A System Dynamics Analysis of ICTs' Diffusion in the Brazilian Market

Graziella C. Bonadia*, Giovanni M. de Holanda, Ricardo B. Martins

Fundação CPqD – Telecom R&D Center

Campinas – SP

Brazil

Abstract

This paper aims at presenting an analysis of the product diffusion process in the Brazilian Information and Communication Technology (ICT) market – an environment that has particular sociocultural characteristics and is strongly affected by external economic factors. Such aspects make more complicated the parameterization based on traditional approaches, such as the Bass diffusion model, since the parameters so obtained do not properly describe the purchase behavior over time. Not considering such influences in the modeling process may lead to inaccurate information about a product or service diffusion pattern and market penetration of the products. The main purpose of the study is therefore to investigate how and to what extent such external factors can influence the product diffusion process, seeking to acquire knowledge about the market and the consumer behavior facing the introduction of a new product or service. Two diffusion processes are analyzed herein by means of a system dynamics simulation model: the DVD player and the TV set were.

Keywords: Innovation diffusion; Extended Bass model; ICT; Decision making; Business dynamics.

***Graziella Cardoso Bonadia**
e-mail: bonadia@cpqd.com.br
Phone: +55 19 3705.6903
Fax: +55 19 3705.5868
SP-340, km 118.5
Bairro Fazenda Paul D'Alho
CEP 13086-902
Campinas – SP
Brazil

A System Dynamics Analysis of ICTs' Diffusion in the Brazilian Market

Graziella C. Bonadia[1], Giovanni M. de Holanda, Ricardo B. Martins
Fundação CPqD
Brazil

Abstract

This paper aims at presenting an analysis of the product diffusion process in the Brazilian Information and Communication Technology (ICT) market – an environment that has particular sociocultural characteristics and is strongly affected by external economic factors. Such aspects make more complicated the parameterization based on traditional approaches, such as the Bass diffusion model, since the parameters so obtained do not properly describe the purchase behavior over time. Not considering such influences in the modeling process may lead to inaccurate information about a product or service diffusion pattern and market penetration of the products. The main purpose of the study is therefore to investigate how and to what extent such external factors can influence the product diffusion process, seeking to acquire knowledge about the market and the consumer behavior facing the introduction of a new product or service. Two diffusion processes are analyzed herein by means of a system dynamics simulation model: the DVD player and the TV set were.

Keywords: Innovation diffusion; Extended Bass model; ICT; Decision making; Business dynamics.

1 Introduction

Behind each innovation emerging in a market, there are several factors acting on its acceptance by consumers. Essentially, such factors are a combination of psychological, anthropological, social and other human aspects, expressed by means of wishes, preferences and needs. In general, the innovations are materialized as new products or services and result from the technology pace, market laws and social arrangements as urban concentration or communities.

In the Information and Communication Technology (ICT) scenario, products and services are created in line with such trends. In part, this process is also a consequence of the increasing reliance on communication artifacts, which demand immediate solutions to match economic and social needs. From a business point of view, the deployment of a new service or product involves risks, which can blur the decision-making process and affect the success of an innovation. From the providers and manufacturers perspectives, there is a general lack of information on when the investments will occur or to what extent the product will penetrate in the market. For this reason, the ability to predict the diffusion process of an innovation is a key issue for telecom service providers and the ICT industry.

That is not a trivial question. Different approaches have been applied to this purpose, among them the logistic and the Bass diffusion models. The logistic model of innovation diffusion,

[1] Author for contact: bonadia@cpqd.com.br

however, does not solve the startup problem, *i.e.*, it is no longer appropriate to explain the arising of initial adopters. In fact, it is a classical dilemma, since the utility of a network increases with the number of users (in accordance to Metcalfe's law, as a quadratic function). So, it brings up the inevitable question: how to overcome this initial barrier in terms of launching a new product or service? Lucky (1997), for example, addresses this problem from a perspective of communications services.

In turn, the Bass diffusion model was proposed in 1969, aiming to deal with the problem of initial adopters. Roughly speaking, in this model the potential adopters become aware of an innovation as consequence of external events, strictly by means of marketing efforts, in such a way that the startup problem is overcome but, however, the market is merely considered like a uniform social structure, as pointed out in (Menezes *et al*., 2005). Such an aspect may be a limitation for assessing the attractiveness and even the profitability of a new product and service, especially when someone considers the value perceived by each user, the fluctuating economic scenario and the complex social networks of a developing country.

Bass model has been largely used to describe product diffusion process[2] and even considering its suitability for predicting analyses, several extensions on its core approach have been proposed (Zabkar and Zuzel, 2002)[3]. Furthermore, as remind Talukdar *et alii* (2002), most analyses of diffusion processes focus on developed economies. In that respect, these analysts are also including emerging markets in their investigation, analyzing the relationship between some environmental factors and the diffusion parameters.

The economic characteristics observed in developing countries significantly affect the nominal diffusion behavior. Such aspects complicate the parameterization based on Bass equations, since the parameters so obtained do not properly describe the purchase behavior over time. Not considering such influences in modeling process may lead to inaccurate information about the diffusion speed and market penetration.

Therefore, this paper aims at presenting an analysis of the product diffusion process in the Brazilian ICTs market, which is strongly affected by external economic factors, as can be addressed by means of a systems thinking approach. The main purpose is to investigate how and to what extent such external factors can influence the innovation diffusion, seeking to acquire knowledge about the market and the consumer behavior facing the introduction of a new product or service. With this analysis, we hope to obtain a more powerful approach for supporting future studies on the introduction of new ICTs.

