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"The influence of company's and public policies over the diffusion of an innovation: the case of the 3d printer in the US"

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"*Success doesn't necessarily come from breakthrough innovation but from flawless execution. A great strategy alone won't win a game or a battle; the win comes from basic blocking and tackling*." -Naveen Jain

The words of the Moon Express CEO may sounds out of context as the incipit of a marketing research like this one, but they are indeed relevant in their deepest meaning. What the American entrepreneur is trying to say is that no matter how good our innovation is or how much we have studied for its according marketing plan, if we are not willing to implement the key actions needed by the new product or service in order to succeed, eventually we are doomed to fail. The managers of ground breaking innovation companies face an imprevedible and shiftable market, which is greatly influenced by the decisions made by several other players, besides the companies' costumers. In order to react proactively to the effect of the actions undertaken by private and public actors, managers should evaluate the impact of those acts over the diffusion of the company's innovation. To do that, marketing managers must widen the scope of their analysis, including factors and market key players that, at the first glance, may seem not relevant to the sales level the company desires. Furthermore, the company management has to be prepared to act and react appropriately, in order to create the best environment for the company innovation to prosper. This research would look into the nature of these elements and market protagonists, seeking the dimension of their impct on the innovation adoption and trying to suggest the managerial implications of the discovery. For this purpose, we will adopt the Bass diffusion model as the academic framework within the boundaries of a multiple regression model and we would use the 3d printer in the US market as the case study.

Chapter 1, Introduction

1.1 Statement of the problem

The exstensive study and the broad attention paid by the marketing academic world to the diffusion processes and models come to no surprise for a watchful eye. Since they provide numbers about the volume and the time framework of the innovation forecasted sales, these researches hand over excellent results and useful tools for understanding the innovation market dynamics in order to allow companies' management to act and react proactively. From the breakthrough work of Rogers and the first formulation of the avant-garde Bass model, researchers and lecturers have striven hard to reshape and refine the basic models through the estimation of the coefficients and the addition of the marketing mix variables. However, these further adjustments have come with some not be entirely negligible costs: first of all, the simplicity of the basic formulation is lost (Golder and Tellis, 1998) and part of the accuracy has been sacrified to a greater amount of parameters (Mahajan and Muller, 1990); furthermore, besides the work of some autors who looked for the influence of economic (Kalish, 1985; Roberts and Urban, 1988) and socio-economic factors (Wareham, Levy and Shi, 2004), little attention has been paid to the impact of the actions of the many stakeholders and institutions present in the framework market on the innovation's diffusions, as well as the effects of social and psychological attitudes of the population not included in the standard Bass model parameters. This study would try to fix this problem.

1.2 Purpose of the study

The aim of this research is to demonstrate the importance and the relevance of the effects that the corporate and public policies have over the diffusion of an innovation within a reference market. For now, we will define the concept of "corporate and public policies" as the set of public and private actors, being them tangible or intangible and unrelated to the marketing mix variables, that influences the adoption or the rejection of an innovation by the selected target. Later on this paper, we will identify the components of the aforementioned policies, we will investigate the consequences and the leverage they have towards the diffusion of the innovation and we will contextualize them in the case of the diffusion of the 3d printer innovation in the United States market.

1.3 Significance of the study

The value of this study relies in providing a tool, an expanded analys, a deep insight, to the management of radical innovations companies, making them able to understand the dynamics beneath the diffusion of their innovative product, letting them grasp the agents that ease the reception or foster the rejection of the innovation. These findings would help the executives in implementing better strategies regarding the timing and the main lines of promotional activities, the eventual lobbying actions needed, the contingent legal responses and the possible istitutional and/or academic innovation's validation required by the innovation to prosper. Moreover, this study would lay the foundations of a new branch of the diffusion field of analysis, combining social and economic insights with advanced statistical tools.

The work will be divided in two parts. In the first part, we will acknowledge the elements of a diffusion process, we will provide an insight of the diffusion theory and we will analyze the innovation chosen for the research purpose. Then, we will proceed by presenting the research model structure and its components, along with the the hypothesis we are going to test. In the second part, we are going to develop the research model by collecting the data needed for the estimation of its parameters. After that, we will implement the model and we will test it with several statistical tools. In the end, we will draw the conclusions of our hypothesis from the outcomes of the model.

First Part

Chapter 2 Literature review and innovation analysis

2.1 Introduction

Before dealing with the core topic of this research, the reader will discover the academic definition of “innovation”, the features that distinguish it, the ways it can be classified and the intrinsic factors that affects the speed of its acception. Moreover, we will make a digression through the origin and the development of the diffusion field of study and we will highlight the main fundamentals and the key components of the diffusion process, while underlyning the central theme during the temporal continuum of these studies. Furthermore, we would present the 3d printer as the chosen innovation for the purpose of this study, giving an overview of the present and future use of this new technology in several industries. Moreover, we will present the 3d printer market in the United States over the period chosen for the research purpose, and we will define the 3d printer perceived attributes of innovation.

2.2. Innovation definition

Using the words of E. M. Rogers, one of the fathers of innovation’s diffusion studies, an innovation is “an idea, a practice, or an object that is perceived as new by an individual or by other unit of adoption”[1]. That being said, the characteristics of an innovation determine the speed at which it will be adopted by the recepient network, the so called *rate of adoption*. These characteristics are:

- *Relative advantage*: the relative advantage that the adopter may receive from owning or using the innovation

[1] E. M. Rogers, “Diffusion of preventive innovations”, Addictive Behaviors 27 (2002) 989–993

is the degree to which it is perceived as better than the product or service it supersedes. This “advantage” may come in the form of a cheaper price, as a social prestige or as a higher level of satisfaction of use. However, it is important to underline that it doesn’t really matter if there is an *objective* advantage from the adoption of the innovation, as long as “an individual perceives the innovation as advantageous. The greater the perceived relative advantage of an innovation, the more rapid its rate of adoption.”[2]

- *Compatibility*: this is the grade to which an innovation is recognized as being persistent with the existing set of values, the previous experiences and the demands of the potential adopters. If the adoption of the innovation requires a change of the old value system, the rate of adoption would be affected negatively and process would take more time;
- *Complexity*: complexity is the degree to which an innovation is seen as difficult to understand and/or use. Innovations that are more difficult to understand would slow the rate of adoption since the new adopters have to develop new skills and patterns of use;
- *Trialability*: this feature describes the accessibility of the innovation for a trial *before* the actual adoption. This charateristic is also called *divisibility*. Innovations that can be experienced before the adoption mean less uncertainty to the people who are thinking about adopting it, speeding up the rate of adoption;
- *Observability*: observability measures the extent to which the benefits of the adoption of an innovation can

[2] E. M. Rogers, “The Diffusion of Innovation”, 4th edn. Free Press, New York (1995)

be seen from the ones that haven't adopted the innovation yet. If it's easy to see the advantages brought by the adoption, individuals would be more likely to engage in it. Observability plays a huge role in peer-to-peer communications, since friends and/or colleagues of the potential adopter could provide evaluations and informations about the innovation;

Other factors that might affect the rate of adoption of an innovation are linked to the other components of the diffusion process. We will deal with them later on this chapter.

2.3 Classifications of Innovation

Even though the concept of innovation is quite basic, something that has a new features, a novelty element from what existed before, it can be distinguished through various categories. Many academics and researchers have been studied these typologies in order to understand the development of innovation, their impact and their sources (Chandy and Prabhu, 2003). Hereafter, the reader will find a brief description of innovation types, along with some useful examples.

A *product* or a *service innovation* concerns the commercial introduction of a product/service that is completely new to the recipient costumers (Schumpeter, 1934).

A *technological breakthrough* is an innovation, may it be a product, a service or a process, which relies upon scientific principles that are deeply different from the ones used for the existing products, services or processes.

A *component innovation* is an innovation which differs from existing products or services because it uses new parts, models or materials but involves “the same core technology as existing products, services, or processes”[3].

An *architectural innovation* or *design innovation* is related to the reconfiguration of the connections and layout of components, but works on the same core technology as existing products, services, or processes (Christensen, 1993).

A *business model innovation* revolves around several systemic changes to the value proposition offered by a company through its entire firrm. Those changes affect all the elements of the marketing mix variables and they have also an impact on the cost structure of the firm undergoing such innovation (Velu, Prabhu and Chandy, 2009). Amazon is regarded as one of the biggest business model innovation of the last twenty years.

A *drastic innovation* is one that makes current products out-of-date. For example, compact disc for pc’s use made the floppy disc obsolete.

An innovation that is a *market breakthrough* increases considerably the marginal utility per dollar of the consumers than the existing products, services, or processes. Nevertheless, it is based on the same core technology as already existing products, services, or processes (Chandy and Tellis 1998).

A *disruptive innovation* (Govindarajan and Kopalle 2006, Christensen 1997) offers a different combination of characteristics, performance, and price relative to products already present in the market, but it is perceived as an unattractive set by the mainstream customers at the time of the

[3] Sood, Ashish and Gerard J. Tellis (2005), “Technological Evolution and Radical Innovations,” Journal of Marketing, 69, 3 (July), 152-168

innovation introduction because of the lower performance on the attributes these customers value. At the same time, the innovation may attract a small group of costumers, creating a niche market. Further developments of the innovation, however, might increment the new product's attributes to a level sufficient to satisfy mainstream customers, hence attracting more of the mainstream market.

A *discontinuous innovation* is one that requires customers to establish different behaviour patterns (Robertson 1967). It changes the current patterns of use or it creates new ones. Typewriters (Chandy and Prabhu, 2010) were discontinuous innovations, since they changed longstanding standards of use among customers.

