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

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Summary

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, which is a an idea, a practice, or an object that is perceived as new by an individual or by other unit of adoption. Then we analyze the characteristics that determine the speed at which it will be adopted by the recepient network, which is the rate of adoption. These features are:

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

- *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 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;

At the same time, we presented the innovation classification, based on how the innovation differs from other existing product or service. These classifications are:

- 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.
- 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 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.

We then approached the concept of the diffusion process and we analyze its elements besides the innnovation one, being them:

- the communication channel through which the process occours. 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;
- the period of time the process takes and how it affects the diffusion. It affects the spread of an innovation through the innovation decision process. This process is the path that a decision making unit takes once it gets in contact with the innovation for the first time;
- the social network where the diffusion process takes place. The social and communication infracstructures of a system eases or impedes the diffusion of innovations in the system itself;

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. These principal processes are the Continuous Ink-Jet Printing, which uses a flow of charged drops and deflect those which are going to be used for the printing, and the Drop on Demand Ink-Jet Printing, whereas 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, they must permit the maximization of the solid loading of suspensions, they must stabilise the suspension against settling, and they have to keep viscosity inferior at 40 mPas.

Then, we presented the present and future main applications of the innovation, 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. Nowadays, the main implementations of the 3d technology are in the healtcare, in the aerospace and in the architectural fields. Later on, 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: 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. 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. These elements that stands for the corporate and public policies implemented within a specific diffusion framework are the set of behaviours, the directive pattern 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 have considered: 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 have used in order to assess the magnitude or the orientation of the above mentioned elements are several. Regarding the banking and financial system, we have considered the cost of capital for both households and companies. Since it affects the quantity of money that both of these subjects can borrow, we expected 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 were 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.

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

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 the research method as 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 collected the data regarding the components of every part 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 could 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 acknowledged 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 concluded that this study represents a good starting point for intensive studies regarding the influence, the effects, of the aforementioned independent variables over the diffusion of an innovation.

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