The diffusion process is analyzed by means of a system dynamics simulation model and the study is focused on the Brazilian market. The products analyzed are the DVD (Digital Versatile Disc) player and the color TV set. The external factors acting on the diffusion model are divided into two categories: (i) a product offered to customers in a non-homogeneous marketplace, *i.e.*, with different potential markets; and (ii) a product offered to a market which is affected by changes in economic conditions or which has operational constraints related to the product commercialization, for example, difficulties in supplying the demand for a new product.

The two products were chosen by some particular reasons. The color TV set is a typical household equipment with a country-wide penetration in Brazil, and its sales rate is therefore sensitive to changes in the macroeconomic scenario. Besides, it allows a rich investigation by

---

[2] See, among others, (Gupta *el al*.,1999; Swami and Khairnar, 2003; Talukdar *et al.*, 2002).

[3] As already argued in (Menezes *et al*., 2005), other extensions considering unusual factors are presented by Bass *et alii* (1994), Mahajan *et alii* (1990) and Wright *et alii* (1997). This latter concerned with hi-tech products.

the fact of representing simultaneously a telecommunication (broadcasting) service – from the broadcasters' viewpoint – and a product – the TV set. On the other hand, despite being to a certain extent a new product, and consequently the available sales data correspond to the early phases of its commercial life cycle, the DVD player investigation provides information on the consumers' response in terms of microeconomic scenario, which may guide future analyses about the launch of products with similar characteristics.

It is worthwhile saying that this paper is not intended to make empirical generalizations either for other products or for other developing countries. As mentioned before, the purpose of the present analysis is only to shed some light on the Brazilian ICTs market in order to obtain a better understanding of the factors determining a product or service adoption. Nevertheless, other case studies are being carried out in order to extend these observations and knowledge to more comprehensive spheres of this market.

2 On the Method of Analysis

The analysis shown in this paper is based on the Bass model, which is enriched by the representation of external factors in order to better reflect the Brazilian market particularities, which are not completely revealed by conventional models. The parameterization process, simulation approach and data gathering process utilized for supporting the present analysis are described as follows.

2.1 The Bass diffusion model in short

The diffusion model proposed by Bass (1969) has been widely used to predict the adoption timing of new technologies. Similar to the logistic model, the adoption curve assumes an S-shaped pattern. However, to explain how the diffusion process leaves the initial equilibrium state, Bass introduced the idea of dividing the innovation adoption rate into two factors, one endogenous, usually called "imitation factor", and the other exogenous, commonly referred to as "innovation factor".

According to Bass, the probability of a person buying a product, by the first time and in a given period of time, is a linear equation of the amount of people that have bought the product. Such a condition results in the following relation:

$$(1)\quad n(t) = pm + [q - p]N(t) - \frac{q}{m}[N(t)]^2$$

where

p is the so called "coefficient of innovation", since it reflects the tendency to innovate without taking the interpersonal influence into account;

q is the so called "coefficient of imitation", since it considers the diffusion rate through the influence of adopters over non-adopters;

m is the total market;

$n(t)$ is the sales at time t;

$N(t)$ is the number of adopters by time t.

2.2 The parameterization process

The estimation of Bass model parameters (p, q and m) may be obtained by using empirical data and the equation (1) in a classical regression analysis procedure. This procedure leads to a good fit even if the diffusion process is not yet completed[4].

For different product diffusion processes, p and q are comparable only if the frequency (*e.g.* monthly, annually) of observed data is roughly the same. On the other hand, this condition does not hold for the parameter m, as it can be compared even if data are collected in different frequencies. However, the decision on whether gathering a more or less frequent observation lies on the main object of the analysis. A more frequent observation of certain diffusion allows a more reliable analysis on a micro environment[5]. As for less frequent observations, the analysis provides insights about general behavior on a macro environment basis.

2.3 Modeling and data collection

With the purpose of providing a better understanding about the factors that historically influenced the diffusion process, modeling resources were adopted in this analysis. The models can be used to investigate the effects of past events on the diffusion, as well as to test hypotheses for identifying key variables. This aspect is important in terms of understanding market trends for the diffusion of a particular product/service and for decision-making in complex environments.

The diffusion process is undoubtedly complex in nature, in which people need to be aware of the attributes of a given product or service. There are a number of interconnected factors acting on the consumers' cognitive process and affecting their attitude and decision rules to adopt the innovation. Besides, such interrelated factors are continuously changing with time and adaptations occur in function of consumer's learning, which, in turn, results from their experience and feedback in the social network. In this sense, linear and equilibrium models are not adequate to handle such an inherent complexity. In line with these concerns, some approaches based on system dynamics applied to the Bass model have been found in literature. Examples of such approaches applied to telecommunications products are presented in (Lyons *et al*., 1997; Park and Kim, 2000; Menezes *et al.*, 2005).

System dynamics was hence utilized in the present study as support for modeling and simulation. As known, system dynamics is a conceptual approach that enables to represent the structure and behavior of complex systems over time, providing a method for systems description as well as a useful computational support for simulation (Forrester, 1999) and (Sterman, 2000). The dynamic models thus constructed play a key role for testing the values obtained with the parameterization and comparing them with real data. Besides, the simulation allowed understanding the influence of external factor on the diffusion process analyzed herein.

The data survey for TV case study did consider the TV set sales combined with the number of homes with TV sets and with the total number of Brazilian homes, in order to formulate the TV penetration in Brazilian residences. By combining these data, it was also possible to exclude repeated purchases. For the DVD player survey, it was assumed that repeated purchases did not occurred, since it still is a product in the early phase of its life cycle.

