# CONCEPTUAL FRAMEWORK AND RESEARCH PROPOSITIONS FOR MODELING THE DIFFUSION OF TECHNOLOGICAL INNOVATION

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**Conceptual framework and research propositions for modeling the diffusion of technological innovation**

**Abstract**

The paper investigates actual directions in diffusion research focusing on simple diffusion models incorporating price effect. We review main papers on diffusion research of the last decade and identify the role and position of diffusion modelling in marketing research. We also perform an empirical analysis of the Bass model and its extensions including price variable. We have four main results. (1) We prove the existence of non-linear correlation between the number of adoptions of LCD televisions and the cumulative sales of the product. (2) There is an evident dominance of the imitation behaviour of Slovak consumers driving the first purchase of LCD television. (3) The price decrease of LCD televisions has a positive influence on the imitative behaviour of Slovak consumers. (4) Slovak consumers do not consider the initial price of LCD televisions as the reference point when deciding about the first purchase. We calculated the peak sales rate and forecasted the timing of peak sales for the year 2013. In addition, this study should serve as a research proposition to marketing scholars and practitioners for a simpler application of diffusion models.

**Key Words:** Behavioural Model, Diffusion Model, Bass Model, Technology Innovation, Quantitative Research

## Introduction and Objectives

The phenomenon of globalization, revolution in information technology, both resulting in acceleration of products´ life cycle, put companies under enormous pressure to continuously innovate and improve the efficiency of their production. New products often decide about company's survival. It is also the speed and efficiency of innovation process that determine the ultimate competitive advantage.

According to recent studies, the percentage of failure of an innovation fluctuates from 5% to 90% depending on the nature of innovation and target customers (Trommsdorff, 2009). Additional sources assume that 97% of new ideas and prototypes of new products do not even enter the market and half of those launched, end in failure within two years (Yongquan, 2009). Anticipating the success of new product or service is therefore one of the most demanding and critical managerial tasks.

The response of customers to launching a new product depends on numerous factors, personal characteristics, risk perception or demographics of consumers, as well as the state of the environment - economy and market. For producers, sellers and marketers, understanding all these factors becomes crucial for successful implementation of new products, especially in case of increasing pressure in a highly competitive environment.

To present date, significant number of empirical studies has been devoted to diffusion of innovation. Impressive results have been achieved at both theoretical and practical level. Creation of models for marketing purposes becomes an essential part of the so-called new marketing (Leeflang, Wittink 2000). Information and communication technologies facilitate collecting and recording of data, analytical software allows a quick and efficient data processing. However, forecasting new product diffusion in comparison with well implemented products has certain limitations:

- Low availability of historical data on past sales;
- Absenting knowledge about new market resulting in high degree of risk for producers as well as other members of distribution channel.

Elimination of these risks might be achieved with sufficient qualitative and quantitative estimation. We believe that diffusion research should focus on (1) how marketing mix variables effect the growth of new product and (2) how diffusion models can become a useful tool not only for predictive but also normative and descriptive purposes in marketing research. We want to emphasize the importance of using quantitative methods in marketing, which often face rejection because of their inaccessibility or complexity. In present era of computerization it is more than desirable to make diffusion modelling more accessible for marketing researchers, but also other stakeholders with a standard knowledge of mathematics and statistics.

This paper is prepared under the project IGM No. 2316069/10 „Methods and tools of continuous improvement of business units in the context of improving their competitiveness”.

### *Objectives*

The central objective of this study is to generate an insight on diffusion modelling and its role in marketing research and practice. Our results offer a conceptual framework that illustrates how diffusion models can become a useful tool to improve the marketing mix of new product. We also perform an empirical analysis and asses the descriptive performance of the basic Bass model and its extensions incorporating the price effect. The purpose of the empirical application is to (1) demonstrate the validity of the models, (2) describe the diffusion of LCD televisions in the Slovak market (3) identify the peak adoption time and rate and finally (4) develop a set of research propositions to facilitate the application of studied diffusion models in marketing research. We also aim to encourage domestic marketing researchers to use quantitative methods more frequently and we hope to broaden the scope of Slovak marketing literature.

## I. Conceptual Framework

We proceed first by discussing the role and position of diffusion modelling in marketing research. Therefore, we review main papers of the last decade (Bass, 2004; Cavusoglu, 2010; Kahn, 2006; Mahajan, 2010; Putsis – Srinivasan, 2000; Rogers, 2003; Trommsdorff – Steinhoff, 2009; Tsai, 2009; Van den Bulte – Joshi, 2007) and put them in relation with core concepts of diffusion research in order to build theoretical foundations for formulating our research propositions. We focus on the contributions of marketing science literature to the understanding of dynamics of innovation diffusion by incorporating decision variables into basic diffusion models.