2.4 Elements of the diffusion process

"Diffusion is the process by which an innovation is communicated through certain channels over time among the members of a social system"[4]. Diffusion is a special kind of communication that deals with the spread of messages that are perceived as new by the recipients. Communication is a process in which participants create and share information with one another in order to achieve a mutual understanding. Diffusion has a special feature because of the novelty of the idea in the message content. Thus some degree of uncertainty and perceived risk is involved in the diffusion process. The main elements in the diffusion of new ideas are: an innovation, whatever kind of communication channels, a period of time and a social system. We have already took care of the definition and the features of an innovation, so from now on we will deal with

[4] E. M. Rogers, "Diffusion of Innovations" Fourth Edition, New York: The Free Press, 1995

the explanation and the formalization of the other components of the diffusion process.

A *communication channel* is the mean through which messages flow from one individual to another. Mass media channels are more efficient in creating and trasmitting knowledge of innovations, while interpersonal channels are more effective in forming and changing the point of view of an individual toward a new idea, and thus in influencing the decision to adopt or reject an innovation. Most individuals judge an innovation not on the basis of scientific research made by experts but through the subjective evaluations of near peers (they can be friends, coworkers, relatives and acquaintances) who have already adopted the innovation.

These *near peers* (Rogers, 2003) hence serve as a role model, whose experimental behavior tends to be emulated by others in their system. In the case of a channel communication held by peers, a huge role is played by the word of mouth communication: the psychological and cultural bias, that are innate in a person to person exchange, have massive implications for the marketing activities needed for creating a positive environment for the diffusion of the innovation.

Within the framework of the diffusion process, the *period of time* affects the spread of an innovation through the *innovation decision process*. This process is the path that a *decision making unit* (Rogers, 2001) takes once it gets in contact with the innovation for the first time. We will now present the steps of the process:

Knowledge – In this phase, the decision making unit has the first contact with the innovation;
Persuasion – During this time, the individual forms an attitude towards the innovation;

Decision – At this point, the person chooses to adopt or reject the innovation;
Implementation – this stage deals with the actions needed to carry out the choice made in the previous step;
Confirmation – the final part of the decision process involves the action that the agent is going to undertake after the implementation of its decision and the attitude that they will develop towards the innovation;

All the stages combinied have consequences on the innovation rate of adoption.

A *social system* is "a set of interrelated units that are engaged in joint problem solving to accomplish a common goal"[5]. The social and communication infracstructures of a system ease or impede the diffusion of innovations in the system itself. We can differentiate among three main types of innovation-decisions that could take place within a social system:

1. *optional innovation decisions*, which are the choices to adopt or reject an innovation that are made by an individual irrespective of the decisions of other members of the system;
2. *collective innovation-decisions,* choices to adopt or reject an innovation that are made by the general agreement of the members of a system;
3. *authority innovation-decisions*, those are the decisions to adopt or reject an innovation that are took by relatively

[5] E. M. Rogers, "*Evolution: Diffusion of Innovations*". International Encyclopedia of the Social & Behavioral Sciences. Elsevier Science ltd, 2001

few individuals in a system who possess power, a high social status, or technical expertise;

A final way through which a social system influences the diffusion of an innovation deals with the consequences that occur to a person or a social system as a result of the adoption or rejection of an innovation.

2.5 Literature review

This part of the study will serve as a quick escursus over the origins and the developments of the diffusion literature, in order to make the reader conscious of the collocation of this study within its reference academic field.

2.5.1 The origin of the diffusion research: the Iowa corn study by Ryan and Gross

The starting point of the whole theory of diffusion is, without any doubt, the socio-anthropological study carried out by Ryan and Gross among the Iowa farmers regarding the adoption of a new type of hybrid corn seed during the thirties.

Hybrid corn was one of the most important new agricultural technologies of the first half of the Twentieth century. The seeds were developed by agricultural scientists at the Iowa State University and they provided an increase harvest of about 20 percent per acre over the previous kind of seeds.

The importance of this study concerns the fact that they laid the foundations od the *customary researche methodology*, which it resulted to be the most used approach by the diffusion researchers. It consists of interviewing the adopters of an innovation and questioning them about the timing of the adoption, the sources of their first contact with the innovation and the aftermaths of adopting it. Moreover, the questions included all of the four principal elements of diffusion, as said before: innovation, communication channels, time, and social system. Additionally, the two rural sociologists also questioned the farmers about their formal education, their age, the farms size, their income, the frequency of which they travelled to the nearby cities, their readership of farm magazines, and “other variables that were later correlated with innovativeness”.[6] The adoption of hybrid corn meant that the individual had to undertake significant changes in his corn-growing practice, making the hybrid corn one of the earliest and most intesive study on a discontinuous innovation.

The sample interviewed by Ryan and Gross was made up by 345 farmers. However, in order to have a consistent time framework of the adoption, the data analysis was based only on 259 respondents. Once all of the data were collected, the two researchers coded the farmers' interview responses into numbers (Rogers, 2003). When those numbers were plotted as an aggregate on a year-by-year basis, the adoption rate formed an S shaped curve over time. Fast forward in the diffusion literature’s evolution, E. M. Rogers will classify the innovation adopters according to the time they embrace the innovation. We will discuss these categories later on this paper.

Through the analysis of the study’s outcomes, Ryan and Gross understood that hybrid corn had spread in the Iowa communities thanks to social relations and interactions, "There is no doubt but that the behavior of one individual in an interacting population affects the behavior of his fellows. Thus, the demonstrated success of hybrid seed on a few farms offers

[6] E. M. Rogers, “The Diffusion of Innovations”, The Free Press, New York, Fifth Edition, 31-35, 273 (2003)

new stimulus to the remaining ones."[7]. They grasped that the core of the diffusion process consists of "interpersonal network exchanges"[8] and the influence that the ones who have already adopted an innovation have on those who haven't yet.

2.5.2 The E. M. Rogers' contribution to the innovation diffusion theory

With the first edition of "Diffusion of Innovations" in 1962, Rogers became one of the founding fathers of the innovation diffusion field of study. Beside the crucial definition of a diffusion process, which is the one that is now universally adopted by the academic world and aforementioned in this paper, one of his main contributions to this sector was the description of the concept of *innovativeness*, which is "the degree to which an individual or other unit of adoption is relatively earlier in adopting new ideas than other members of a social system"[9]. Applying this reasoning to the gathered outcomes of the spread of an innovation, Rogers classified the adopters of an innovation on the time of the adoption. Using the Bell curve draw on the gaussian function related to the data of the adoption of the innovation, Rogers split the adopters in five categories:

1. *Innovators* - These are the first 2.5 percent of the individuals in a system to adopt an innovation. Among these categories, innovators are the most risk loving ones. In order to be an innovator, an individual must have the financial resources needed to counterbalance the eventual negative outcomes of the innovation. Moreover, they must be able to understand and

[7] Ryan, B. & Gross, N. (1943). The diffusion of hybrid seed corn in two Iowa communities. *Rural Sociology*, 8, 15–24.
[8] E. M. Rogers, "The Diffusion of Innovations", The Free Press, New York, Fifth Edition, 31-35, 273 (2003)
[9] E. M. Rogers, "*Diffusion of innovations",* New York: Free Press, 1962

implement the technical knowledge the innovation may need. Furthermore, the innovator have to find a way to cooperate with the high uncertainty level associated with the early stage of an innovation life-cycle. Within his/her system, the innovator plays the essential gatekeeping role (Rogers, 1962) in the diffusion process: they allow the flow of the new idea within the boundaries of their network.

2. *Early adopters* - These are the next 13.5 percent of the individuals in a system to adopt an innovation. According to Rogers' work, this adopters' category has the greatest degree of opinion leadership within their reference systems. They are the one sought by the potential adopters in order to get advice and information about the innovation. They are less risk loving than innovators and they serve as role model for the other individuals in the social system. The early adopter conveys his/her subjective evaluation of the innovation to near-peers through personal relationships.
3. *Early majority* - This is the next 34 percent of the individuals in a system to adopt an innovation. The early majority is just one step ahead of the average member of a system in the diffusion innovation process. Those individuals are psychologically more prone to follow than to lead. In the diffusion process, they provide the link among the system's interpersonal networks.
4. *Late majority* – They embody the next 34 percent of the individuals in a system to adopt an innovation. Some of the late majority individual adopt the innovation due to the "increasing network pressures from peers."[10] They

[10] E. M. Rogers, "*Diffusion of innovations*". New York: Free Press, 1962

are risk adverse and they need the system norms have to favor the adoption in order to do so.

5. *Laggards* - These are the last 16 percent of the individuals in a system to adopt an innovation. Many of laggards are isolates in the social networks of their system. They are change adverse and they must have the certainty that the innovation would not fail before even think they can adopt it.

These categories are useful for the marketing managers of innovation companies because they help them to better target and refine their audience and the innovation promotional activities.

Later on his works, Rogers stressed the importance of the opinion leaders, while theorising a basic two-step flow model of mass communication. This simple model suggests that communication messages flow from a source through mass media channels to opinion leaders, who pass them on to their followers (Rogers 1995). The model focuses attention on the "inter-media interface"[11] that takes form between mass media channels and interpersonal communication channels. The former are the main creators of *awareness-knowledge* of innovations, whereas the latter are crucial in persuading individuals to adopt or reject innovations.