---

[4] A good fit may be obtained when diffusion has reached the middle of the whole process, which is around the inflexion point of the curve.

[5] Although, it may also cause undesirable effects such as introducing random noise, which can adversely affect the parameterization.

3 Influence of External Factors on Diffusion Process

When a new product or service is launched, it is difficult to predict which external effects might influence the diffusion dynamics. Several factors impacting users' attitude and adoption decisions change over time, in such a way that driving forces for adopting innovations are changed as diffusion process evolves (Waarts *et al*. 2002). There are some events which may decrease the diffusion speed or even block it. This state of affairs is usually found in developing countries where the population is very sensitive to economic issues.

In these countries, the consumer behavior is more influenced by variables like interest rate, exchange rate, availability of credit and so on. In the eighties, Brazil suffered a deep economic recession. This period of time was strongly marked by high inflation, which contributed to the economic slowdown. Government's efforts were not enough to hold inflation down and to expand business. On the contrary, as Rigolon and Giambiagi (1999) remind, the economic policies of this period of time may have caused the inflation-growth, since the risks of new monetary rules were considered in the financial-economic evaluation. This conjuncture changed the consumption profile of the Brazilian population, which was forced to diminish their expenditures, mainly the acquisition of non-essential goods. The standard of living fell in comparison to previous decades[6].

In the mid-nineties, a new economic plan (called "Plano Real") was successful in reducing the Brazilian inflation rate, allowing a slightly enhancement in average incomes. Besides, at this time, credit lines became available and the consumer durables could be obtained in relatively smaller installments. As a consequence, the market experienced an increase in consumption, mainly from 1994 up to 1998. In 1999, a new economic crisis influenced the growth pace (Rigolon and Giambiagi (1999)) and the consumption fell down again influencing several sectors of the economy. Such an economic behavior influences the diffusion of products and services in different proportions. As a mean of comparison, the time series of the real variation of Brazilian and American GDPs are shown in Figure 1.

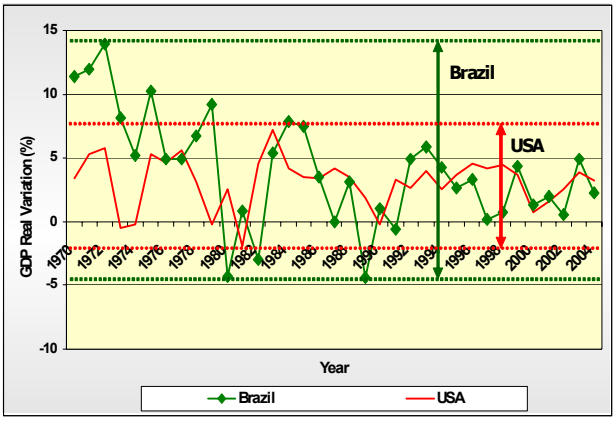

Figure 1. Percent Change from Preceding Period in Real GDP of Brazil and USA[7].

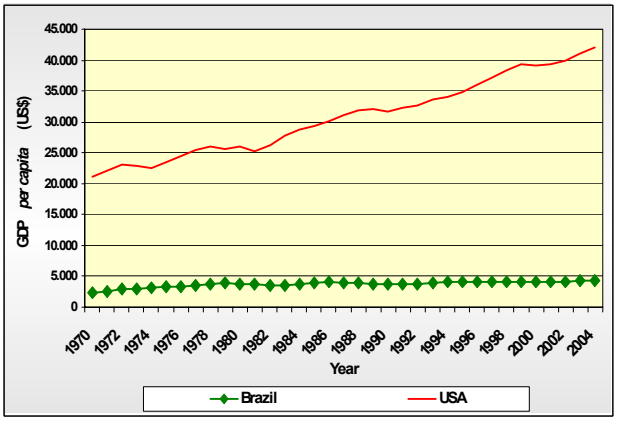

Figure 2. GDP *per capita*[8].

[6] An economic overview of the period is shown in Belluzzo and Coutinho (1998).

The American GDP deviation in three elapsing decades is smaller than the Brazilian one. The maximum range of variation in American real GDP was 9%, while in Brazil the maximum range was about 18%, reaching in some occasions to significantly negative values. The difference between the GDP *per capita* from these two countries is too high to not consider the minimum income for essential goods.

The GDP *per capita* of Brazil is too close to their consumption power of essential goods and any deviation of the GDP might influence the consumption profile differently from what occurs in developed countries, mainly in terms of ICT products and services. The time series of GDP *per capita* in both countries are shown in Figure 2.

Thus, it is important to consider the high sensitivity about the market behavior of developing countries, observing such deviations in economic activities. Since the majority of Brazilian population has an income barely enough to purchase essential goods, any deviation in economics scenario is fundamental for composing the potential market. The diffusion curve sensitivity to such factors depends also on the type of product or service being offered, especially on price levels and product attractiveness.

In a micro environment basis, another factor often observed in developing countries is the replanning of marketing strategies to reach a new target market. In Brazil, as in other developing countries, any deviation in price level may allow or prevent segments of the population from being potential users of a certain ICT product or service. Although this portion of the population has consumption potential in a given time, other external events, such as macroeconomic changes, may affect this new condition, diminishing the purchase possibilities and slowing down the diffusion process.

The population growth is another factor that may influence the diffusion process, mainly in countries with young population. If the product has a long period of diffusion and a large target market (*e.g.*, color TV set), the population growth may substantially affect the diffusion process. Indeed, m is no longer constant on time.