### *Diffusion Models in Marketing Research*

Leeflang and Witting (2000) defined model as “a representation of the most important elements of a perceived real-world system”. Quantitative models help to recapitulate the results of marketing research and should lead to plausible conclusions (Fransen-Paap, 2001). Specifically, quantitative models in marketing explain variability in market performance caused by explanatory marketing mix variables, such as price, distribution or advertising efforts. In addition, several implicit benefits of model approach in marketing have been identified by marketing academics:

- Models indicate gaps in our marketing decisions and define areas for future research (Lesáková D. et al. 2010);
- They help to improve marketing analysis procedures (Lesáková D. et al. 2010) and represent main driving forces in marketing knowledge as they produce generalizable phenomena (Leeflang, 2000);
- They allow identifying hidden problems that will occur after the creation and application of a model – as the difference between how management perceives the problem and how it is shown by the model (Leeflang et al. 2000).

Leeflang and Witting (2000) also identified 5 historical eras of model building in marketing[1]. Last decade, also called *the era of new marketing,* focuses on consumer preferences, their behaviour and specific needs. In present era, the role of model approach is to anticipate and simulate new products introduction, to study the effects of repositioning, price changes, and promotional activities on firm’s revenue, profit and market share.

Some authors (M. Wedel et al., 2000), regarding the future direction of research in modeling marketing decisions, call for a global database or platform, which would collect research findings and provide comprehensive insights on quantitative models. We also believe that this would extend the possibilities of using analogy in case of new products and partially solve the problem of data availability.

As for the typology of marketing models, it is important to note that same model may have different categorization. Therefore authors do not clearly define diffusion models in a specific category of models – descriptive, normative or predictive, as proposed by Leeflang and Witting (2000). Most authors (Mahajan et al., 1990; Bass et al. 1995) assume that although diffusion models have been traditionally used in context of sales forecasting,

[1] for further information see Leeflang and Witting, 2000.

descriptive and normative uses of diffusion models help either to develop optimal marketing strategies or to test hypotheses related to diffusion research.

However, according to Leeflang and Witting (2000), diffusion models belong to the category of behavioural models. These are models with behavioural detail which refers to their capacity to show “how marketing variables influence variables such as brand awareness, brand image, motivation to purchase”. They aim to clarify the mechanism inside the “black box” of consumer behaviour (Lesáková D. 2010).

**TABLE 1: Predictive, Descriptive and Normative Application of Diffusion Models**

| Author | Diffusion model | Implication | Use |
|---|---|---|---|
| **Bass et al. (1994)** | Generalized Bass model | - New product planning when no prior data are available | Predictive |
| | | - Guessing parameters and the diffusion pattern by analogy | Predictive |
| | | - Analyzing the effect of different marketing policies on the location of diffusion curve and timing of the peak | Normative |
| ***Van den Bulte, Joshi, (2007)*** | Two-segment Mixture Model | - Proportion of adoption by influential do not has to decrease monotonically | Descriptive |
| | | - Indentifying long-time opinion leaders to develop more effective network marketing efforts | Normative |
| ***Cavosoglu et al. (2010)*** | Three-segment Model with Opponents | - Categorization of the segments of adopters | Descriptive |
| | | - Describing diffusion of all technologies, where significant anti-adoption forces are present | Descriptive |
| | | - Quantification and optimization of promotional effect | Normative |
| ***Tsai et al. (2010)*** | Model with price variable | - Costs and prices of technology innovation decline as a result of experience and learning | Descriptive |
| | | - Price influences imitation behaviour of adopters rather than the market potential | Descriptive |

Categorization of diffusion models may serve as guide to identify their managerial implications. Table 1 is a listing of main implications of diffusion models in fields of marketing and management. We review the generalized Bass model and three of its most recent extensions, one incorporating decision variable. We use the classification by predictive, descriptive and normative uses.

### *From Bass Model to Models with Decision Variables*

Bass model is a first-purchase growth model that describes cumulative distribution of adoption of innovation over time (Mahajan et al. 1995). For years of diffusion research, Bass model has been the basis for numerous extensions aiming to eliminate its limitations.

Most investigations dealing with Bass diffusion model have been carried out in North America and Europe (Rogers, 2003), although in recent decade, the same model has become popular in fast developing Asian countries – Taiwan, South Korea, Japan or China (Lee et al. 2006, Tsai et al. 2009, Wang et al. 2011). It still remains one of the most widely used models in marketing (Rogers, 2003).

Researchers now seek to develop a generalized model that would include decision variables and offer more normative uses in strategic marketing planning. To conceptualize the issue of incorporating decision variables into diffusion models, we firstly review the basic Bass model and the conditions of its application on technology innovation. Afterwards, we discuss possibilities of including price effect into the simple time-series model and forecasting the adoption of LCD televisions in Slovakia. Based on theoretical and empirical knowledge we develop three hypotheses that will be tested.