[11] E. M. Rogers, "Evolution: Diffusion of Innovations", International Encyclopedia of the Social & Behavioral Sciences, Elsevier Science Ltd, 2001

2.5.3.1 Evolution and development of Innovation Diffusion Models

Hereafter we will present some of the most meaningful models formulated in the academic field of the diffusion of innovations. We will exclude our referential model, the Bass Diffusion one, from this review in order to give it the proper attention later on this paper.

2.5.3.2 The agent-based model

The agent-based model differentiates from the other kinds of diffusion models because of the unit of study is the individual or the agent, instead of the population. The definitions of these individual units may be related to theory concepts, such as innovativeness or satisfaction, or be based upon agent’s attributes like psychodemographics or upon the product characteristics. The ability to define multiple agent types representing units with different roles in the system allows system heterogeneity to be taken into account in the model. This hetegogeneity reflects on the different probabilities that the potential adopters have to actually engange on the innovation.

2.5.3.3 Inter-firms diffusion model

Among the academic studies of innovation diffusion, the inter-firms diffusion process looks at the pattern of the innovation spreading among firms within an industry. The aim of these models is to investigate the timing and the factors leading to the adoption for the first time of at least one unit of an innovation by an individual firm.

The pattern of diffusion across firms is usually measured by the cumulative number of users over time. In statistical terms, the graphical representation of the cumulative density function forms growth curve, the growth tends to be slow in the early years of the innovation introduction, then it experiences a rapid increase up to the inflection point, after which the growth speed decreases till the reaching of the saturation point. Such kind of models is often referred as "epidemic model", because of the similarity with the diffusion of a disease. Epidemic models state that the growth rate of the innovation spread among the firms is proportional to the probability of being in contact with the innovation, the proportion of effective contact and the proportion of the units that have already adopted the innovation.

Mansfield (1963) states that within the boundaries of the epidemic model, the main cause that deters potential users from adopting the innovation is uncertainty and lack of information about it. However, as more firms adopt the innovation, the likelihood of contact increases and with it the chance to receive information about the innovation, reducing the uncertainty surrounding it. Hence, by assuming that what drives this diffusion process is primarily information acquisition, Mansfield derives the logistic cumulative density function for the number of users over time:

$$St = \frac{1}{1 + exp - (\alpha + \beta t)}$$

St indicates the proportion of adopters that increases over time following a growth curve where: the numerator is the saturation point, which is assumed to be equal to 100%, α is the date of the beginning of the diffusion process and β is the speed through which the innovation is spreading across firms. Mansfield further assumes tha the intensity of β is determined by certain firm's features such as the profitability of the innovation adoption, the size of the investment needed to adopt it and the number of the current firms that are using it.

2.5.3.4 Probit models

Probit models analyse individual choice regarding adoption decisions. Following the logic behind these models, the reason why some people become adopters, while others doesn't partecipate in the spreading of the innovation, has to be sought in the fact that those individuals differ in some characteristic, let's called it X, which affects the profitability of adopting the innovation. In particular, they will adopt the innovation if X exceeds some threshold level, Ux, and individuals wil present different Ux. Traslating the probit model in a inter-firms contest, Davies (1979) argues that a firm will choose to adopt the innovation at time t if its expected return exceeds its threshold Ux. Moreover, Davies supposes that Ux is a function of the firm size, of the learning and searching costs, of the opportunity costs, of the switching costs, and of the presence or the absence of tech-savy people among the firm staff.

2.5.3.5 Centralized and Decentralized Diffusion Systems

In 1971, Professor Donald Schon pointed out that there was a discrepancy between the diffusion theory and the reality of emerging diffusion systems. He defined the at the date classical diffusion model as a *center-periphery model*, within its system, the innovation "exists fully realized in its essentials, prior to its diffusion"[12] and has its origin from some expert sources, being them research and development organizations or istitutional bodies. The innovation is then handed to the potential adopters, who can just passively adopt or reject the new product. Schon noted that this formulation of diffusion models didn't represent the cases in which innovations originate from several sources,

[12] Donald A. Schon, "*Beyond the Stable State*", Harmondsworth: Penguin, 1971

following a diffusion horizontal network. He affirmed that often innovations come from the work of the very adopters, "spreading horizontally via peer networks, with a high degree of re-inventing occurring as the innovations were modified by users to fit their particular conditions."[13]. Decentralised models work best in the case of innovations with low technological intesity, while centralised models fit best innovations that the adopters may not feel the need to adopt, for example innovations regarding medical vaccination.

2.6 Innovation Analysis

In this section the reader will be offered with an overview of the innovation chosen for the goal of the research, how it works, its main economic applications and its likely future developments.

2.6.1 The origins of 3d printing

The origins of 3d printing, and generally speaking the dawn of the Layer Manufacturing technologies, can be traced back to the birth of the first stereolithography machine in 1988. Originally, it was thought that the main utilization would be for rapid prototyping. However, as soon as new materials and processes were discovered, it was quickly realized that the implementations of this new technology were virtually infinite.

At the beginning, the research efforts were oriented towards different kinds of machines based on the Stereolithography and the Selective Laser Sintering technologies, focusing on the issues of process control and material features. Eventually, the Three Dimensional Printing technology emerged as the most competitive process in terms of cost and speed of execution.

[13] Donald A. Schon, "*Beyond the Stable State*", Harmondsworth: Penguin, 1971

3D printing is mainly based upon two types of ink-jet printing technology:

1. Continuous Ink-Jet Printing: this technology uses a flow of charged drops and deflect those which are going to be used for the printing.
2. Drop on Demand Ink-Jet Printing: this procedure puts the ink jet printing head over the place where the 3d printing is going to take place, only after that it deposits the drop.

These two processes differ also in other features such as the drop formation velocity (higher for the Continuous method), and the fluid viscosity needed by the machine (lower values of viscosity for the DoD method).

The possibility of subsequential overprinting leads to the creation of the third dimension, where each layer must solidify. In order to do so, there must be some peculiar properties of the fluids, which make them suitable for printing. These properties, given by the principles of the fluid mechanics, must permit "to maximise the solid loading of suspensions, to keep fluid properties within a printable window, to stabilise the suspension against settling, to keep viscosity < 40 mPas."[14]

Depending on the practical result wanted from the printing process, one may want to apply one of the two main technologies or the other.

The advantages of using the 3d printing technology over the usual manufacturing procedures include the possibility to experiment innovative designing, high adaptability levels, less time to market, and less tooling requirements. Moreover, 3D printing manufacturing is quicker and less

[14] D. Dimitrov, K. Schreve and N.de Beer, "Advances In Three Dimensional Printing – State Of The Art And Future Perspectives", Journal for New Generation Sciences: Volume 4 Number 1

expensive, because it reduces stocking and transportation costs. This innovation is especially useful in those industries which are characterized by high customization of the products, low production volume, and high value; for example, aerospace and healthcare markets.

2.6.2 3D Printing Applications

The aforementioned advantages of 3D printing over other classical manufacturing technologies are provocking significant changes in the way many products are designed, developed and produced. The application segments include:

- Aerospace industry and automotive consumer products, due to the possibility of producing the same aircraft/automotive parts with the lowest weight possible and the highest grade of costumization, it comes with no surprise that these are the two sectors that are increasing the use of 3d printing technology;
- Healthcare, 3D printers are increasingly being used in medical device manufacturing to create customized medical devices, such as medical devices that more accurately replicate the human form. These products include hearing aids, orthopedic implants and dental implants; moreover, future applications such as 3D-printed organs and blood vessels are in development;
- Architecture, there has been a huge increase in using 3d printing technology for creating pieces and parts that together build up a house or a building;

Other markets that are experiencing a significative switch from traditional manufacturing practices to 3d printing are the government and defense, the industrial business machines one, and the education and research field.

2.6.3 The 3d printer attributes of innovation

Now we are going to take into account the attributes that affect the rate of adoption of the 3d printer as an innovation.

The *relative advantage* that comes from owning a 3d printing is different for each category of its users. Households and companies might get peculiar advantages by the usage of the 3d printer. The former get the chance to prototype everything that comes to their minds, as long as buying online 3d printing projects. Nevertheless, the latter see their production process completely turned around, as now they are able to print what once they had to mold, with a great cut in costs for raw materials; moreover, the level of customization of the final product allowed by the 3d printer makes the companies able to catch that part of their target audience that needs a product with several and distinctive features. Since the relative advantage of owning a 3d printer is remarkably high, we expect that, because of this, the rate of adoption would be positively affected.

Regarding the *compatibility* attribute, the 3d printer is an innovation which is recognized as being persistent with the existing set of values, the previous experiences and the demands of the potential adopters. Because it does not require a change in values of the potential adopters, the rate of adoption of the 3d printer innovation would speed up.

The *complexity* attribute of the 3d printer could be relevant, since the use of this innovation requires the potential adopters to implement a new process with several brand new components. This feature would impact the rate of adoption negatively.

The *trialability* of a 3d printer is quite high, since it takes only a 3d printer in display at the sales point of the innovation producers in order to give a sample of the elements and the use of this innovation.

The *observability* of a 3d printer depends mainly by the individual connections that the households and the potential adopting companies have within their reference network. We believe that as soon as one companies adopts the 3d printer, a spill over effect wuold occour within the boundaries of the same industries. Furthermore, if a private costumer belongs to a cluster of innovators, the chance that they have to get in contact with someone who has already adopt the innovation are higher than the chance that the same costumer has to see the benefits of the adoption of the innovation if they do not have some peers that are risk adverse.

2.6.7 The U.S. 3D printing market

The reason behind the choice of the United States market as the benchmark for the analysis of the diffusion of the 3d printer innovation is to be found in the size and the importance of this very market. First of all, North America accounts for the largest market share on a global level, with roughly the 40% of the global market in 2013. Secondly, the United States hosts within their border two of the main key players of this industry, such as 3D Systems and Stratasys. Lastly, this industry is fully supported and endorsed by the political administration and by many stakeholders.

