Company Family, Innovation and Colombian Graphic Industry: a Bayesian Estimation of a Logistical Model

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Abstract. This study presents a comparative analysis of the management of innovation among family and non-family companies of the Graphic Communication Industry in Colombia. For which a questionnaire was applied in order to know the divergences in the innovation process carried out by these two types of organizations. From this, the methodology of Generalized Linear Models (MLG) was used and the Bayesian inference was used on the parameters of the model, analyzing the effect of the family business, the products that commercialize on the management of innovation in goods observed as a product tangible Obtaining in this way, the identification of some characteristics of innovation management and divergences with non-family companies, among them: a tendency towards the type of preferred innovation, the different sources and objectives to innovate, and the factors that hinder its process of innovation.

Keywords: Logistic model; Bayesian Inference; MCMC; Innovation management; Family and non-family business.

1 Introduction

Innovation in any organization is vital for successful performance and long-term survival [1]. The positive relationship between the company's capacity for innovation and results is well established and applies equally to all companies, including family firms [2]. This type of organization is of great importance for the economic development of the Society since, according to a study carried out by the Center for Family Business of the University of St. Gallen-Switzerland (2014), family firms Constitute between 80% and 90% of companies worldwide [3]. For its part, the Graphic Industry in Colombia is composed

mostly of family-type companies and according to information provided in the first Sustainability Report [4] this sector is classified as world-class because of its growth potential And internationalization, which is justified because it is considered "as a thermometer for the performance of the economy, for the services it provides to third parties, constituting itself as raw material for other sectors such as services" [5]. It is also a great generator of employment in the country, and in 2014 forged 531,924 jobs according to the Great Integrated Survey of Homes developed by DANE [6].

Therefore, the main objective of this research was to identify the main characteristics of innovation processes and their management in family enterprises, and then to determine, through a comparative analysis, the divergences of innovation management The non-familiar companies of the Printing and Graphic Communication Industry in Colombia.

The methodological approach used has an analytical and explanatory scope, considering as a unit of analysis family and non-family businesses, for which a census of the most representative companies of the sector was carried out according to their level of sales obtained in 2015, Formally established (with NIT and commercial register), obliged to report their financial statements to the Superintendency of Corporations, within which 99 companies were obtained. Then, a questionnaire was designed taking into account the purpose of the research, which was validated, through a process of awareness and pilot application to 10 companies, from which the survey was adjusted where there was low understanding of the questions. Finally, we applied and obtained data to check the correlation between the familiar and non-familiar business characteristics of the innovation generated, through a descriptive statistical analysis and the use of different models such as Generalized Linear Models (MLG) Provide a unified framework for the treatment of exponential family regression models. This problem typically involves the presence of non-normal response variables [7]. In addition, MLG's were considered in which the response variable is measured in binary scale and the logit link function was used for its natural interpretation as the log of Odds [8]. We used the methodology proposed by [9] to perform Bayesian inference on the parameters of the model. This approach is based on simulation and involves the use of Monte Carlo Markov Chains (MCMC) techniques. Finally, the usual Iterative Weighted Least Squares algorithm [7] is extended to include a simulation step based on the Metropolis-Hastings algorithm [10] [11].

2 Methodology

Family and non-family businesses were considered as a unit of analysis, for which a census of the most representative companies of the sector was carried out according to their level of sales obtained in 2015, formally established (with NIT and commercial register), Obliged To report their financial statements to the Superintendency of Corporations, in which 99 companies were obtained. Subsequently, a questionnaire was designed, based on surveys already applied successfully, such as: The survey of

innovation in business 2010-2013, National Institute of Statistics of Spain [12], The EDIT, of the National Administrative Department of Statistics - [13] and the survey proposed in the Bogotá [14], in addition to the work done by The Observatory of Family Business, in its barometer of the Family Business of the Region of Murcia, Spain. Its validation was made through a process of awareness and pilot application to 10 companies, from which the survey was adjusted, until obtaining the final results.
This was structured in eight blocks of questions: 1) Basic information of the company, 2) Incidents in the period 2009-2015, 3) Personnel dedicated to the activities of Innovation and Research and Development (R & D), 4) Activities carried out For the generation of innovations, 5) Innovations developed between 2009-2015, 6) Sources of information used for the development of innovation, 7) Objectives of innovation for the company and 8) Factors that hinder innovation..
Regarding the statistical analysis, we used the MCMC methodology which is based on the construction of a transition density function $q(x, x^*)$ Such that the Markov chain has equilibrium probability given by $\pi(x)$ which is the density to be replaced. A sample of x generated from π is obtained [9] by:

1. Start with $\boldsymbol{x} = \boldsymbol{x}^{(0)}$ and make $t = 1$.
2. To sample $\boldsymbol{x}^{(t)}$ of $q(\boldsymbol{x}^{(t-1)}, \boldsymbol{x})$.
3. Increase t to 1 and return to step 2.