In general, Bass model assumes the existence of two means of communication that drive the diffusion process of an innovation – mass media or external influence and word-of-mouth or internal influence. Bass (1969) distinguishes two categories of potential adopters. Those, who are influenced exclusively by mass media communication, are also called innovators while adopters driven by word of mouth communication have a strong imitation behaviour and are therefore called imitators. As the result, the probability of adoption of an innovation at time t depends on three elements:

- External or innovation factor p
- Internal or imitation factor q
- Cumulative fraction of real adopters at time t

This may be also written as:

$$f(t)/[1- F(t)] = p + q\ F(t)\ , \qquad (1)$$

or:

$$n(t\ ) = [p + q\ *\ N(t)/M]\ [M - N(t]\ , \qquad (2)$$

where M represents the market potential, n(t) = Mf(t) is the number of adoptions at time t, N(t) = MF(t) is the cumulative number of adopters at time t.

Before we start modelling the diffusion of LCD televisions, we need to identify specific characteristics of studied innovation and develop hypotheses concerning the diffusion process on the Slovak market. Application of Bass model also requires respecting certain conditions (Mahajan et al. 1995). Therefore we briefly discuss main characteristics of LCD televisions in order to discover whether Bass model is suitable for describing the diffusion of LCD televisions.

*Conditions of application of the Bass model*

(1) Bass model is designed to describe the initial purchase of durable products with a longer period of replacement. LCD televisions represent a category of durable products. In our empirical study we will consider the replacement demand negligible.

(2) Care must be taken to the definition of adopting unit because of possibility of multiple users. In our case, the adoption unit is equal to a Slovak household[2].

(3) Bass model applies to the generic demand for a product category. The aim of this study is to describe the category adoption pattern represented by LCD televisions of all sizes and technology generations.

(4) The diffusion process might be retarded by supply restrictions caused by limited production capacities. Taking into account the strategic position of Slovakia, open European market, numerous foreign suppliers as well as domestic producers of electronic devices, we consider the "condition of unrestricted supply" to be satisfied.

[2] M=2 071 743 households (Data source: Štatistický úrad SR, 2000).

LCD televisions are widely spread as the main type of television replacing cathode ray technology in most households; in context of diffusion theory, they should be regarded as consumer durables. Due to their technological advantages – slimness, higher resolution, lightness and additional functions, they are at the same time viewed as a technology innovation. Therefore LCD televisions possess properties of both durable and high-technology commodities (Tsai et al., 2010). In addition, we plot the data for seven periods and observe that a bell-shaped curve is being created. When data plotted on cumulative basis, a non-linear correlation seems to appear. We conclude that Bass model is suitable for describing the diffusion of LCD television on the Slovak market and we develop the first hypothesis.

***Hypothesis 1: There is a non-linear correlation between the cumulative number of adopters of LCD televisions in time (t) and the total number of purchases in the (0, t) interval.***

In case of technology innovations, the existence of two segments of potential adopters has been confirmed by several empirical studies. Innovators, also called "technology enthusiasts" ignore risks related to an unknown product and feel attracted by benefits of the innovation. On the other hand, the risk-averse majority of potential market needs information and seeks legitimating from consumers that have already adopted the innovation. According to empirical research (Van den Bulte - Joshi, 2007) as well as conclusions made by Rogers (1958), the importance of personal influence in consumer purchasing process is higher than the influence of mass media. In case of highly technological products, the coefficient of innovation $p \to 0$, while the coefficient of imitation $q>0$. Furthermore, Slovakia is a high power distance country with medium uncertainty avoidance level and low individualism index, which indicates lower innovativeness of Slovak consumers (Geert Hofstede™ Cultural Dimensions, 2011). By deduction, we develop second hypothesis.

***Hypotheses 2: In case of LCD televisions, the imitation behaviour is more dominant than the innovative behaviour of Slovak consumers.***

*Incorporation of the price effect*

There has been a discussion among diffusion researchers whether price influences the market potential or the rate of adoption. Bottomley and Fildes (1998) identified two approaches concerning the influence of price on variables in diffusion model:

1. Price affects the market potential. As the price declines over time (due to decreasing costs resulting from the experience curve), the number of potential adopters is expanding.

2. Price affects the rate of adoption rather than the market potential. Price reductions accelerate the adoption decisions of potential adopters while the size of the market remains constant over time. Several empirical results show that especially in case of more expensive goods, price variations affect the rate of adoption rather than market potential´s size (Bottomley-Fildes, 1998). In addition, Tsai et al. (2010) assumes that according to the characteristics of LCD televisions the price impact affects the imitative behaviour of potential adopters.

According to GfK study conducted in 2008, Slovakia is in the second half of 40 European countries regarding the purchase power, with EUR 6102, which is approximately 50% of the European average. Based on all these assumptions, we develop the third hypothesis.

***Hypothesis 3: Price variations influence the imitative behaviour of Slovak consumers and represent the main driver of diffusion of LCD televisions.***

Another interesting assumption concerning the price effect on diffusion process was made by Bass et al. (1994). The empirical study proves that Bass model fits without decision variables in case when percentage changes in decision variables are approximately constant.