In 2012, President Obama created the National Network for Manufacturing Innovation (NNMI), which consists of regional hubs that would speed up the development and the adoption of

3d manufacturing technologies. Moreover, the same Administration launched an institute with the aim of further U.S. capabilities in this important emerging manufacturing technology and would pilot principles, along with providing and guidance for companies and consumers involved with this innovation. Six federal agencies — the Departments of Defense, Energy, Commerce, and Education; the National Science Foundation; and NASA — jointly committed to form a pilot institute.

Regarding the trend of the 3d printing industry, if we observe the revenues growth rate, it comes with no surprise that this market suffered a decline of 10.5% between 2008 and 2009, due to the impact of the financial crisis over the investment capital market. However, now the situation is fully recovered, with an average annual growth of 22.8% in the last five years and an expected 15.7% growth rate for the next five years. The market revenue and demand have continued to grow in recent years, as downstream customers have more money available to invest in 3D printers. Additionally, new features and lower prices are winning over customers that were previous holdouts.

The last year, 2014, the profit of the 3d printing market were around $250.6 millions, the exports accounted for $599.1 millions and at least 50 industries were involved in the commercialization and in the distribution of this innovation. Right now, the US market leader key players in this sector are 3D Systems Corporation with the 19.5% of the market share and Stratasys Inc. with the 18.4%. of the market share.

Chapter 3 Research Model

3.1 Introduction

In this chapter we will deal with the core of this research, being it the analysis of the influence that companies' and public policies have on the diffusion of an innovation. First, we will define our hypothesis and we will give the definition of "companies and public policies", we will delineate their components and we will evaluate their singular effect on the diffusion of an innovation. Then, we will explain the structure of the research, being it the inclusion of the results of the Bass model within the equation of a multiple regression model. We will consider the elements of the industrial and public policies as the independent variables and we'll take the innovation sales as the dipendent variable. By doing that, we will be able to compute the regression coefficients for every indipendent variable. Lastly, we will test our hypothetis by evaluting the statistical goodness of fit of the regressors.

3.2 Hypothesis Development: the influence of corporate and public policies over the diffusion of an innovation

The core hypothesis of this research is that there is a group of factors included in the policies implemented by the innovation companies and by the public authorities, that influences the diffusion of an innovation and that most of the diffusion models and studies fails to take it into account. By analyzing the data and their trends, the hypothesis is that is possible to compute the parameters through which the elements of corporate and public policies influence the sales of an innovation.

In this section, we will define the concept of “corporate and public policies” and we will state the elements that put together form this notion.

For the sake of this study, when we talk about corporate and public policies we are referring to the set of behaviours, the directive patterns chosen, the combination of actions made by several bodies, among which we find the companies themselves, industrial unions and foundations, and the government authorities that shape the legal, the social and and the economic structure of the referential market or system. The combined effect of the actions undertaken by these bodies leverages, supports or obstructs the diffusion of an innovation.

Within the boundaries of this combination, we will consider: banks, lending istitutions, the country’s legal framework, industrial unions, the presence or the absence of lobbying activities, the taxation structure of the referential country, the public and private investment for research and development activities, and the legislation regarding the classification and the protection of patents.

The variables that we are going to use in order to assess the magnitude or the orientation of the above mentioned elements are several.

Regarding the banking and financial system, we will consider the cost of capital for both households and companies. Since it affects the quantity of money that both of these subjects can borrow, we expect that lower interest rates have a positive effect on the diffusion of the innovation. Piana (2004) found out that the prevailing interest rate on the market is a key determinant in choosing to adopt, with too high interest rates discouraging innovation diffusion.

About the taxation structure, we are interested in the percentage of capital gain due to the fiscal autorithy and the tax break granted for the companies and the households that invest in research and development activities. A high level of capital gain taxation deters the innovation’s diffusion among the companies that want to adopt it and their investors, since the earnings would be severely affected by the tax rate. Instead, a huge tax break favours the diffusion of the innovation because it makes the adoption of the innovation cheaper for the companies that want to turn around their business processes by including in them a new procedure.

The percentage of public and private expenditure for research and development activities over the country gdp is a good indicator of the country predisposition for the diffusion of an innovation: the higher, the better. Levi and Shi (2004), investigated socio-economic factors underlying the diffusion of the internet and 2G mobiles in the US. They found that the innovation adoption is positively correlated with r&d expenditure per capita.

3.3 Research structure: the Bass Diffusion Model

The Bass model of diffusion has been chosen as the backbone of our research analysis due to its peculiar features that we are going to examinate.

First of all, the Bass model can be used to foresee the timing and magnitude of the sales of an innovation, when the sale peak is going to happen and how long is going to take for the unavoidable decline in sales to show up. Hence, for marketing managers, the Bass model has its main applications in the synchronization of marketing mix variables activities with the sales forecast, in the decisions about new product feasibility, and in the products' performance follow ups. For the purpose of this research, it provides a useful framework where we can test the impact of the influence of a heterogeneous audience on an innovation sales.

Secondly, it is one of the simplest model of diffusion. In its basic formulation, It includes only three parameters that can easily be estimated. As a matter of fact, in order to determine the diffusion curve, parameters p, q and m need to be identified. Indeed, Bass (1969) developed a method of estimating these parameters, using the statistical tool of ordinary least squares (OLS) multiple regression. Some versions and developments of the models, made by Bass himself and several other autors, use alternative statistical inference instruments in order to catch the values of these parameters under the hypothesis of unstable innovation recepient population, and more than one generation of the product; however, for the sake of this research, we will use the estimations of these parameters already made for mature economies, in order to focus on the intesity of the effect of corporate and public policies over the spreading of the innovation.

Thirdly, the Bass model is the only model among the ones that relies upon a distribution following S-shaped curve, that encompasses the innovative and the imitative behaviour of the individuals introduced by Rogers. The external communications channels that trigger the *innovativeness* of the induviduals are incorporated in the p parameter. This means that we can leave aside from our analisys the consequences of the mass-media communications, the newspaper ads bought by the innovation's company, and the firm's internet presence. The imitation propension of the population is covered by the q parameter, so in our analysis we will not have to deal with the repercussion of word of mouth through the interpersonal channels in the diffusion of the innovation. Indeed, through the Bass model we get rid of those crucial variables in order to spot a light on the influence of the elements of our core analysis protagonist.

Furthermore, the Bass model considers the market as an aggregate, and since we want to examine the influence of the stakeholders and the other entities responsible of the corporate and public policies on the diffusion of an innovation on a whole market level, the model meets our needs.

Moreover, this model is tested on the first purchase of consumer durables, so it fits with the concept of an innovation bought by households as well as the same product bought by companies for process-making renovation purposes.

Lastly, this model works. Bass (1969) tested his model on the early sales data for eleven consumer durables. Results showed that the model had a good fit to the sales curves, representing first time purchases or innovation adoptions, for all of the eleven product categories in his study. Furthermore, additional studies of the Bass model have given strong empirical support for the structural solidity of the model in several and distinct cases. We will mention the studies of Jeuland (1994) composed by 32 data sets, scattered between Europe and the United States; the research carried out by Akinola (1986) in Nigerian farms; the work of Lawton and Lawton (1979) in the diffusion of educational innovations in the US. All of these studies shown R2 values concerning their OLS models above 0,95.

3.3.1 How the Bass Diffusion Model works

The basic assumption that underlays the Bass model is that part of the adoption of an innovation depends on the imitation actions undertaken by a section of the analysed population, while another part is linked to the intrinsic innovativeness charateristic of other individuals.

Essentially, the Bass model derives from a "hazard function, it states the probability that an adoption will occur at time t given that it has not yet occurred"[15]. So, the fundamental function of the Bass model is

$$\frac{f(t)}{1 - F(t)} = p + q * F(t)$$

Where

$f(t)$ is the change rate of the installed base fraction

$F(t)$ is the installed base fraction, it stands for the number of units within the system

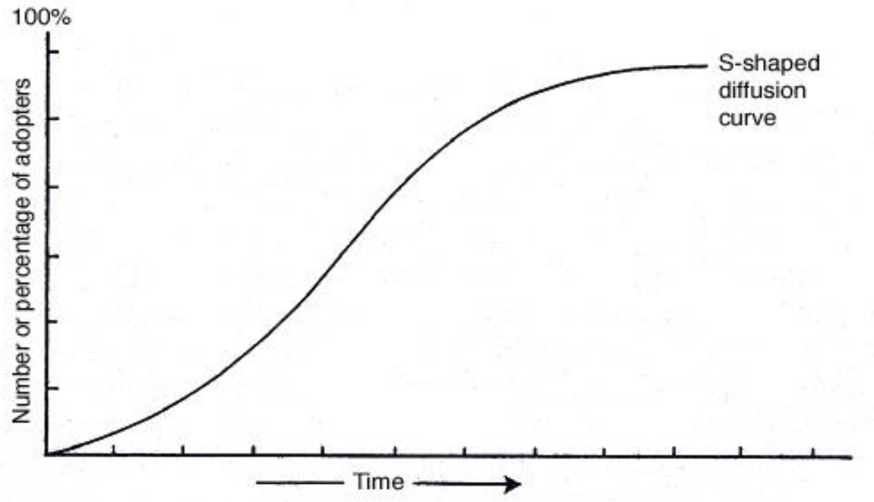
p is the constant propensity to adopt that is independent from how many other individuals have adopted the innovation before

[15] K. D. Lawrence et al., "Forecasting new adoptions: a comparative evaluation of three tecniques of parameter estimation", Advances in Business and Management Forecasting, Volume 6, 86-93, 2009

time t. It incorpates the effects of advertising and communication through mass media channels

q is the imitation coefficient, it captures the disposition of a part of the population to be influenced by the adopting behaviour of other individuals. This parameter reflects the power of wordouth and interpersonal communication within social relationships.

