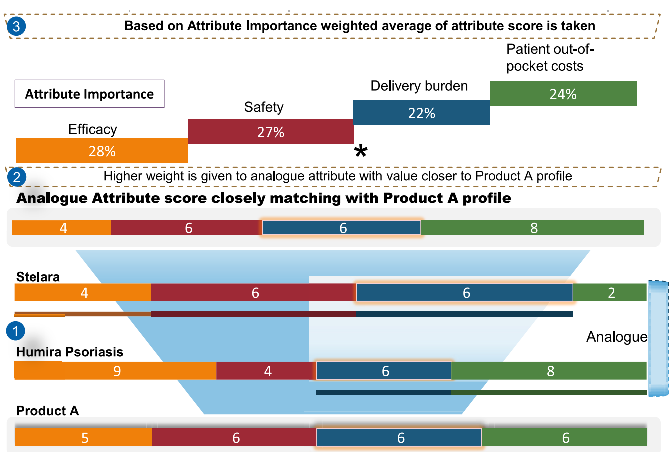

Figure 4 Steps in parameter estimation for Product A

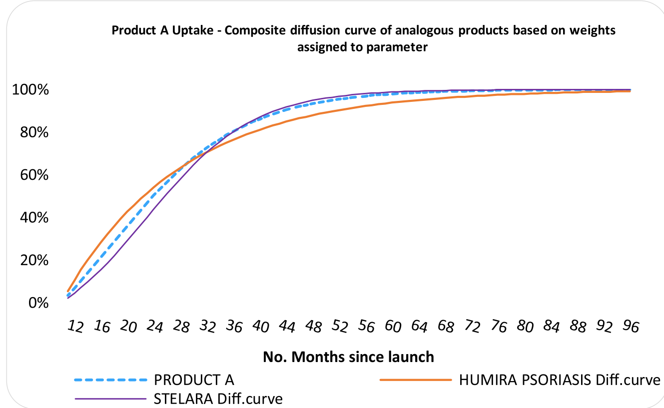

Figure 5 Product A uptake curve

Modeling the Impact of the Marketing Mix or Any Other Parameter

$$f(t)=[p+\frac{q}{m}F(t)]\,[m-F(t)]*Z(t)$$

Equation 3 Generalized Bass Diffusion model

One can use a generalized form of the Bass model that considers these two types of marketing-mix variables, price, and promotion. In its functional form, the generalized Bass model is the same old Bass model from Equation 1 multiplied Z(t), an expression of marketing effort. However, one can substitute Z(t) with any other variable that impacts uptake. One example is positive uptake lift attributed to a higher cancer screening rate.

Why is the S-curve Not Visible in Historical Data?

One reason is that innovative brand uptake typically follows the r-curve instead of the S-curve. Multiple causative factors lead to r-curve adoption, such as competition between products, higher adoption due to new medical data, price, and promotional impact. One can create an average benchmark by taking multiple analogs and using the Bass model. Another reason is that the Bass model is a model of growth and does not model the "Discontinuance Curve". Bass model neglects the possibility of instantaneous adoption and discontinuation. In summary, the article reflects an opinion that the Bass model should be a key component of opportunity estimation exercise for novel therapies. Bass model, along with its innovation and imitation, provides a better understanding of therapy adoption.

Appendix

1. DiMasi JA, Grabowski HG, Hansen RW. Innovation in the pharmaceutical industry: New estimates of R&D costs. J Health Econ. 2016;47:20-33. doi:10.1016/j.jhealeco.2016.01.012

2. Arnold DG, Troyer JL. Inhibit Pioneering Innovation ? 2016;2(2).

3. Bass FM. a New Product Growth for Model Consumer. Manage Sci. 1969;15(5):215-227. http://www.jstor.org/stable/2628128.

4. Publishing LS. Pharmaceuticals : An Evidence-Based Approach by Gary Johnson.

5. Muller E, Peres R, Mahajan V. Innovation diffusion and new product growth: Beyond a theory of communications. Work Leonard Stern Sch Business, New York Univ New York. 2007;(April).

6. Bottomley P. A meta-analysis of applications of diffusion models: F. Sultan, J.U. Farley and D.R. Lehmann, Journal of marketing research 27 (1990) 70–77. Int J Forecast. 1990;6(4):584-585. doi:https://doi.org/10.1016/0169-2070(90)90047-F

7. Fourt LA, Woodlock JW. Early Prediction of Market Success for New Grocery Products. J Mark. 1960;25(2):31. doi:10.2307/1248608

8. Fisher JC, Pry RH. A simple substitution model of technological change. Technol Forecast Soc Change. 1971;3:75-88. doi:10.1016/S0040-1625(71)80005-7

9. Bass's Basement Research Institute. Which Bass Model Equation Should I Use? http://bassbasement.org/BassModel/WhichBassModelEquation.aspx. Accessed February 27, 2018.

10. Bass FM, Krishnan T V, Jain DC. Why the Bass Model Fits without Decision Variables. Mark Sci. 1994;13(3):203-223. doi:10.1287/mksc.13.3.203

11. Islam T, Meade N. Modelling diffusion and replacement. Eur J Oper Res. 2000;125(3):551-570. doi:10.1016/S0377-2217(99)00225-8

12. Danaher PJ, Hardie BGS, Putsis WP. Marketing-Mix Variables and the Diffusion of Successive Generations of a Technological Innovation. J Mark Res. 2001;38(4):501-514. http://www.jstor.org/stable/1558615.

13. Kim N, Bridges E, Srivastava RK. A simultaneous model for innovative product categorysales diffusion and competitive dynamics. Int J Res Mark. 1999;16(2):95-111. doi:10.1016/S0167-8116(98)00026-3

14. Little JDC. Decision Support Systems for Marketing Managers. J Mark. 1979;43(3):9. doi:10.2307/1250143

15. Citation R. Is there a Benefit to Screening for Abdominal Aortic Aneurysm in the Irish Male Population between the ages of 55 to 75 years ; an Ideal Opportunity Group for Evaluating Cardiovascular Risk Factors ? 2011.

16. Ofek E. Forecasting the Adoption of a New Product. 2009;5(1969):215-227.

17. Ganjeizadeh F, Lei H, Goraya P, Olivar E. Applying Looks-like Analysis and Bass Diffusion Model Techniques to Forecast a Neurostimulator Device with No Historical Data. Procedia Manuf. 2017;11(June):1916-1924. doi:10.1016/j.promfg.2017.07.334

18. Ofek E. Examining the Adoption of Drug-Eluting Stents. Harvard Business School Case, 509-028 (2008).

19. Albers S. Cross-Functional Innovation Management: Perspectives From Different Disciplines. Secaucus, NJ, USA: Springer-Verlag New York, Inc.; 2004.

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Shyam has 11 years of experience in business analytics, strategic planning and forecasting. He has worked with pharma brand teams on delivering various life cycle management solutions. His past roles include working as analytics support for Oncology franchise contributing to performance tracking, StratPlan, budget exercise and many more. Shyam has led forecast development for CVM franchise, and product portfolio forecasting using time series forecast modeling.

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