Additionally, Tsai et al. (2010) discusses the optimal expression for the price reduction which he defines as the price gap in the interval [0, t]. The price at t=0 refers to the initial price when the product was first promoted on the market. Consumers remember this price as a reference point to determine whether they will purchase the product. We wonder if it is the case of Slovak consumers and therefore we proceed to estimation procedure with three models – Bass model, modified model with P (0) as the reference point and modified model with P (t-1) as the reference point.

## II. Methods: Estimation Procedure and Empirical Findings

The aim of our empirical study is to describe properly the estimation procedure and to propose guidelines facilitating the application of studied diffusion models.

We estimate the Bass diffusion model and two extensions incorporating price variable, using the nonlinear square estimation (NLS). Maximum Likelihood Estimation is also applicable to Bass model but the NLS estimation may perform better fit and predictive validity (Srinivasan, Mason, 1986). We use statistical software Eviews 6.0 to estimate parameters of the three models.

### *1. Background and Data*

Slovak market of electronics has been influenced by growing popularity of LCD televisions since 2005. While in 2003 flat televisions represented hardly 2% of the market, in 2004 the percentage changed to 9% and at the end of 2005, LCD televisions together with PDP televisions occupied 37% of the Slovak market.

In particular, the average annual prices of LCD televisions have decreased since 2004. As shown on Fig.1, the prices decreased in 2005-2007 faster than in 2007-2010. Finally in 2010, the average price of LCD television represented only 30% of the price in year of introduction. The influence of economy of scale reached by producers is therefore evident.

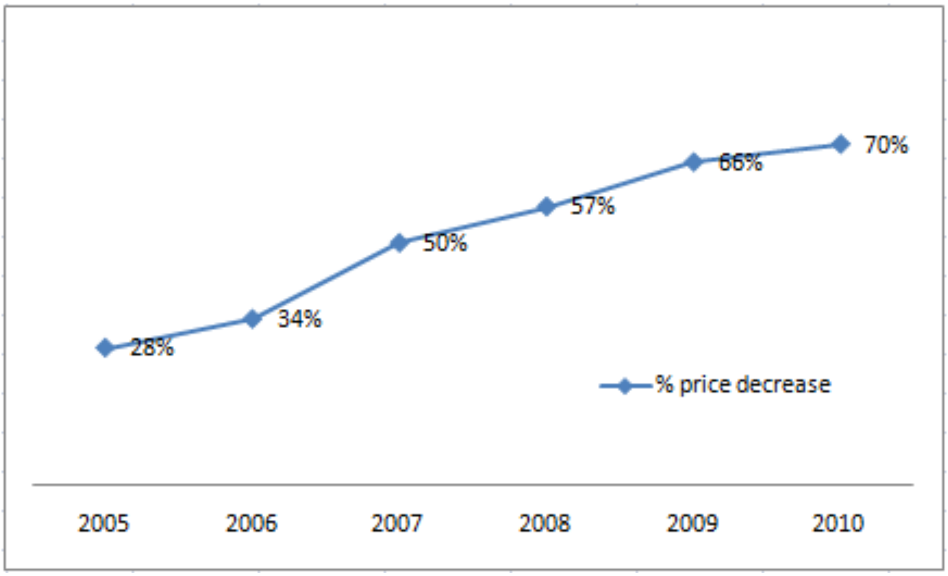


**Fig. 1:** The Pattern of Average % Price Decrease of LCD Televisions in Slovakia in 2005-2010 (Data source: GfK Retail and Technology 2011)

In our study, we use annual sales data (2004-2010) of LCD televisions generated by GfK Retail and Technology panel. We study total sales in units for all size categories of LCD televisions as well as average retail prices in EUR. Annual price is calculated as the average of monthly prices. We use realistic prices without price deflator because we believe this may be a more realistic representation of consumers' perception (Bass et al. 1994).

The market potential M is supposed constant and it is equal to the total number of Slovak households from year 2000 (Data Source: Population and Housing Census 2001). We set the adoption unit equal to a household and consider that each household is able to buy one LCD television. Sales refer exclusively to first purchase because of supposed durability of studied product.

### *2. Model Propositions*

We develop two alternative models based on the propositions of Tsai et al. (2010), letting M be the total number of potential adopters, p and q the coefficients of innovation and imitation, N (t) the cumulative number of adoptions and the terms $[P(0) – P(t)]^{\delta}$ and $[P(t) – P(t-1)]^{\delta}$ the price difference in the intervals [0, t] and [t-1, t]. The price P(0) refers to the price in 2004, that we consider to be the year of introduction of LCD televisions on the Slovak market (sales in 2003 are negligible).