If we integrate the above function, we obtain the graph showing the cumulative probability of adoption over time.



It also shows the change of the speed of the diffusion process as more and more units of the system adopt the innovation. At the beginning, we observe a slow rate of adoption, then it accelerates because besides the innovators, the imitators are starting to buy the innovation. Soon after that, we can see how the function shows an inflection point, right after that the change rate decrease as less agents are going to adopt the innovation.

If we apply the F(t) function to the sales of the innovation we have that

$$N(t) = [p + q * N(t-1)] * [m - N(t-1)]$$

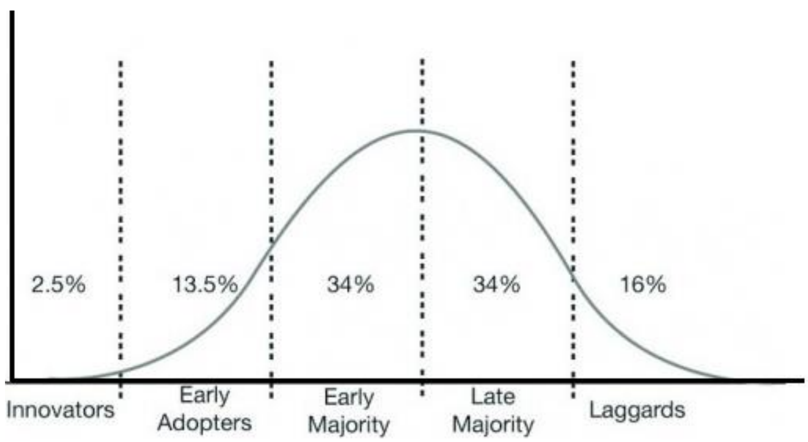
where

N(t) stands for the number of adopters for the n period

N(t-1) are the adopters of n-1 period

M is the potential market of the innovation

Therefore, the number of new adopters is a function of the previous period adopters along with the natural predispositions of innovativeness and imitation of the system population, all based upon the market potential.



As shown above, we have the graph of the density function of the adoption over time, where on the x axis we find the percentage of the innovation adoption and the time is depicted on the y axis. In the graph there are reported the Rogers' classifications of the innovation adopters based on the timing of their adoption.

3.3.2 Criticisms over the Bass Diffusion Model

Even though the Bass model is known for its accuracy and its efficiency, there are some circumstances in which it does not work so well.

The model works better when the markets taken into account for the goal of the analysis are the US or one from the European countries. The research of Heeler and Hustad (1980) points in this direction, because of the lack of fit of the timing of the sales peak in the model in more than one third of the data cases placed in international countries. Under these conditions, sometimes it seems like that the model's forecasts "are inaccurate before the sales peak and especially prior to the point of inflection"[16].

Furthermore, it happens that the instability of parameters leads to the inaccuracy of model's forecasts being not accurate, unless the entire growth history is included in the regression used to estimate them (Mahajan, Muller and Bass, 1990). However, waiting for complete data reduces the model's utility, because "parameter estimation for diffusion models is primarily of historical interest; by the time su cient observations have developed for reliable estimation, it is too late to use the estimates for forecasting purposes"[17]

[16] P.N. Golder and G. J. Tellis, "Beyond Diffusion: An Affordability Model of the Growth of New Consumer Durables", Journal of Forecasting Forecast. 17, 259-280, 1998

[17] Mahajan, Muller and Bass, "New Product Diffusion Models in Marketing: A Review and Directions for Research", Journal of Marketing, Vol 54 January 1990, pages 1-26

Besides those three inaccuracies that do not really affect the development of our analysis, the Bass Model provides weak forecasts in three different cases:

- when the population is heterogeneous; heterogeneity in the population suggests systematic differences in adoption times across the individuals that form the recepient network. Aggregate diffusion model, such as the Bass one, see the innovation diffusion process as analogous to the spread of a disease. In the words of Gatignon and Robertson (1986), "the behavioral assumptions underlying aggregate level consumer diffusion models are typically simple and do not provide a behavioral explanation for the rate or pattern of diffusion". This inaccuracy is due to the mathematical form of the Bass model, which requires the assumption that the potential adopter population is homogeneous. This assumption of homogeneity implies that, at any point in the process, all individuals who have not alredy adopted the innovation have the same probability of adopting in a given time period, so that "the differences in individual adoption times are purely stochastic"[18].
- when within the diffusion social system, the system stakeholders have a huge influence over the diffusion process; the Bass model could not comprehend within its forecasting capacity the effects on dynamics of the diffusion systems made by the actions undertaken by the agents of the innovation ecosystem. The agents might be new players in the innovation market, a sea change in the market sentiment or behaviour regarding the innovation, purchasing group made by the costumers, pressure groups created by the

[18] Rabikar Chatterjee and Jehoshua Eliashberg (1990), The Innovation Diffusion Process in a Heterogeneous Population: A Micromodeling Approach, *Management Science*, Vol. 36, No. 9 (September 1990), pp. 1057-1079

innovation spin off workers, the cultural and educational associations and institutions that may cause techno-economic shift of the system and the impact of the work of potential competitor companies.

- when there are specific corporate and public policies that could foster or deter the rate of adoption of the innovation. The behaviours and the actions of the government bodies and authorities as long as the choices made by the corporate level management impact deeply the diffusion rate of the innovation and yet there are no variables nor coefficients that take into account these elements in the Bass diffusion model;

Through this paper, we will try to improve the forecasting accuracy of the Bass model by including, in a widen model, variables that stand for the corporate and public policies that affect the innovation sales.

3.3.3 Use of the Bass Diffusion Model for the research purpose

In order to catch the effect of the impact of corporate and public policies over the diffusion of an innovation, we will use the Bass Diffusion Model to predict the sales of 3d printers in the US market over a six years period, from 2009 to 2014. After that, we will use those results as a costant in the multiple regression model we are going to build. By doing so, we will expand the model forecasts by including the intensity of the influence of the US public and corporate policies in the 3d printing market. The next paragraph will explain the process behind the construction of this new model.

3.4 Research structure: the multiple linear regression model

A multiple linear regression model equals the value of a dipendent variable, being it the innovation sales growth rate in this research, to the sum of the value of the independent variables, the elements of the corporate and public policies stated above, of which each of them is multiplied for their constant β, which is the variation of the dipendent variable associated to a 1% variation of the independent variable.

Right below there is the equation of the population regression line in the multiple linear regression model. In this case, there are three independent variables.

$$E\left(Y_i \middle| X_{1i} = x_1, X_{2i} = x_2, X_{3i} = x_3\right) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + u_i$$

β_0 is the intercept of the straight line, it gives us the value of the sales when the indipendent variables area equal to 0. In this study, β_0 will have the value of the sales forecasted by the basic version of the Bass Diffusion Model.

X_1, X_2 and X_3 are the independent variables that influence the sales of the innovation, in addition to what the Bass Model already forecasts. For this study, the independent variables would be the cost of capital, the innovation tax break rate and the country research and development expenditure over the GDP.

u_i is the error, the statistical noise. It stands for all the factors responsible for the difference among the Y*n* observed and the same value forecasted by the multiple linear regression. For this research, we will consider the intensity of u_i as the combined effect of the gini index, the corruption level and the Hofstede analysis index on the diffusion of the 3d printer innovation.

β_1, β_2 and β_3 are the regression coefficient of their independent variable X. They evaluate the effect of a unitary variation of their according X on the dependent variable Y, while the other independent variables are kept fixed. In order to calculate them, we will use the OLS method. In the next chapter, we will explain how the assumption od the OLS for the multiple regression are fulfilled.

Second Part

Chapter 4 Data collection and data analysis

4.1 Introduction

In this chapter we will build, use and test the multiple regression model we theorised in chapter three. First of all, we implement the Bass Model for the sales of 3d printers in the United States from 2009 to 2014, by doing so, we will be able to evaluate the β_0 of the multiple regression model. Then, we will add the components of the corporate and public policies defined in our hypothesis as the independent variables of the model. After that, we will find the value of the regressor coefficients for every independent variable. Next, we will take into account the determinants of the regression error. At the end, we will test the statistical goodness of fit of our estimation.

4.2 The Bass Diffusion Model for forecasting 3d printer sales in the U.S.

In order to use the Bass Diffusion Model, we have to determine the value of the model's parameters. The next paraghraps will deal with the computation of the model's elements.

4.2.1 The potential market for 3d printers in the U.S.

The estimation of the *m* parameter, being it the potential market of the 3d printer innovation, would be made upon the forecasted growth of the US 3d printer market made by IBISWorld and canalys. For the sake of this study, we will take the potential market as the forecasted sales for 3d printers in the United States for the year 2018, being them around the value of US$16.2 billion. This value will be adjusted to each year of the analysis using the market revenues growth rate as the discount rate.

4.2.2 The previous adopters

The numbers of the adopters at t-1 could be find in the sales data provided by the IBISWorld Industry Report on 3D printer manufacturing in the U.S. Hereafter we willl show the values.