Generally, the influence of macro environment issues on diffusion behavior is only compensated by reactive actions. On the other hand, the analysis on a micro environment basis allows the decision maker to act proactively. In this sense, the next sections explore the modeling of the presented factors by modifying the pure Bass diffusion model.

4 Modeling External Factors

The external factors commented in the previous section do change significantly the traditional diffusion pattern for new products and services. If such factors occur during the diffusion process simulated with the parameters estimated by the Bass modeling, these outcomes may be completely different from what is observed with actual data. Then, it is necessary to include some modifications in the Bass model with the purpose of adjusting the curve simulated to describe the diffusion behavior observed[9].

The external factors discussed herein may be classified into two categories:

- Type I: the external factor affects the potential market.

---

[7] Source: IPEA - Institute of Applied Economic Research (Brazil) and BEA - Bureau of Economic Analysis (USA). Available, respectively, at: www.ipeadata.gov.br and www.bea.gov

[8] Source: IPEA and BEA, 2006.

[9] It is important to point out that, in this modeling, we assume that the introduction of the above external factors does not invalidate the Bass diffusion model.

- Type II: the external factor affects the product acquisition process.

The relationship diagram for the "modified" Bass diffusion model containing both categories of external factors is shown in Figure 3. This modified model has three new elements. The first one corresponds to an intermediate process between potential market and adopters[10], emerging a new category: the acceptors. The second adjustment takes into account the distinction between potential and target market, in such a way that users belonging to the potential market have not only a latent desire, but income for purchasing the product or service, while the others have the latent desire and no income for acquiring it. At last, the third adjustment introduces two access controllers, which regulate the number of users with and without income for purchasing.

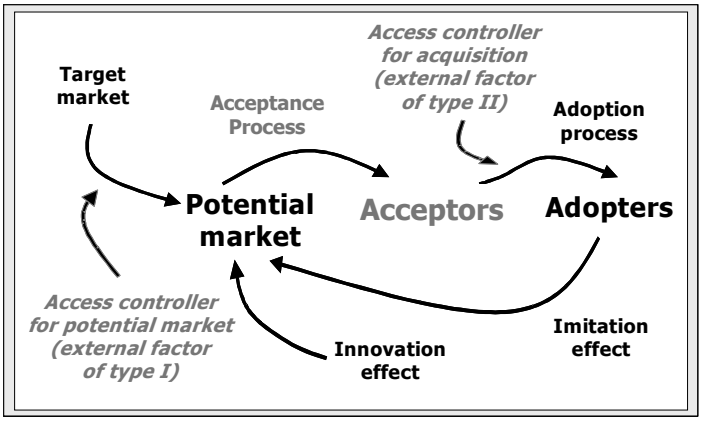

Figure 3. Relationship Diagram with External Factors.

The access controller related to the potential market enables a new segment of the target market to participate in the diffusion process if an external factor of type I occurs. Once the entrance is allowed, the potential user should not return to the target market, in such a way that this user will unavoidably acquire the innovation. The access acquisition controller avoids the purchase completion if some external factor of Type II occurs during the process.

4.1 External factor of Type I

When a product is launched, the number of potential adopters depends on two main issues: attractiveness and price. If the product is redesigned to fulfill new needs, with modifications in price or functionalities, it is possible to observe variation on the number of potential adopters as a function of the new perceived value. This situation is so identified as an external factor of Type I and its influence on diffusion process occurs by modifying the number of potential adopters (and, consequently, m).

Such changes in the micro environment lead to a rapid response on the consumer behavior. Consequently, the analysis should be based on a more frequent observation of the sales and on a short to mid-term approach, in such a manner that it is possible to foresee[11] the potential market that an ICT (product or service) may reach in a certain time.

One way of dealing with such issues and fitting the models to a more adequate diffusion behavior is to separate the analysis in *two* different diffusion models. The first part considers the sales accomplished from the launch of the product/service, given a micro environment scenario (*e.g.* price level, market image) of that period of time, up to the moment in which

[10] In accordance with Rogers' classification (Rogers, 1983).

[11] Here, the predicting purpose is more related to foresight than to a quantitative estimation. For details in foresight, see, for example, (Grupp and Linstone, 1999).

this scenario changes. The second part begins at the moment of this change. In markets highly sensitive to economic fluctuations, each reduction in the price level brings more potential adopters into play and, by means of the parameterization process outlined in Section 1, it is possible to determine the related values for p, q and m. It is important to remind that the current value of m reflects the eventual enlargement of the number of potential adopters, i.e., the market size related to a new price level is equal to the market size related to the previous price added by the new population enabled by the access controller as consequence of the external factor of Type I.

The population growth is another example of external factor of Type I, but in a macro environment basis. The gradual increase of the potential adopters transforms the total market size (m) in a time-dependent variable. In this situation, it is possible to suppose that the gradual growth of potential adopters (due to population growth) does not cause suddenly alteration on the diffusion pattern, since changes like these can only modify the consumption profile in long term and in a gradual manner. So, by dividing the diffusion process into small time intervals (as small as desirable), the modifications in each segment of the diffusion curve will not be perceived. As consequence, it is assumed that during all diffusion process the population growth does not alter the consumption behavior in terms of purchase decision. In other words, p and q are assumed constant during the diffusion process being modeled.

4.2 External factor of Type II

In this analysis, the influences of negative changes in the macroeconomic conditions over the diffusion behavior are considered as external factors of Type II, in a macro environment basis. As previously argued, in a market like the Brazilian one, the purchasing power is more susceptible to these factors due to the low average income of the population. Although the potential adopters have been convinced by the innovation idea, the acquisition process does not likely occur due to this economic barrier.