***MODIFIED MODEL M1***

$$n(t) = [p + q * [P(0) - P(t)]^{\delta} * N(t)/M] [M - N(t)] \qquad (3)$$

***MODIFIED MODEL M2***

$$n(t) = [p + q * [P(t-1) - P(t)]^{\delta} * N(t)/M] [M - N(t)] \qquad (4)$$

Coefficient δ refers to price elasticity which represents the marginal effect of price reduction on internal influence q (Tsai et al., 2010).

### *3. Parameter Estimation*

Parameters we estimate include innovation coefficient p, imitation coefficient q and the price elasticity δ for modified models. Results of estimation, as well as values for the coefficient of determination $R^2$ and the sum of squared errors SEE, are represented in Table 2.

**TABLE 2: Parameter Estimates with $R^2$ and Sum of the Squared Errors**

| Model | Coefficient Estimates p | q | δ | R2 | SEE (E+09) |
|---|---|---|---|---|---|
| Bass model | 0,006935 | 0,44653 | - | 0,946716 | 1,86 |
| Modified Model M1 | -0,007009 | 26719,71 | -1,575388 | 0,985319 | 0,387 |
| Modified Model M2 | 0,008239 | 0,287645 | 0,095166 | 0,944159 | 1,47 |

The fits of the Bass model and the model M2 are quite good as the value of $R^2$ is approaching 1. Parameter estimates p and q have the correct signs and are relatively close to the generalized values (see Mahajan et al. 1995). On the other hand, parameter estimates for the model M1 p and δ have both incorrect sign; the value of parameter q is inappropriate.

The estimated coefficients in Bass model are statistically significant, with t-statistics in near and in excess of 2,78 (Tab. 3) on the 0,05 significance level. Parameter q in the Bass model shows much higher significance than all other estimated parameters.

After the first estimation, we consider the results for the modified model M1 to be unsatisfying. Therefore we might omit the model from further consideration.

**TABLE 3: Tests of significance for the parameter estimates p, q, and δ**

| | | Prob. | t-stat |
|---|---|---|---|
| Bass | p | 0,2299 | 1,366955 |
| | q | **0,0001** | **10,70009** |
| M1 | p | 0,4703 | -0,824153 |
| | q | 0,7688 | 0,321674 |
| | δ | 0,00384 | -3,539378 |
| M2 | p | 0,3583 | 1,0824 |
| | q | 0,3158 | 1,201276 |
| | δ | 0,6529 | 0,497762 |

| t-stat | |
|---|---|
| tab 0,05 | 2,78 |
| tab 0,01 | 4,6 |
| tab 0,005 | 5,6 |

In addition, we calculate beta coefficients for all parameter estimates of the two models. Beta coefficients indicate the percentage of variation of adoptions explained by the estimated parameters. The results are represented in Table 4.

**TABLE 4: Beta Coefficients for Estimated Parameters p, q and δ**

| | | beta coeff. | adj beta coeff. | % | adj% |
|---|---|---|---|---|---|
| **Bass** | p | 0,015293352 | 0,014478461 | 2% | 1% |
| | q | 0,984706648 | 0,932237539 | 98% | 93% |
| **M2** | p | 0,021068917 | 0,019892408 | 2% | 2% |
| | q | 0,735570899 | 0,694495884 | 74% | 69% |
| | δ | 0,243360184 | 0,229770708 | 24% | 23% |

For the Bass model, the imitation factor represented by q is dominant. In the modified model M2, the percentage of p remains low, while values for coefficient of imitation and the price elasticity are both significant.

### *4. Forecasting, Peak Sales Rate and Timing*

We apply estimated parameters calculated for the two models to obtain forecasted sales. We choose the Mean Absolute Percentage Prediction Error (MAPE) to compare the forecasting capability of the two models because of its simpler interpretation. A small value of MAPE indicates that the model follows the actual data very closely (Cavusoglu et al. 2010). When two models are compared, smaller value of MAPE provides a better fit to data. Results are represented in Table 5. We calculate the Mean Absolute Percentage Error as:

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\frac{|Y_t-\hat{Y}_t|}{Y_t} \quad , \qquad (5)$$

where $Y_t$ represents real sales and $\hat{Y}_t$ is the forecasted value using Bass model and modified model M2. The results are represented in the Table 5.

**TABLE 5: Mean Absolute Percentage Prediction Errors (MAPEs) of LCD Televisions Shipments by Using the Bass Model and Modified Model M2**

| | MAPE | Results |
|---|---|---|
| Bass Model Fited | 31% | reasonable |
| M2 Model Fited | 37% | reasonable |
| | | |
| [0,10%] | excellent | |
| [10%, 20%] | good | |
| [20%, 50%] | reasonable | |

For both models, MAPEs are situated in the interval [20%, 50%]. This means that the forecasting capacity of the two models is reasonable (Tsai et al. 2010). In addition, Bass model performs slightly better than the modified model. However, results have confirmed the suitability of both models in determining the LCD televisions adoption trajectory.