For a sufficiently large t, x^t Is a sample of $\pi(x)$.A scheme of methodology MCMC is the Metropolis-Hasting algorithm [10]. A general transition density function $q(x, x^*)$ and is defined

$$\alpha(\boldsymbol{x}, \boldsymbol{x}^*) = min\left\{1, \frac{\pi(\boldsymbol{x}^*)q(\boldsymbol{x}^*, \boldsymbol{x})}{\pi(\boldsymbol{x})q(\boldsymbol{x}, \boldsymbol{x}^*)}\right\}. (1)$$

$$\tilde{y}_i = \eta_i + (y_i - \mu_i)g'(\mu_i) y W_i^{-1}(\beta) = b''(\theta_i)\{g'(\mu_i)\}^2, \quad i = 1, \dots, n. (2)$$

The MCPI algorithm is as follows:

1. Start with $\boldsymbol{\beta} = \boldsymbol{m}^{(0)}$ and make $t = 1$;
2. Get $\boldsymbol{m}^{(t)}$, The weighted least squares estimator of $\boldsymbol{\beta}$ like if $\tilde{\boldsymbol{y}}(\boldsymbol{m}^{(t-1)}) \sim \boldsymbol{N}(\boldsymbol{X\beta}, \boldsymbol{W}^{-1}(\boldsymbol{m}^{(t-1)}))$, And the covariance matrix $\boldsymbol{C}(t)$.
3. Increase t to 1 and return to step 2.

$$\text{Where } \boldsymbol{m}^{(t)} = \left(\boldsymbol{X}'\boldsymbol{W}(\boldsymbol{m}^{(t-1)})\boldsymbol{X}\right)^{-1}\boldsymbol{X}'\boldsymbol{W}(\boldsymbol{m}^{(t-1)})\tilde{\boldsymbol{y}}(\boldsymbol{m}^{(t-1)}) (3)$$

$$\text{And} \boldsymbol{C}(t) = (\boldsymbol{X}'\boldsymbol{W}(\boldsymbol{m}^{(t-1)})\boldsymbol{X})^{-1} (4)$$

The Bayesian version of the MCPI algorithm was developed by West (1985) for the special case of canonical link functions $\theta_i = \eta_i, i = 1, \dots, n$. Gamerman (1997) Illustrates

the extension to general link functions, the idea is to combine step 2 of the algorithm with an a priori distribution$\boldsymbol{N}(\boldsymbol{a},\boldsymbol{R})$ for$\boldsymbol{\beta}$. This step is then replaced by:

Obtain the a posteriori distribution $\boldsymbol{N}(\boldsymbol{m}^{(t)},\boldsymbol{C}^{(t)})$ for $\boldsymbol{\beta}$ Combining prior distribution $\boldsymbol{N}(\boldsymbol{a},\boldsymbol{R})$ for$\boldsymbol{\beta}$with the observations made$\tilde{\boldsymbol{y}}(\boldsymbol{m}^{(t-1)})\sim \boldsymbol{N}(\boldsymbol{X\beta},\ \boldsymbol{W}^{-1}(\boldsymbol{m}^{(t-1)}))$; The values are obtained

$$\boldsymbol{m}^{(t)} = \left(\boldsymbol{R}^{-1} + \boldsymbol{X}'\boldsymbol{W}(\boldsymbol{m}^{(t-1)})\boldsymbol{X}\right)^{-1}\left\{\boldsymbol{R}^{-1}\boldsymbol{a} + \boldsymbol{X}'\boldsymbol{W}(\boldsymbol{m}^{(t-1)})\tilde{\boldsymbol{y}}(\boldsymbol{m}^{(t-1)})\right\}.(5)$$

$$\boldsymbol{C}(t) = (\boldsymbol{R}^{-1} + \boldsymbol{X}'\boldsymbol{W}(\boldsymbol{m}^{(t-1)})\boldsymbol{X})^{-1}.(6)$$

The logistic regression model can be represented (McCullagh & Nelder, 1989) as:

$$logit\pi_i = log\left(\frac{\pi_i}{1-\pi_i}\right) = \boldsymbol{x}_i'\boldsymbol{\beta},(7)$$