Year	Sales in $
2009	501.371.036
2010	619.694.601
2011	756.027.413
2012	925.377.554
2013	1.140.065.147
2014	1.400.000.000

For the study analysis calculations, we will take into account the growth rate, *g*, experienced by the sales numbers.

Year	*g*
2009	22.10%
2010	22.35%
2011	22.63%
2012	23.00%
2013	23.34%
2014	23.58%

4.2.3 The innovativeness and the imitation coefficients

For what concerns the p and q parameters, this study will rely upon the research made in 2002 by Talukda, Sudhir and Ainslie[19] and the Gelper and Stremersch paper of 2014[20]. For this study's purpose, we will take their results for p and q appropriately

[19] Talukda ,Sudhir and Ainslie (2002). Investigating new product diffusion across products and countries. *Marketing Science*, 21(1), 97–114

[20] Gelper and Stremersch (2004). "Variable Selection in International Diffusion Models". Working paper

calculated for mature markets such as the United States one. Regarding the p value, we will have it at 0.001, while the q value is estimated at 0.509.

4.2.4 Bass Model forecasted sales for 3d printer in the US

Now that we have all the elements needed, we are able to compute the 3d printer sales forecaste through the calculation stated by the Bass Model. Hereafter we will show the results in US$.

Year	Forecasted sales in US$
2009	225246110.4
2010	225.860.345
2011	276.129.260
2012	340.939.630
2013	419.817.049
2014	501.478.706

If we compare the forecasted sales of 3d printers in the US with the actual sales data we clearly see that the Bass Model underestimates the value of the sales. This leaves room for the research's hypothesis, since we are going to add the factors that explain this discrepancy.

Since we are going to use the dependent variable expressed as a growth rate, we are interested to present the results of the β_0 in the same fashion.

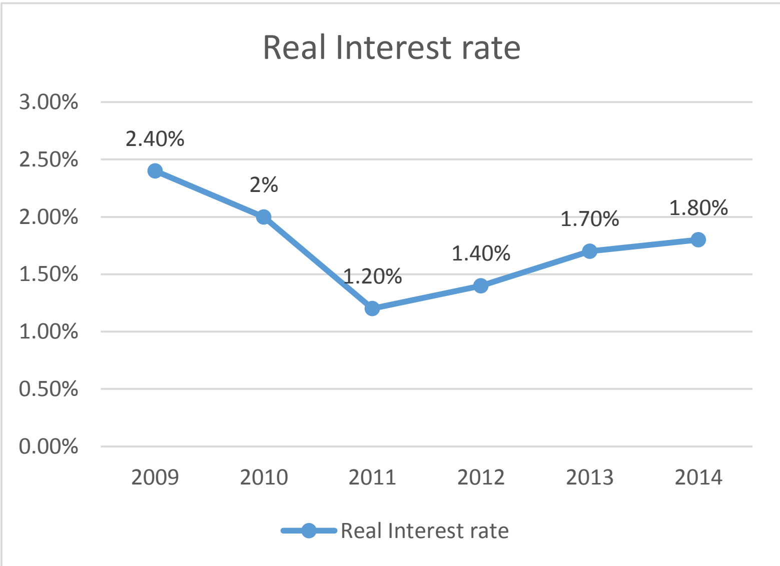
Year	Growth rate of forecasted sales by the Bass Model
2010	0.27%
2011	22.26%
2012	23.47%
2013	23.14%
2014	19.45%

Following the data showed in the table, we are able to compute that the average growth rate of the sales forecasted by the Bass Model is 18%.

4.3 The independent variables

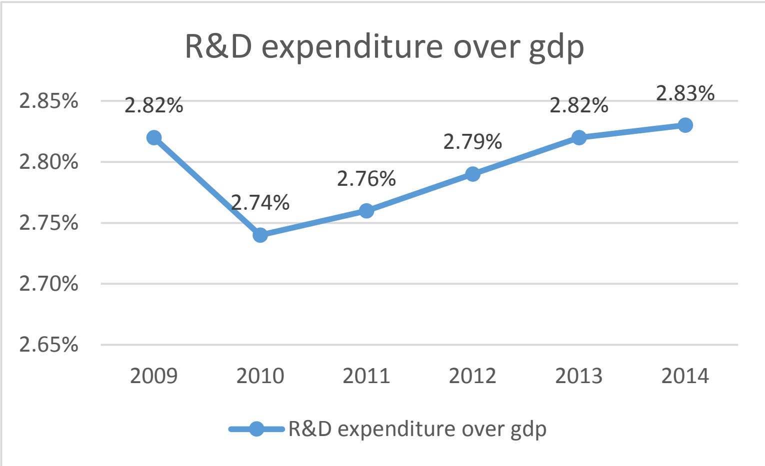
As said before, for this paper we will rely upon three independent variables that the hypothesis recognizes as determinants to the innovation diffusion.

Starting with the interest rate, we chose the real interest rate, which is the annual lending interest rate adjusted for inflation as measured by the GDP deflator, and the data about it were provided by the World Bank for the period 2009-2014.



As we can see, since 2011 we observe an upward trend for the real interest rate. Later on we will discuss its impact over the 3d printer sales in the United States during the same period.

Regarding the values for the U.S. expenditure for research and development activities, we took the data provided by the American Association for the Advancement of Science and the World Bank. In particular we are interested in the r&d expenditure, both public and private over GDP.



As we can see from the graph, the drop of r&d investments caused by the financial crisis and the lack of capitals has been recovered over the years.

Our last independent variable is the tax break granted by the U.S. Administration for companies that invest in 3D printing technology. From the fiscal year of 2012, thanks to the emanation of an act by the Congress, the US companies that invest in the adoption of 3d printers can have a fiscal credit up to the 13% of the investment. Since this tax break was not present for the whole period of this study, for the years 2009-2011 we will take it as 0%.

4.4 The determinants of the regression error

As we said in the third chapter, one of the elements of a multiple linear regression is the error or the residual. It incorporates every factor responsible for the difference between the actual value of the dependent variable and what the multiple regression forecasts. For the sake of this study, the factors included in the regression error will be the Gini index, the Hofstede analysis and the corruption level. Hereafter we will examine every one of these components, as we are trying to take into account the other factors neglected by the basic formulation of the Bass diffusion model.

4.4.1 The Gini index of income inequality distribution

The Gini index measures the extent to which the distribution of income or consumption expenditure among individuals or households within an economy deviates from a perfectly equal distribution. This index is based upon the Lorenz curve, which plots the cumulative percentages of total income received against the cumulative number of recipients, starting with the poorest individual or household. Therefore, the Gini index measures the area between the Lorenz curve and a hypothetical line of absolute equality, expressed as a percentage of the maximum area under the line. Hence, if it is represented as a percentage, a Gini index of 0 stands for the perfect equality, while an index of 100 implies perfect inequality. Van den Bulte and Stremersch (2004) discovered that there is a positive association between the ratio of q and p and the Gini coefficient of income inequality, supporting the income heterogeneity hypothesis.

The United States is a country that shows a medium degree of inequality, having its Gini index around the half of the distribution. In the table are represented the Gini index values in the United Stated for the time framework of this study.

Year	Gini Index
2009	0.468
2010	0.470
2011	0.477
2012	0.477
2013	0.476
2014	0.475

The data were taken from the reports provided by the United States Census Bureau.

4.4.2 The Hofstede Country Analysis

The Hofstede Analysis takes its name from Professor Geert Hofstede, who conducted one of the most comprehensive studies of how values in the workplace are influenced by culture. He analysed the value scores of a large database of employee among IBM branches scattered around the world between 1967 and 1973. The data covered more than 70 countries, from which Hofstede first used the 40 countries with the largest groups of respondents to draw his conclusions regarding the influence of the country's culture on the values and the behaviour in the workplace. Successives researches validated the earlier results by including in the respondent groups commercial airline pilots and students from 23 countries, as long as civil service managers, 'up-market' consumers and 'elites' in 19 countries.

The results of these studies lead to the categorization of the Hofstede dimensions of the national culture, which are:

- Power Distance Index (PDI); this dimension deals with the fact that all individuals in societies are not equal, and it expresses the attitude of the culture toward these power inequalities among us. This index is defined as the degree to which the less powerful members of institutions and organisations within a country expect and accept that power is distributed unevenly.
- Individualism versus Collectivism (IDV); societies are labeled as more inclined towards individualism or towards collectivism according to the degree of interdependence that they maintain among their members. In Individualist societies people are only supposed to look after themselves and their direct family. In Collectivist societies people belong to groups that take care of them in exchange for their loyalty.
- Masculinity versus Femininity (MAS); this dimension of analysis takes into account what values drives the society taken under examination. A high score on this dimension indicates that the society will be driven by competition, achievement and success, while a low score means that the dominant values of the society are the care for others and the quality of life.
- Uncertainty Avoidance (UAI); this dimension revolves around the way that a society deals with the fact that the future can never be known. Basically, it measures the risk orientation of a society and the beliefs, the lifestyle and the istitutions that have been created to manage the risk.
- Long term orientation (LTO); this dimension describes how every society has to maintain some connections with its own past while dealing with the challenges of the present and future, and how societies prioritise these two existential goals differently. Societies

who score low on this dimension prefer to maintain traditions and norms while viewing social change with suspicion. Those with a culture which scores high, take a more pragmatic approach because they encourage the change thus they see it as a natural step in the society development.