We plot real data and forecasted data in Fig. 2 to see the adoption pattern. The S-shape of the adoption curve is evident with inflexion point in 2006.

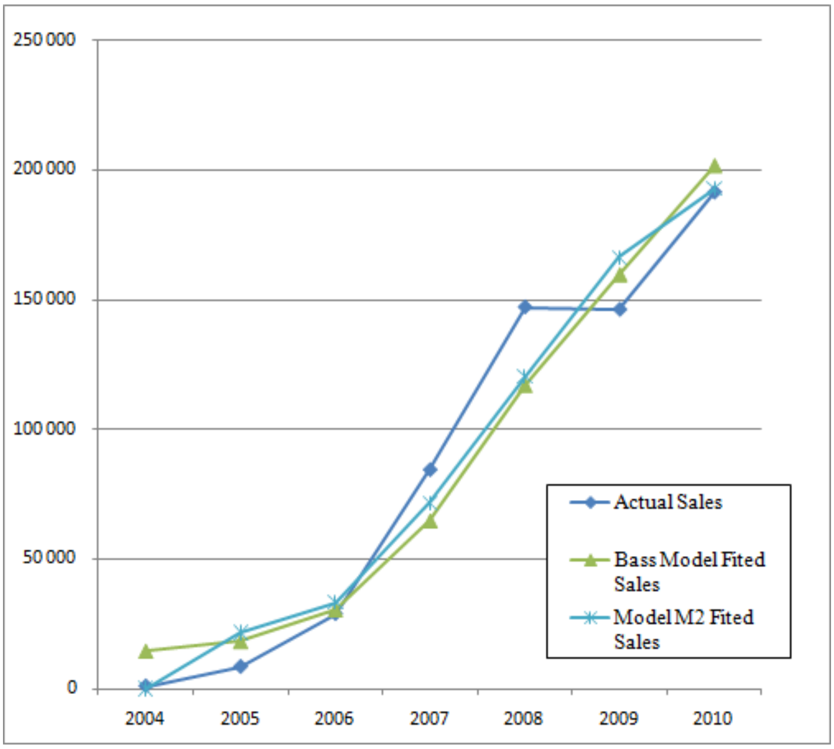


**Fig.2:** Actual and Predicted Adoption S-curve of LCD Televisions Using Bass Model and Model M2.

Given by Bass (1969), peak sales rate and timing is obtained by the mathematical derivation of Equation 2. The expressions are:

$$\textbf{\textit{Peak sales sate}} = \frac{M(p+q)^2}{4q} \qquad (6)$$

$$\textbf{\textit{Timing of peak sales}} = \frac{ln\,(\frac{p}{q})}{p+q} \qquad (7)$$

To obtain the forecasts of these quantities, we used the estimates p and q calculated for the Bass model.

| | |
|---|---|
| **peak sales** | *238513,404* |
| **timing** | *9,18466813* |

The results above indicate that the maximum rate of adoption will be reached in the ninth period (equals to 2013) with maximum annual sales 238 513 units; thereafter the rate of adoption decreases and the market saturation is reached around the year 2026 (Fig. 3). The graph below is obtained from Excel Macro developed by Bass Research Institute, after replacing the predefined parameters p, q and M by estimated values. The peak rate is close to our value, while the timing of peak sales is forecasted for the same year 2013. The small difference is caused by a different estimation procedure used in the Macro (discrete form of Bass equation).