Similarly, the purchase desire for a new product or service may have been disseminated to some geographic areas where the required infrastructure is not available. Services as cable TV, broadband Internet and mobile telephony are typical examples in which such an infrastructure problem may be observed. In a micro environment basis, this problem represents another aspect of the external factor of Type II[12].

The Bass model assumes that the product or service will be deterministically acquired in a given time, *i.e.*, and consequently there are no factors affecting the purchase process. As before mentioned, such a fact is not a reasonable assumption for developing countries. In this sense, the present approach utilizes Bass model added by two elements with the objective of analyzing the influence of external factors of Type II on the diffusion process. The first element is an access controller that behaves as an inhibitor of the adoption process. The second element is an intermediate step before the adoption process. As depicted in Figure 3, this new step is named as acceptance process, in which the consumers of the potential market are submitted to typical influences of Bass process, *i.e.*, they know about the product or service and develop a purchase attitude. However, they contribute to retard the adoption process as consequence of the external factors of Type II.

When external factor of Type II is strongly present in a market it is worthwhile saying that the diffusion process exhibits significant distortions in the S-shaped pattern. In such cases, the

[12] Although, to some extent, it can be modeled as external factor of Type I. This would be the case if there was a narrow time between the launch and the availability of the service in the geographic area, due to the fact that the demand was not restrained for a long period of time.

parameterization, as described in Section 2, is not a viable option. Thus, the only way to model the diffusion process is to infer the parameters from comparing the similarity with other cases. This simulations and sensitivity analysis provide insights for strategic decisions, particularly concerning investment timing.

5 Case Studies

The approach on how to investigate these external factors was applied in two case studies of Brazilian consumer's purchasing behavior: the DVD player and the color TV set diffusion processes. The DVD player study clearly demonstrates the need of considering the change on potential market during the diffusion process. In the color TV set case, the continuous change in the target market (population growth) and, at the same time, the variations in economic conditions lead to a differentiated purchasing behavior.

5.1 DVD player

In Brazil, the DVD player diffusion process was initiated in 1999, in accordance to Eletros[13] database. Since then some changes have occurred in the price level and in the product features, what has gradually modified the value perceived by the consumers. Approximately 17 months (May 2000) after the DVD player launch, its price had fallen down by almost 50% of the initial value. According to market analysts, such a reduction was more due to strategic decision than to any evolution in the product learning curve.

When the price reached lower levels, the number of potential adopters started increasing. Probably, this external factor was the main factor motivating the faster diffusion speed observed in that period of time, together with the gradual rising in the attractiveness. This latter due to: technology improvement and a larger content offering (release of new DVD tittles).

In order to consider this external factor, the classical diffusion model was divided into two systems, corresponding to different time periods with monthly data. This mechanism allowed simulating an external factor of Type I. The first period of time considered for parameterization extends from the beginning of the diffusion process up to the 16th month (April 2000). After this period of time, the number of adopters is relocated in the second system and this information is used to calculate the new parameters, considering the subsequent data on the diffusion process[14].

The division into two data series facilitated the modeling process and allowed a visualization of the entire diffusion behavior during the period of analysis. The same historic data was used to carry out another assay, considering the pure Bass diffusion process, *i.e.* not taking into account the influences of this external factor on modeling. These two assays were compared in terms of goodness of fit[15] by means of a simple measure of distance between observed and expected data. The parameters (*p, q* and *m*) of each assay and for each part of diffusion curve in the second assay are shown in Table 1.

---

[13] Eletros – National Association of Manufacturers of Electro Electronics Products.

[14] This analysis considers a historic series up to 2002, due to the fact that, from that date on, the sales data are expressed in an annual basis.

[15] How well a model fits a set of observations. The least value has a better fit.

Table 1: DVD player parameters

Assay	*p*	*q*	*m*
Pure Bass	0.0012	0.112	2,810,000
Ext. Factor Type I			
Jan/99 – Apr/00	0.0086	0.202	67,000
May/00 – Sep/02	0.0025	0.090	4,520,000

The comparison between historical data and the outcomes of both diffusion models (with and without considering the external factor of Type I) are shown in Figure 4 for cumulative sales and sales per period, both related to DVD players.

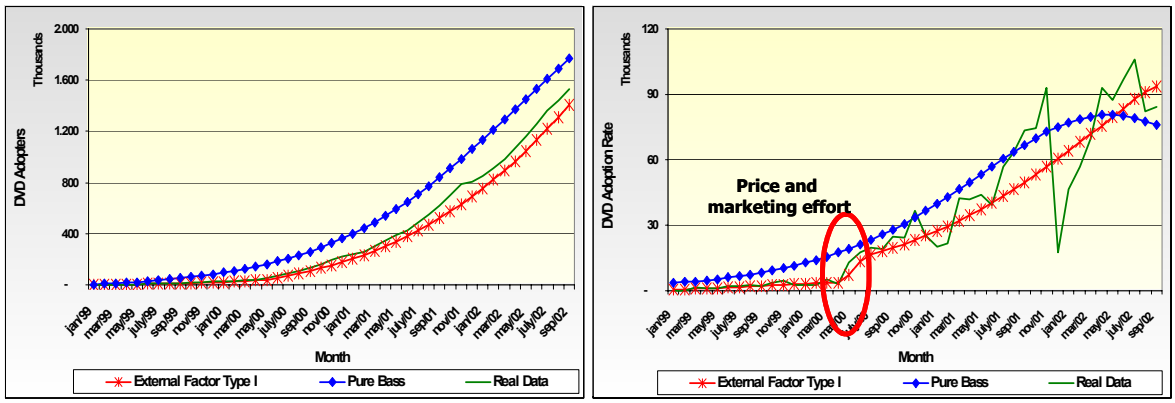

Figure 4. DVD Player Cumulative Sales and Sales per Period[16].