- Indulgence versus Restraint (IND); this dimension is about how the society allows the people to live their desires and impulses against how the society can ban or deter those behaviours. It has a lot to do with the way children are raised and educated

The social and psychological orientation of the population gives off how the individuals will respond to the action undertaken by the companies and the government authorities through the implementing of corporate and public policies. We are particularly interested in the Power Distant Index, in the Uncertainty Avoidance Index, in the Masculinity Index and in the Long Term/Short Term Orientation Index. Van den Bulte and Stremersch (2004) found out, through a study based on 746 different Bass estimations spread over 75 consumer durables and 77 countries, that the q /p ratios of the Bass model are negatively associated with individualism or positively associated with collectivism, positively associated with power-distance, positively associated with masculinity and they have negative association with uncertainty avoidance. Moreover, Steenkamp, Hofstede and Wedel (1999) found out that on a national level, individualism and masculinity were positively related with innovativeness, and uncertainty avoidance was negatively related to it.

Now we are going to explore the US culture through the dimensions of the Hofstede Analysis, in order to catch which features could influence the diffusion of an innovation within the country.

Regarding the Power Distance Index, Americans are positioned quite low with a score of 40. This means that they fairly accept the inequalities among the society they live in. About the diffusion of an innovation, this could mean that they are more prone to accept decisions about their production or consumption patterns made by “someone” in a higher position in the authority ranking.

The United States are one of the country with the highest level for the Individualism dimension, with 91 as a value. It means that American people only look after their family and the smaller circle of aquaintances. This could stand for a higher degree of innovativeness among the American people.

The score of the US on Masculinity is quite high, being it set at 62. This means that this society is mainly lead by the “you must be the best, you must win” values. This means that they should be more inclined to try or to buy an innovation if this would stand for an act of winning or an act of superiority among their peers.

The United States score as a country with a low Uncertainty Avoidance Index. This means that the Americans are more prone to accept new ideas coming from different sources. Regarding the diffusion of an innovation, this score tell us that American people are willing to adopt an innovation, they will not make a stand against it.

In the Long Term Orientantion Index, the United States are positioned as a country with a medium rank, being it 26. This value in this dimension does not give off good predictions of the behaviour of the American people regarding the adoption or the rejection of an innovation.

The United States scored as an indulgent society, with a value of 68 for this index. This could mean that impulsive purchases of an innovation could happen very easily.

4.4.3 The Corruption Level

The consequences of a corruptive behaviour over the making of or the implementation of the corporate and the public policies that favour or deter the spreading of an innovation could not be forecasted in advance, since there is no way to know if the corrupted people are pushing for or against the diffusion of the innovation. Anokhin and Schulze (2009) posit that better control of corruption is associated with rising levels of innovativeness and entrepreneurship.

The data needed for the writing of this paragraph have been taken from the annual reports of Transparency International, which is an organization that monitors the corruption level of every country of the world. Every year they provide a corruption perception index with the values of said index for every country, those value can range from 0 to 100. The higher the value, the less the country is corrupted.

In the table below we will show the US corruption index value for the time framework of this research, as long with the ranking of the United States in the least corrupted countries in the world.

Year	Index value	Ranking
2009	75	19
2010	71	22
2011	71	24
2012	73	19
2013	73	19
2014	74	17

As we can see from the index results, the United States are relatively stable both in their index value and in their positioning, since they move within the numbers of the twentyfive least corrupted countries in the world. However, even if we can grasp the intensity of the corruption phenomenom in the United States, we cannot speculate about the effects that corruption events may have over the diffusion of an innovation, since we do not know who bribes who and for what purpose these corruptive actions take place.

4.5 The construction of the multiple regression model

4.5.1 Valutation of the regression coefficients: assumptions

Now we have the foundations upon which we can build a multiple regression model. Our goal is to catch the value of the regression coefficients, so we can have the intensity through which the independent variables influence the sales growth rate of the 3d printer. In order to estimate these parameters, we will use the OLS method. For the multiple regression, this method requires four assumptions to be satisfied. We well briefly discuss them.

1. The conditioned distribution of the error u, given the values of the independent variables, has a mean equal to 0. For this model, it implies that the combined effect of the variables that stand for the statistical error of the regressioni has an average of 0 for the period in which the model is applied.
2. The independent variables are independently and identically distribuited. Since the data were collected through a causal simple sampling, this assumption holds true.
3. The third assumption of the OLS tells that the extreme outliers are unlikely.
4. Absence of perfect collinearity. This assumption means that none of the regressors is a linear function of another one. In the model we are going to build, this assumption stands.

4.5.2 Valutation of the regression coefficients, estimation

We found the intensity of the regression coefficients by analyzing the partial variation of the dependent variable linked to the variation of one of the independent variables, while keeping the other ones. Data were found by using the excel analysis tool. We will show the results for each regressor coefficient.

Variable	Coefficient
Bass Model forecasted sales growth rate	0.1841
R&D over GDP exp. growth rate	1.6057
Real interest rate	-0.2707
Tax shield rate	0.064

We can draws some useful conclusions by the results obtained for the regression coefficients.

First of all, the estimation of the bass model forecasted growth rate as a constant in this regression model is consistent with the average bass model forecasted growth rate observed.

Secondly, since the coefficien is positive, we confirm the hypothesis that an increase in the r&d over gdp expenditure is positevely correlated with the sales growth rate of 3d printers.

Thirdly, as expected, an increase in the real interest rate is negatively correlated with the sales growth rate of the innovation. As borrowing becomes more expensive, companies and households are deterred from investing in the innovation.

Lasty, as we supposed, we found a positive correlation with the tax credit granted by the US fiscal administration and the sales growth rate.

4.5.3 The error values

Previously, we acknowledged the values of the parameters which influence the residuals of the regression. Now, we have computed the intensity of the regression errors. In the table below, we will present the 2009-2014 results for the residuals and the standardized residuals, which are the residuals divided for their estimated standard deviation. This step is necessary when we take into account that different residuals have different variances.

Year	Residual	Standardized Residual
2009	-0.0019	-0.8203
2010	0.0008	0.3429
2011	0.0011	0.4774
2012	-0.0035	-1.4932
2013	0.0004	0.1824
2014	0.0031	1.3108

4.6 The multiple linear regression for the 3d printer sales

Now that we have collected all the data needed, we are able to bulid a regression for the 3d printer sales in the United States. The general formula to forecast the sales of this innovation within the framework market is:

$$Y = 0.18 + 1.61X_1 - 0.27X_2 + 0.064X_3 + u_i$$

Taking the Bass Model results as our β_0, we can estimate the likely grow rate of sales of this innovation

4.7 Hypothesis testing

In this section we will test the goodness of fit of the estimation made for the regression elements. First, we are going to focus on the consistency of the regressors evaluation, then we will test the multiple regression as a whole.

4.7.1 Statistical goodnees of fit of the regressor coefficients

In order to estimate the goodnees of fit of the regressor coefficients, we will carry on a hypothesis testing using the t stastistic and the p-value of the coefficients. In the table below are shown the standard error, the t statistic and p-value for every coefficient estimated.

Variable	Standard Error	T statistic	p-value
β_1	7.3505	0.2184	0.8473
β_2	0.5137	-0.5270	0.6507
β_3	0.0351	1.8245	0.2096

We then move to the construction of the hypothesis, assuming a level of confidence with α=0.05. We can now build up the hypothesis regarding the goodness of fit of the estimation of the regressor coefficients. For the sake of it, we will have the same set of hypothesis for every coefficient estimation. We want to reject the case in which all the coefficients are equal to 0, because that would mean the independent variables have no effect whatsoever on the dependent variable. That being said, our hypothesis system would be:

The null hypothesis

$$H_0 : \beta_1, \beta_2, \beta_3 = 0$$

While the non-null hypothesis is

$$H_1 : \beta_1, \ \beta_2, \beta_3 \neq 0$$

Since the p-values of all the regression coefficients are greater than the level of significance α=0.1, we tend to accept the null hypothesis. However, due to the peculiar magnitude of the coefficients (being them so close to 0) and the small numbers of observations, these results have a low statistical significancy. We are going to test the goodness of fit of the whole regression using different tools.

4.7.2 Statistical goodness of fit of the whole regression

In this section, we will use some statistical tool in order to test the goodness of fit of the whole regression.

4.7.3 R^2

The R^2 of a multiple regression represents the fraction of the sample variance explained or predicted by the regressors. It can range from 0 to 1 and it is calculated by dividing the explained sum of squares for the total sum of squares. Hereafter we will show the results calculated with the excel analysis tool.

R^2	**0.837054711**

If we look at this results, we could say that the regressors explain the 83% of the dependent variable variance. However the R^2 grows everytime we add we add a new independent variable to the regression, so it provides an overestimation of the regression goodness. In order to mitigate this distorsion, in the next paragraph we are going to calculated the corrected R^2.

4.7.4 Corrected R^2

The Corrected R^2 is a modified version of the R^2. It does not grow as a new regressor is added to the regression. It improves the goodness of the toll by multiplying the standard R^2 for the ratio between *n*-1 (with *n* being the number of osservations of the regression model) and $n - k - 1$ (with k being the number of the regressors). In the table below we will show the result of the corrected R^2 for the whole regression.

R^2 corrected	**0.592636777**

As we can see, the R^2 corrected states that almost the 60% of the dependent variable variance can be explained by the variance of the independent variables.

4.7.5 SER, Standard Error of the Regression

The Standard Error of the Regression is the estimation of the standard deviation of the error u_i, expressed in the dependent variable unit of measure. Furthermore, it is an evalution of the dispersion of the distribution of the dependent variable Y around the regression line. It is calculated by dividing the explained sum of squares with $n - k - 1$, again with n being the number of the observation and k being the amount of regressors. The Standard Error of this regression is shown in the table below.