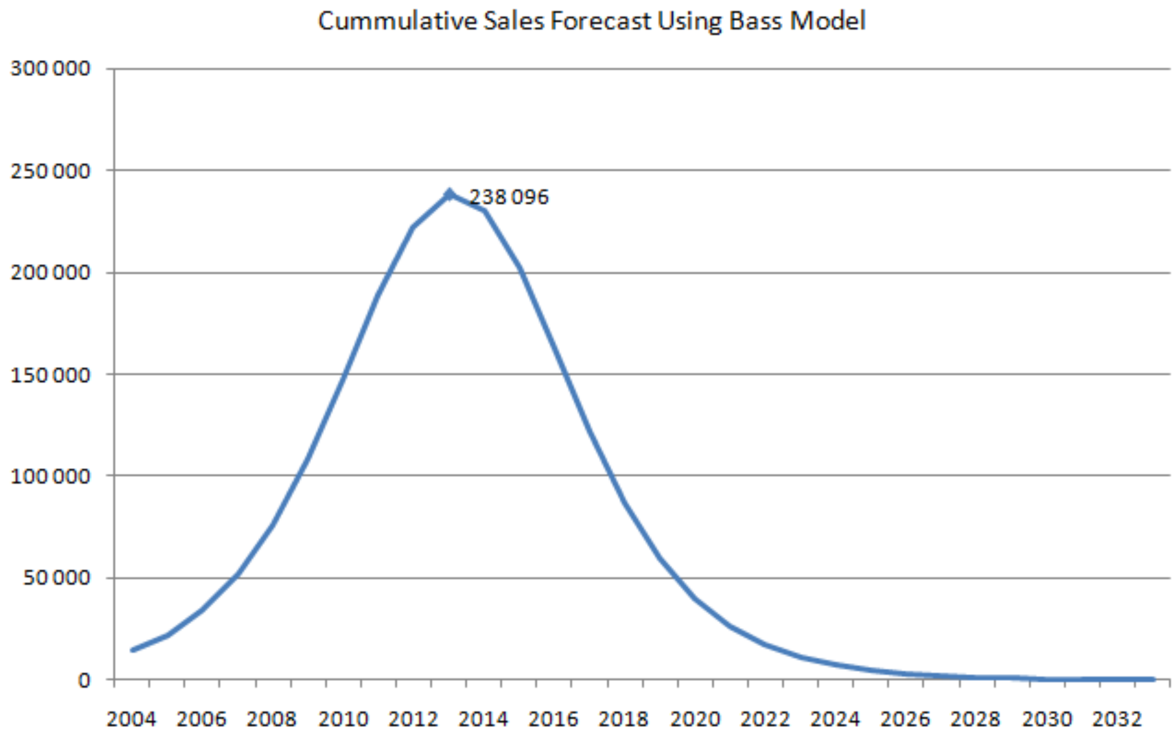


**Fig. 3:** Predicted Bell-Shaped Curve Representing Cumulative Adoptions Estimated using Discrete Form of Bass Model.

### *5. Further tests: Autocorrelation*

To test the correlation of residuals, we evaluate the Durbin – Watson statistics generated for the two models using the E-views software. For the Bass model, the value is equal to 1,37293 while for the modified model M2 the value is 2,109695. If the value of Durbin – Watson test statistics is near 2, there is no autocorrelation. Model M2 performs better results concerning autocorrelation as the Bass model.

## III. Findings and Discussion

Based on empirical findings, we proceed by evaluating hypotheses that we formulated in Section I.

Results of estimation, especially values of coefficient of determination, have confirmed **Hypothesis 1** concerning the existence of non-linear correlation between the number of adoptions of innovation and the cumulative number of adopters, as more than 94% of variation of dependant variable was explained by proposed polynomial equations.

In addition, the values of estimated coefficients confirm **Hypothesis 2** concerning the dominance of imitation behaviour of Slovak consumers. In both models, coefficient of innovation p was much smaller than q and even smaller that values of p obtained in prior empirical studies.

Results obtained by using Bass model indicate that Slovak consumers are imitators rather than innovators. They are strongly influenced by previous adopters and the internal influence which is represented mostly by word-of-mouth communication.

We also compared alternative models incorporating price effect. The first model M1 did not fit well as two of three estimated parameters had a negative sign. The second model M2 performed better than M1 and described the adoption process very well. We proved that decreasing price of LCD televisions may strengthen the imitation behaviour of potential consumers. We confirm the **Hypothesis 3** and assume that Slovak consumers are willing to purchase the product if the price decreases.

Surprisingly, the results show that Slovak consumers do not memorize initial price P(0) as the reference point. Tsai et al. (2010) analyzed the global adoption of LCD televisions using the model M1 (Equation 3). Their study shows that if the price drops fast, people remember the initial price and use it as a reference point to determine whether they purchase the product. This is not the case of Slovakia, where people hardly remember the initial price and compare the actual price with price from previous period.

It is important to note that other factors may have influenced the diffusion process of LCD televisions in Slovakia, such as the advertising expenditures, but also the increasing popularity of PDP televisions. In 2011, Slovak households are replacing analogue broadcasting by digital broadcasting. This factor may also influence the future diffusion process of LCD televisions.

According to Bottomley and Mason (1998), “there are still no conclusive guidelines identifying how and when prices affect innovation diffusion”. Srinivasan (1986) argues that it is important to focus on a specific purpose when searching for the right model to describe diffusion of innovation. We have shown that Bass model and its extension are both suitable for describing the diffusion process of LCD televisions in Slovakia. While Bass model performs better in forecasting the penetration trajectory, the modified model describes the rate of diffusion including marketing decision variable. This is useful for marketing practitioners deciding about marketing strategies. Therefore we believe that choice of the right model should be based on the purpose of study – whether we seek a descriptive, normative of predictive use.

## IV. Limitations and Further Research

The main limitation of the purposed procedure is the availability of data. In our study we analyzed sales data for only one product category. In addition, first 7 years of data were available that may have produced quite unreliable results. Thus, Bass diffusion model is specific for its capacity to forecast the diffusion process even when few data are available. This also explains the observation that performance of modified model with price effect is not superior to the Bass model. Relative performance of models including decision variables tends to improve as the length of estimation period increases (Bottomley-Mason 1998).