By polynomial regression, the parameterization using the pure Bass fits the data in an aggregate manner. Such an approach does not take into account the possibility of a certain event completely altering the prior behavior. Its measure of fit resulted in 81.8, while the assay that considers the external factor resulted in the value 13.9, therefore this latter assay better fits the real behavior. The process of dividing the data set into two periods allowed considering the new behavior that emerged from the change on price strategies.

5.2 Color TV set

In Brazil, the color TV sets started to be sold in 1973. Its diffusion process was slightly "compressed", mostly due to the economic conditions of the last 30 years. Around the eighties, as mentioned in Section 3, there was a recession period of time hindering the TV set purchases. By the middle of the nineties, with the perspective of growth return, there was the liberation of the demand that was restrained until that time, enhancing TV set sales. Another issue to be considered is the gradual inclusion of the households increasing along the last 30 years (about 150%[17]) as an external factor of Type I.

By overcoming modeling constraints, it was included a filter mechanism based on the following function of the real variation on Brazilian GDP[18]. This function considers the

[16] Source: Eletros. Available at: www.eletros.org.br

[17] Source: IBGE – Brazilian Institute of Geography and Statistics. Available at: www.ibge.gov.br

[18] This paper is not intended to search the real function that correlates the real demand behavior. It is intended to illustrate the best treatment for modeling each type of external factor. It is a huge simplification of the relationship between GDP and demand but the aim at this point is to understand and model only the behavior of the demand.

moving average (MA) related to the previous ten years of a given instant "t" in the time period of the analysis.

$$Filter(t) = \begin{cases} \dfrac{MA(10)\ of\ real\ Brazilian\ GDP\ variation\ (t)}{100}, & for\ 1973 \le t \le 1982 \\ \dfrac{0{,}7 * MA(10)\ of\ real\ Brazilian\ GDP\ variation\ (t)}{100}, & for\ 1983 \le t \le 1993 \\ \dfrac{MA(10)\ of\ real\ Brazilian\ GDP\ variation\ (t)}{100}, & for\ 1994 \le t \le 2004 \end{cases}$$

The external factor of Type II was included in this study by two different assays, seeking to illustrate the macroeconomic impacts on diffusion behavior. In one assay, the filter was arranged as an access controller for the potential market, similarly as done in the DVD case for the external factor of Type I, limiting the number of households that could become adopters. In the other assay, the controller was intercalated as an acceptance process (before the adoption process), as external factor of Type II. The relationship diagrams for both assays are illustrated in Figure 5. In addition, a pure Bass process was also simulated with the purpose of comparison.

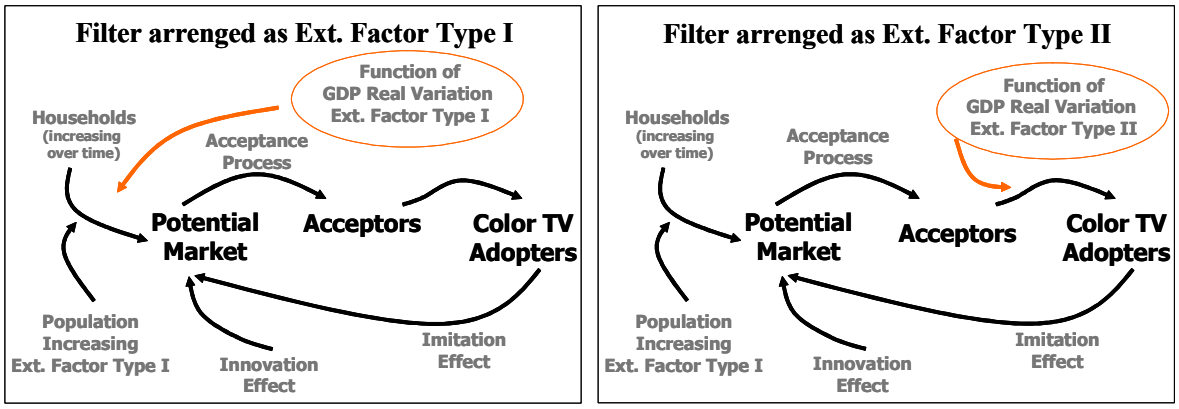

Figure 5. Relationship Diagram for the two color TV set assays.

In Brazil, the color TV set diffusion process was largely affected by external factors of Type II. Since the influences of these factors over the diffusion pattern are not entirely known, the parameterization by means of regression (as mentioned in Section 2) is consequently a complex issue. In order to overcome such a constraint, the parameters used as a basis for evaluating such effects were obtained by combining the *p* and *q* values found by Talukdar *et alii* (2002) for developing countries, and the values obtained from the parameterization of the black and white TV set diffusion process in Brazil[19], as shown in Table 2. The total market (*m*) is assumed to be the number of Brazilian households.

Table 2: Color TV set parameters

Assay	*p*	*q*
Talukdar *et alii* (2002)	0.0003	0.550
B&W TV set	0.0210	0.157
Color TV set	0.0110	0.350

[19] Source: CPqD analysis.

The simulation outcomes for both assays and pure Bass diffusion process are shown in Figure 6.