Standard Error	**003671723**

4.7.6 Hypothesis testing: diversity of variances with the F stastistic

In order to test the goodness of fit of the regression estimation, we will implement the F statistics test for the relationship among the variance of the dependent variable and of the independent ones. We want to prove that the variance of the regression dependent variable and the variances of the independent variables are not casually different. The first step that we have to take is to calculate the variance for every regression variable.

Variable	Variance
Y	0.0000331
X_1	0.0000001
X_2	0.0000187
X_3	0.0050700

Then, we are going to estimate the S_x, which is simply the ratio between the variance of the variable and $n - 1$.

Variable	S_x
Y	0.000006619
X_1	0.000000025
X_2	0.000003733
X_3	0.001014000

We then compute the F statistic for every coefficient and the dependent variable by dividing the greatest S between them with the other one.

Variable	F statistic
S_y/Sx_1	263.3527851
S_y/Sx_2	1.77
Sx_3/S_y	153.1968897

Now, we define the hypothesis we are going to test. The goal of this test is to determine if the variance of the dependent variable is statistically different from the variances of the regressors. In order to do so, we will delineate the null hypothesis as

$$H_0 : S_y = S_{x1},\ S_y = S_{x2},\ S_y = S_{x3}$$

While the non-null hypothesis will be

$$H_1 : S_y \neq S_{x1},\ S_y \neq S_{x2},\ S_y \neq S_{x3}$$

We proceed by choosing the level of confidence of the hypothesis testing, by stating that the study α will be at 5%. We then look up in the F statistic table linked to this level of α and we search for the value of the F with n – 1 and n – 1 degree of freedom. The F value with α at 5% and with five and five degrees of freedom, since both the numerator and the denominator of the F calculation are divided by five, is 5,05. The rejection region of the null hypothesis is:

$$F \geq F_\alpha$$

In this case, we can prove that only the variance of the sale growth rate and the variances of the r&d investments over gdp rate and the tax credit rate are different in a statistical substantial point of view. Since the real interest rate F is lower than the F_α, we have to accept the null hypothesis for this regressor: their variance are casually different.

4.8 Conclusions

Throughout this chapter, we have build a multiple regression model using the Bass Model results as the β_0. Then, we have computed the regression coefficients of the chosen independent variables as long as the estimation of the regression errors. After that, we tested the statistical goodness of fit of the coefficient regressors estimation with the Student's t-distribution. We found out that due to the peculiar value of the coefficients and the small amount of observations, we had to accept the null hypothesis for every one of them. Later, we focused the analysis on the whole regression goodnees of fit. We computed the R^2 and the corrected R^2 of the regression and we indeed found evidences substaining the influence of the variances of the independent variables over the variance of the sales growth rate, since the corrected R^2 is at 0,6. At the same time, we calculated the Standard Error of the regression, which is 0,0037. After that, we implemented the F statistics over the variances of the dependent variable and of its regressors. We accepted the non-null hypothesis for the difference in variance regarding the r&d expenditure over gpd rate and the tax credit rate, we accepted the null hypothesis for the real interest rate regressor. Thus, the results of the hypothesis testing prove that there is indeed an influence of the r&d expenditure over gpd rate and the tax credit rate over the 3d printer sales growth rate, whereas we concluded that the real interest rate does not have a statistical significant impact over the diffusion of the study's innovation.

Chapter 5 Conclusions

5.1 Overview of dissertation

We began this study by underlining the lack of consideration of the modern diffusion studies show over the influence and the effects that corporate and public policies, intenteded as the actions and the decisions made by the corporate management and the government authorities, have over the diffusion of the innovation. We stated that the combined impact of those factors accounts in the level of sales of the innovation and the aim of this study was to proved that.

Later, we provided the reader with an insight of what is a innovation, and the characteristics that determine the speed at which it will be adopted by the recepient network, the rate of adoption. At the same time, we presented the innovation classification, based on how the innovation differs from other existing product or service.

We then approached the concept of the diffusion process and we analyze its elements, being them the communication channel through which the process occours, the period of time the process takes and how it affects the diffusion, and finally the social network where the diffusion process takes place.

We started the literature review by illustrating the first diffusion study made by Ryan and Gross and how it put the foundations of the modern diffusion theory. Later, we focused on the huge contribution made by E. M. Rogers, with a peculiar attention to the definition of the adopters of an innovation based on the timing and the features of the individuals. After that, we presented a digression of the most important models of diffusion. Our attention was addressed particularly on the agent-based model, which shifts the focus from the decisions of a whole population to the choices made by the single individual. We then moved to the analysis of the inter-firms diffusion model, which takes the firm as the element of the diffusion analysis. We discovered that, within this framework, the biggest deterrent of the innovation's adoption is the lack of information that the firm experiences regarding the innovation itself. We went ahead and we presented the probit model, which link the probability of the adoption of an innovation to the utility thresold that the adopters set for the innovation. We finished the accademic review by presenting the Centralized and Decentralized Diffusion Systems theory, which dissects the diffusion process by focusing on the origin of the innovation, recognizing the adpoters as one of the sources of innovation and describing horizontal patterns of diffusion.

We carried on the study by giving an overview of the innovation upon which the hypothesis were going to get tested, being it the 3d printer. We began the innovation analysis with the study of the birth of the Layer Manufacturing technologies, which eventually lead to the two main modern 3d printing processes. Then, we presented the present and future main applications of the innovation. Then, we examineted the attributes of the 3d printer as an innovation, and the effects of these features over its rate of adoption. At last, we gave an overview of the 3d printer market in the United States.

Next, we developed the research method to be implemented in the formulation and the validation of the research hypothesis. Firstly, we defined the hypothesis and we listed the elements that compose the corporate and public policies that affects the diffusion of an innovation, as long with the data needed to asses them. Later, we defined which variables stands for the population heterogeneity and the stakeholders of the innovation social system, and how it is possible to asses their magnitude. Then, we postulated a sales forecasting model, based upon the results of the Bass Diffusion model in the reference period, and the outcomes of a multiple regression analysis with the elements of the corporate and public policies as independent variables and the heterogeneity measures and the stakeholders stimated influence as the statistical noise.

We then moved to the explanation and the definition of the Bass Model. We presented its components, the way it works, and its main inaccuracies. We eventually computed the results of the forecasted level of sales of the 3d printer within the US market over the time framework of the study.

We collected the data regarding the components of every variable of the regression and the we checked the four assumptions needed for using the OLS method. We estimated the value of the regressor coefficients over the growth rate of the 3D printer sales within the period 2009-2014 in the US market. We tested the coefficient regressors hypothesis with the Student's t-distribution statistic and we found out that, due to the peculiar values of the regressors and the small amount of observations, we had to accept the null hypothesis for the regressors' coefficients. We widen the hypothesis testing by dealing with the statistical goodness of fit of the whole regression. We computed the R^2 and the corrected R^2 and we discovered that there is indeed an influence of the variances of the parameters of the corporate and public policies over the sales growth rate, since their variances account for the 60% of the innovation growth rate variance. After that, we used the F statistic to test the significance of the difference between the dependent variable variance and the independent variables ones. We discovered that there is a non casual difference only for the r&d expenditure over gdp rate and the tax credit rate variables, since the variances of the innovation sales growth rate and of the real interest rate are just casually different.

Eventually, we can draw some useful conclusions from the results of this study. First of all, we discovered that the Bass Model provides in average an accurate estimation of the constant term of the multiple linear regression, so it's a good starting point for the construction of a multiple regression forecasting model.

Secondly, we acknowledge that there is indeed an influence of the r&d expenditure over gdp rate and of the tax credit rate over the diffusion of this very innovation, so part of the study's hypothesis holds up true. Moreover, we had to discard the hypothesis that the real interest rate has an impact over the diffusion of 3d printers in the U.S., since there's no statistical evidence that their negative correlation is more than a casual event.

At the end, we can conclude that this study represents a good starting point for intensive studies regarding the influence, the effects, of corporate and public policies over the diffusion of an innovation.

5.2 Implication for Practice

The managerial implications of the findings of this study are several. First, it is possible to develop better forecast diffusion model if there are included the variables through which the audience of the innovation affect its diffusion. By analysing the trend of the factors included in the model, the intensity through which they have an impact on the innovation sales could be estimated. More accurated sales forecasts help the management of a company to better allocate the budget among the business activities, this leads to an increase in the company's operative efficiency.

The second main consequence of this research outcome are the precautionary moves that the management of an innovation company can undertake in order to enhance or counteract the factors influence. Since the main actors behind the implementation of corporate and public policies are institutions, government branches, banks and finanancial companies, and organizations, news and informations about the next moves of these actors help the company's management on improving the strategic plan of the diffusion of the innovation, along with implementing new plans. Moreover, the management of the innovation companies could and should take this study results as a basis upon which react proactivetely regarding the heterogeneous audience of the innovation. They should develop and enforce contingent strategies, besides the innovation marketing plan, aimed to steer the factors that influence the innovation diffusion, in order to create a favourable environment for the innovation to grow within.

5.3 Recommendations

Even if the hypothesis of this study have been tested correctly, the sample through which the research has been carried on may not be representative of the all innovation typologies. This means that the values found can be applied only in the case of the 3d printer within the US market. An extensive study upon the influence of the heterogeneous audience depicted in this research over the diffusion of an innovation should include a significant number of markets, an observable variety among the markets of the values of the heterogeneous audience's elements and a good level of disparity among the innovations tested.

Furthermore, the same approach used in this paper could be implemented over a multigenerational diffusion model of innovation. In this way, the statistical goodness of fit of the regressors could be improved by the greater amount of available data.

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