The model should be demonstrated to work with several data sets if we want to draw relevant conclusions on model performance. To evaluate the predictive validity, a variety of forecasts should be produced for a range of similar durable goods. In addition, Bottomley and Mason (1998) propose that using out-of-sample data rather than fit to historical data increases the reliability of the model. In the end, each modification should be compared with well–accepted models; in our study we used only the generalized Bass model.

There also might be a problem when forecasting the diffusion process using the modified model, because of the need to project price series. This could produce more errors of prediction, what proves that models incorporating decision variables are suitable for normative uses rather than forecasting purposes. Other additional tests to evaluate the forecasting capacity may be done, such as the step-ahead forecasting (Bass et al, 1994) or the cumulative relative absolute error (Bottomley-Mason, 1998).

Furthermore, proposed models, as well as the Bass model, do not identify the two segments of adopters. The segment of imitators requires different means of persuasion than the segment of innovators. Identifying these segments correctly may help practitioners to optimize their advertising efforts and develop optimal pricing strategies. In addition, our proposed model supposes that only imitators are influenced by the price decrease. This might differ from one product category to another.

Further investigation is needed concerning the incorporation of other marketing variables into the diffusion models, such as advertising expenditures and distribution.

We believe that exploration in these areas would bring a lot of interesting and useful results.

## V. Managerial Implications

As the Bass model is simple and model parameters have a clear economic and managerial significance, is has been used by numerous companies such as Eastman Kodak, IBM, AT&T and others (Wang et al. 2011).

Three sets of managerial implications arise from this study – predictive, descriptive and normative uses. We discuss these below.

*Predictive uses*

In our study, we used historical data to fit the Bass model and its extension with price variable in order to compare their validity. In addition, we calculated maximum peak sales and timing of peak sales using the formulation proposed by Bass (1969) and used by current scientists (Tsai et al. 2009; Orova – Komáromi, 2003). Identifying these two values is important for planning purposes. Practitioners can analyze whether the sales rate has reached the target level and decide when and how to apply marketing tools effectively.

In case of no historical data available, there is an opportunity of guessing parameters by analogy (Mahajan et al. 1995) by grouping analogous products for which no historical data are available, such as 3D televisions recently introduced on the Slovak market.

*Descriptive uses*

Both models have shown that in case of LCD televisions, the imitative behaviour of Slovak consumers is superior to the innovation tendency. This indicates that the effect of mass media communication is low and consumers are influenced by word-of-mouth communication. Moreover, communication through mass media might be more important for earlier adopters rather than the later majority (Rogers, 2003).

Also price reductions that have shown positive influence on imitative behaviour with a positive price elasticity equal to 0,6529. The imitative behaviour became dynamic, influenced by the difference between the actual price and the price of previous period. In addition, we observed that Slovak consumers do not consider the initial price of LCD televisions to be their reference point when deciding about the purchase. Therefore, we recommend practitioners to concentrate their advertising efforts on stimulating the word-of-mouth effects and communicating the price reductions of LCD televisions in combination with the benefits of product, such as the slimness, higher contrast, energy saving, etc. In case of marketing communication, we recommend using advertising at points of sale, offering additional services, online referral program and rewarding loyal consumers (discounts…) to boost the peer-to-peer communication.

*Normative uses*

Modified model with price effect can be used as a decision-support tool to evaluate competing price strategies. When launching a new product, there are two optional pricing strategies for a firm to choose (Mahajan et al., 1990):

(1) Market skimming is used when the market is still developing. The pricing strategy sets the initial price higher and allows decreasing over time.

(2) Market penetration aims to gain the largest market share possible by using lower prices that can be increased once the innovation is well positioned on the market (sales peak of diffusion curve).

In case of LCD televisions, the results show that practitioners can expand their sales using the strategy of market skimming: through price reductions that have direct influence on imitative behaviour of the potential adopters. For analogous products such as PDP or 3D televisions, the same pricing strategy would enhance the diffusion process.

In addition, by using different sets of parameters, managers are able to generate several diffusion scenarios:

(1) with $p=0$, the influence of imitation factor can be isolated, managers can focus on pure imitators and test the effects of tools to enhance the word-of-mouth communication,

(2) with limited influence of the imitators (small $q$ and $\delta$) managers can observe the force of mass media communication on the diffusion process and improve the effectiveness of advertising expenditures,

(3) using different price strategies, managers can evaluate the influence of price decrease on peak sales rate, the timing of peak sales, the position and shape of the diffusion curve or the timing of market saturation

To conclude, it is important to acknowledge that more empirical evidence is needed. The framework of the model is well suited to include other theoretical and practical extensions. Managers should check our assumptions concerning Slovak market against data from their own observations. By sharing their experiences, they can contribute to further validation of presented diffusion models and development of diffusion research in other areas of social science. For this purpose, we offered a simple step-by-step methodological guide for estimating the market evolution of a specific product category. However, similar theoretical and methodological approach is suitable for any product or service, which is new to customers and even a small amount of sales data is available.

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