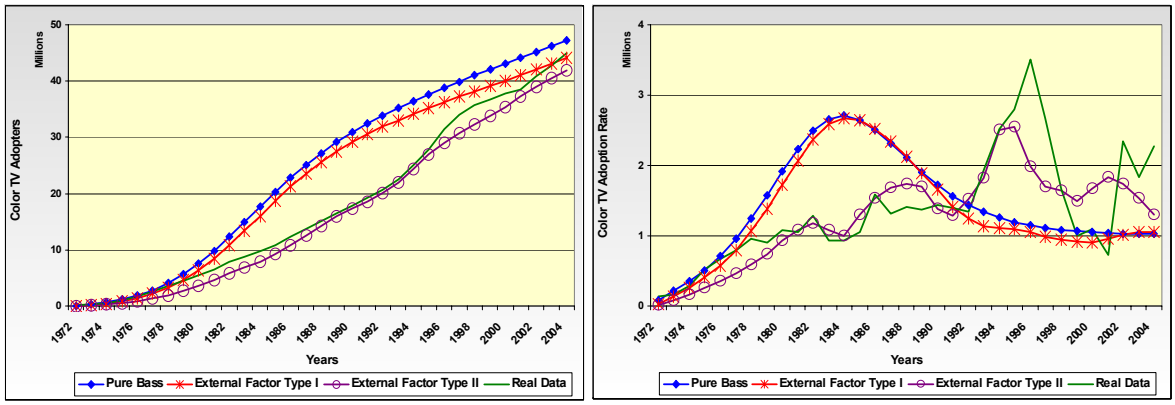

Figure 6. Accumulated Sales and Sales per Period of Color TV set[20].

The adjustments in the Type I assay and in the pure Bass process did not properly represent the external influence on the curve behavior as shown in Figure 6. The dynamics of Bass model is responsible for that, since any disturbances in economic conditions taking place after an individual being included in the potential market will not prevent the purchase completion in a certain time. The measure of fit in the pure Bass process and in the Type I assay resulted in 17.7 and 16.7, respectively. Although there is a slight difference between these values, it is not enough to consider it remarkable.

In the Type II assay the disturbances were simulated along the process when economic barriers emerged. In this case, the controller hindered some individuals (in the acceptance process) from accomplishing the purchase. The measure of fit in this case resulted in 8.9, which is approximately 50% of the pure Bass process and therefore more suitable for the present analysis. This approach tends to be more realistic and it is very useful in developing countries where any alteration in economics may interfere in the natural diffusion process of ICT products and services because of the general low income of their inhabitants. The mechanism for handling macroeconomic barriers as an external factor of Type II was more suitable in qualitatively representing the purchase behavior, as discussed in the following conclusions.

6 Discussions and Conclusion

The present study makes clear the importance of analyzing products or services under multiple perspectives in order to learn about the real introduction of an innovation in the market, relegating the ideal diffusion process to a secondary role. The economic characteristics observed in a country like Brazil significantly affect the nominal diffusion behavior. Such aspects complicate the parameterization based on Bass equations, since the parameters so obtained do not properly describe the purchase behavior over time. Not considering such influences in the modeling process may lead to inaccurate information about the diffusion speed and market penetration.

The *ex post* analyses carried out in the two case studies show the high influence of the external factor on the diffusion process, in such a way that it must be considered in *ex ante*

[20] Source: IBGE, Gazeta Mercantil: Panorama Setorial, Eletros and ABINEE – Brazilian Electrical and Electronics Industry Association.

analyses in order to provide more reliable outcomes. On the other side, the difficulty of foreseeing these factors adds a new point of discussion: the efficiency of forecasting techniques for quantifying the diffusion parameters. This difficulty is easily perceived when the external factor is of macroeconomic nature, characterizing an uncontrollable variable for analysts and decision makers. In such a case, forecasting approaches may be more effective in enhancing the predictability related to the innovation diffusion.

The influence of the economic conjuncture on the diffusion process was illustrated by the color TV set study. The building of macroeconomic scenarios and the system dynamics simulation provided useful information for identifying bottleneck areas in the diffusion behavior. The analysis carried out showed that the Brazilian GDP variation had influence on the TV set purchases. By including the external factor of Type II in the diffusion modeling, it is possible to acquire a better understanding on the relationship between macroeconomic scenarios, consumption behavior and diffusion process. However, it is necessary to have in mind that each product has an inherent set of values, which determines its attractiveness to the people. Besides, the consumer behavior changes over time, imposing limits on the quantitative results obtained for the relationship between economic conjuncture and consumption behavior. Consequently, one should consider more the general trends and patterns than the numbers *per se*.

The external factor of Type II was highlighted by the color TV set modeling. The effects of such a factor are observed on the diffusion behavior, which assumes an atypical S-shaped pattern. The inclusion of modifications in the Bass model, *i.e*., the acceptance process as an intermediate step in the diffusion modeling (before the purchase step) and access controller (acting as an inhibitor of the purchase completion), was essential in terms of fitting the simulation data to real diffusion.

The DVD player study confirmed that the low price strategy contributed to a significant increase in market size, what is quite natural. Initially the estimated market was 70 times smaller, since only the highest socio-economic groups were able to purchase it. Taking into account that the average income in Brazil is very low, which is normally allocated to basic needs, it is possible to observe how these markets are highly sensitive to price.

Yet, the DVD player modeling showed interesting results by analyzing the external factor of Type I, including an access controller that enabled the entry of a new segment into the potential market. The results were particularly interesting by showing effective manners of evaluating changes in market size and by revealing the behavior that emerges from the disturbance in the *status quo*.

Concerning the methodological approach proposed and discussed in this paper, we can briefly conclude as follows. The Bass model was extended in order to encompass two types of external factors. The results obtained with this procedure shown two main benefits: (i) the extended model provides a better fit for some ICT diffusion behavior in Brazil and consequently acquiring knowledge on its history (*ex post* analysis), and (ii) a more realistic parameterization whose p and q thus obtained may be used in *ex ante* analyzes for similar products. When this parameterization is not possible, due to lack of data, an alternative is to consider metrics from other markets, which, despite being not subject to the same external factors have higher maturity. However, the use of the parameters so obtained should be followed by a sensitive analysis in order to identify the outcome variations.

Another general remarkable aspect is concerned with the fact that, differently from developed countries, in Brazil the bottleneck point in diffusion process, at least for the products analyzed herein, is less related to attractiveness than to purchasing power. In function of the average income being limited for a considerable part of the population, the diffusion speed of an

innovation is very slow and, in the absence of a price policy for new groups of consumers, it may result in a stagnated process due to the market saturation. As consequence, it is reasonable to suppose that each socio-economic segment has a microstructure in accordance with Rogers' classification (1983), but with their own parameters (diffusion speed, for instance). However, here there is a point that requires additional studies in order to validate to what accuracy the Bass model may be extended and reproduced in different periods of time. For that, it would be necessary to stress the mathematical analysis and take a broader statistical basis into account, including data from other ICT products and services.

As a final remark, this analysis led to an in-depth investigation of historic events that shaped the scenario of the color TV set and DVD player diffusion in Brazil. In a broad sense, such an investigation contributed to a better understanding of some particularities of the Brazilian market, specifically on the manner it reacts to external factors and how an innovation may be spread in this market. All the acquired experience can be used for planning new ICTs (either products or services) in accordance with the needs and interests of all agents involved in an initiative of this nature.

References

Bass, F. M. A new product growth model for consumer durables. *Management Science*, 15, p. 215-227, 1969.

Bass, F. M., Krishnan, T., and Jain, D. Why the Bass Model Fits Without Decision Variables?. *Marketing Science*, 13 (Summer), p. 203-223, 1994.

Belluzo, L. G. M. and Coutinho, R. *Capitalist Development in Brazil.* (in Portuguese). Instituto de Economia da Unicamp, 1998.

Forrester, J. The Beginning of System Dynamics, 1989. Available at: <http://sysdyn.clexchange.org/sdep/papers/D-4165-1.pdf>. Accessed on 28 August 2006.

Grupp, H., Linstone, H.A. National Technology Foresight Activities Around the Globe: Resurrection and new paradigms. *Technological Forecasting and Social Change*, 60, p. 85-94, 1999.

Gupta, S., Jain, D. C., and Sawhney, M. S. Modeling the Evolution of Markets with Indirect Network Externalities: An Application to Digital Television. *Marketing Science*,18 (3), p.396-416, 1999.

Lucky, R. W. New Communications Services – What Does Society Want? *Proc. of the IEEE*, 85 (10), p. 1536-1543, 1997.

Lyons, M. H. *et alii* Dynamic Modeling of Present and Future Service Demand. *Proc of the IEEE* 85 (10), p. 1544-1555, 1997.

Mahajan, S., Muller, E., and Bass, F. M. New Product Diffusion Models in Marketing: A Review and Directions for Research. *Journal of Marketing*, 54, p. 1-26, 1990.

Menezes, E., Ogushi, C.M., Bonadia, G.C., Dall'Antonia, J.C., Holanda, G.M.,. Socioeconomic Factors Influencing Digital TV Diffusion in Brazil. *Proc. 23rd International Conference of the System Dynamics Society*, Boston, 2005.

Park, K. and Kim, B. Dynamic Competition in the Industry with Rapid Technological Change and High Network Externality. *Proc. Informs & Korms*, Korea, p. 266-272, 2000.

Rigolon, F. J. Z., and Giambiagi, F. The Brazilian Economy: General Panorama. (in Portuguese). BNDES,1999. Available on www.bndes.gov.br/conhecimento

Rogers, E. M. *Diffusion of Innovations*. The Free Press, 1983.

Sterman, J. D. *Business Dynamics – Systems Thinking and Modeling for a Complex World*. McGraw Hill, 2000.

Swami, S., and Khairnar, P. J. Diffusion of Products with Limited Supply and Known Expiration Date. *Marketing Letters*, 14 (1), p. 33-46, 2003.

Talukdar, D., Sudhir, K., and Ainslie, A. Investigating New Product Diffusion Across Products and Countries. *Marketing Science*, 21 (1), p. 97-114, 2002.

Van den Bulte, C. New Product Diffusion Acceleration: Measurement and Analysis. *Marketing Science*,19 (4), p. 366-380, 2000.

Waarts, E., Van Everdingen, Y. M., and Van Hillegersberg, J. The Dynamics of Factors Affecting the Adoption of Innovations. *The Journal of Product Innovation Management*, 19, p. 412-423, 2002.

Wright, M., Upritchard, C. and Lewis, T. A Validation of the Bass New Product Diffusion Model in New Zealand. *Marketing Bulletin*, 8, p. 15-29, 1997.

Zabkar, V. and Zuzel, B. Bass New Product Diffusion Model: Estimation and Findings. In: *Development in Statistics,* Mrvar, A. and Ferligoj, A. (eds.). Metdoloski zvezki, 17, Ljubljana FDV, 2002.