Where$\boldsymbol{x}_i$Is a vector of covariables corresponding to continuous measures and dummy variables or levels of a factor and $\boldsymbol{\beta}$Is the vector of parameters. This model is widely used to analyze data involving binary or binomial responses and some explanatory variables. It provides a technique analogous to those of multiple regression and ANOVA for continuous variables [15].
To perform a complete Bayesian analysis of the logistic model it is necessary to define the likelihood function of the data and the a priori distribution for the parameters of the model. For the case of the exponential family the log-likelihood is given by:

$$l(y;\ \theta,\phi) = \sum_{i=1}^{n}\frac{y_i\theta_i - b(\theta_i)}{\phi_i} + c(y_i,\phi_i).(8)$$

The normal a priori distribution for $\boldsymbol{\beta}$is of the form

$$\pi(\boldsymbol{\beta}) \propto exp\left\{-\frac{1}{2}(\boldsymbol{\beta}-\boldsymbol{a})'\boldsymbol{R}^{-1}(\boldsymbol{\beta}-\boldsymbol{a})\right\}.(9)$$

This allows us to construct the complete conditional posterior distribution for $\boldsymbol{\beta}$, given by:

$$\pi(\boldsymbol{\beta};\boldsymbol{y}) = l(\boldsymbol{y};\ \boldsymbol{\theta},\boldsymbol{\phi})\pi(\boldsymbol{\beta}) \propto exp\left\{-\frac{1}{2}(\boldsymbol{\beta}-\boldsymbol{a})'\boldsymbol{R}^{-1}(\boldsymbol{\beta}-\boldsymbol{a}) + \sum_{i=1}^{n}\frac{y_i\theta_i - b(\theta_i)}{\phi_i}\right\}.(10)$$

The iterative weighted least squares algorithm proposed by Gamerman (1997), is described below:

1. Start with $\boldsymbol{\beta} = \boldsymbol{\beta}^{(0)}$and make$t = 1$;
2. To simple $\boldsymbol{\beta}^{*}$Of the proposed density function $N(\boldsymbol{m}^{(t)},\boldsymbol{C}^{(t)})$ and

3. Accept this with transition probability $\alpha(\boldsymbol{\beta}^{(t-1)}, \boldsymbol{\beta}^{*})$ and make$\boldsymbol{\beta}^{(t)} = \boldsymbol{\beta}^{*}$, in another case, remain in$\boldsymbol{\beta}^{(t)} = \boldsymbol{\beta}^{(t-1)}$;
4. Increase t to 1 and return to step 2.

The moments of the proposed density are given by:

$$\boldsymbol{m}^{(t)} = \left(\boldsymbol{R}^{-1} + \boldsymbol{X}'\boldsymbol{W}\left(\boldsymbol{\beta}^{(t-1)}\right)\boldsymbol{X}\right)^{-1}\left\{\boldsymbol{R}^{-1}\boldsymbol{a} + \boldsymbol{X}'\boldsymbol{W}\left(\boldsymbol{\beta}^{(t-1)}\right)\tilde{\boldsymbol{y}}\left(\boldsymbol{\beta}^{(t-1)}\right)\right\}. \quad (11)$$

$$\boldsymbol{C}(t) = (\boldsymbol{R}^{-1} + \boldsymbol{X}'\boldsymbol{W}(\boldsymbol{\beta}^{(t-1)})\boldsymbol{X})^{-1}. \quad (12)$$

Therefore, the transition is made from the previous state $\boldsymbol{\beta}^{(t-1)}$.
For the construction of the model, the data were considered in binomial form, consisting of the proportion of companies that develop innovation in goods, considered as tangible products. The relevant covariables are the family type (2 types: family and non-family) and the type of main product that the company sells (3 types: public trade, books and other products). The odds of success are related to the covariates $logit(\pi_i) = \boldsymbol{x}_i'\boldsymbol{\beta}$ for$i = 1, \ldots, 6$.

3 Results

The descriptive analysis previously performed on the various aspects and dimensions that characterize the Graphic Industry in Colombia, allows to affirm that it is a dynamic sector with a high evolution of the business influenced by the new technological tendencies that have led the companies to rethink the Business model and with a high level of internal competence.
In the last decades this sector has received a special boost, favored by the development of technology and communications, which has allowed to expand its spectrum of activity towards other sectors and markets with innovative products[16]. In the Graphic Sector in Colombia the way people access information has changed, both the media and publishers are constantly changing, has changed from paper to digital form. This technological development has produced the variant of the net activity of the print to the activity of the communication and, therefore, has demanded new skills and abilities in the direction of the companies.
It is expected that the trends of the Graphic Communication Industry will continue in the digital and ICT sphere. Strong dynamics are perceived in the research and innovation of subjects such as hypermedia, digital content, platforms and electronic and virtual supports[17]
As to the specific characteristics of the innovation management carried out by the companies studied, of the 99 companies in the sample, there are 59 companies of the family type and 40 of a non-family type. Of these, 44 marketed public-trades, 21 books and 34 other products. These characteristic results of the Colombian printing industry

show that the innovation process in family and non-family enterprises, if it differs in some specific cases, among them:

- As regards the objectives of companies in the Graphic Sector to innovate, they are highlighted both for family and non-family firms, the following in their order: Higher quality of goods and services, greater production capacity, penetration In new markets, to obtain a wider range of goods or services.
- Regarding the qualification of the personnel, the non-family companies have a greater percentage of doctors dedicated to R & D activities by 20%, compared to the family ones with 13%. In the same way, it can be observed that non-family companies in terms of professionals (Engineers, Designers, among others) devote a greater proportion in R & D activities by 41%, compared with family members by 36%. But in technical personnel, it was found that family companies spend more people on R & D activities by 21% compared to non-family by 14%.
- Family companies have directed the strategy of acquiring external R & D towards the design of services and processes that allow the creation of an added value to the customer and, therefore, an important degree of customer loyalty. The great challenge of family businesses is survival and to overcome it, they need to grow with added value that differentiates them over time, because this group of family businesses is faced with very changing conditions, both business and the environment,so they can be more innovative. As for non-family businesses, as well as family businesses, they continue to drive innovation activities towards service, but in a lower percentage of participation.
- In the face of the acquisition of other external knowledge for Innovation, this strategy is highly used by family companies aimed at improving processes that allow them to optimize resources.
- As for the factors that make the innovation process more difficult for family businesses, the costs have a greater impact because there is a greater lack of funds and, therefore, it is more complicated the financing of sources external to the company. Firm, thus fulfilling the theoretical characteristics associated with financial capital, in that in family enterprises this element may affect different aspects of their innovation process, such as the orientation to operate in dangerous investments to the detriment of the security of the Family or financial sources used to finance different innovation projects. And also factors related to knowledge for family businesses are important the lack of qualified staff and the difficulty to find cooperation partner for innovation, as for the lack of information on technology and the market, are aspects of medium relevance. And for the market factors, the uncertainty regarding the demand for innovative goods and services is very important, more than the market is dominated by established companies. The factors mentioned have a medium to low relevance for the non-family business, and are proportional in the different options offered.
- The survey allowed us to collect information on the different types of innovation, which shows that, in product-driven innovation, family firms show better impacts than non-family ones. Faced with organizational innovation, the survey allows us to see that family companies perceive that they have higher and higher impacts than non-families in aspects such as:

•Reduction of response time to customer needs.
• Lower costs per unit produced.
• Improved information exchange within your company or with others.

And for non-family companies, they show greater results than those of the family in: improving skills for the development of new products or processes.
Faced with the correlation analysis, the following model is proposed:

$$logit(\pi_i) = \log\left(\frac{\pi_i}{1-\pi_i}\right) = \beta_0 + \beta_1 familiar + \beta_2 tipo\_producto, \quad (13)$$

The following results are obtained in Table 1 for the model parameters obtained by running a chain with 10000-iterations and a 2000-iteration burn period with an a priori non-informative, due to the few studies on This issue developed in Colombia and an acceptance percentage of 78.8% of the transition probabilities. Figure 1 shows the results of the chains for the parameters of the model, also the Kernel density graphs and the autocorrelograms are shown; These illustrations suggest convergence of all the parameters of the model.

Table1. Statistical empirical summary a posteriori for model parameters. Source: Own elaboration (2015) based on survey results. Program used R (Free Software)

Parameters	Mean	Sd	Mode	Lh	2.50%	median	97.50%
(Intercept)	2.38	0.716	2.197	2.197	1.131	2.329	3.894
x1	-2.028	0.708	-1.85	-1.85	-3.521	-1.993	-0.765
x2	0.715	0.743	0.631	0.631	-0.649	0.692	2.215
x3	0.479	0.576	0.454	0.454	-0.649	0.482	1.598

The median and 90% credibility intervals of the a posteriori samples for the model parameters reflect that the effect of the family and non-family firms and the type of main product that the companies commercialize are significant to explain the innovation in goods Considered as tangible products. Interpretation of model parameters as Odds Ratio (OR) was performed (see Table 1).

We interpreted the parameters of the model as Odds Ratio (OR), it was found that family companies have a chance to perform innovation activities in Exp (-2.028) = 0.132 times that if it were unfamiliar, that is, Family businesses are less likely to undertake these innovation activities. On the other hand, it is observed that the chance to carry out innovation activities in the companies that sell books is greater in 2,044 times than if the company developed other products and the chance of having innovation activities in the goods of the commercial companies is 1,615 times higher than companies that manufacture other products.

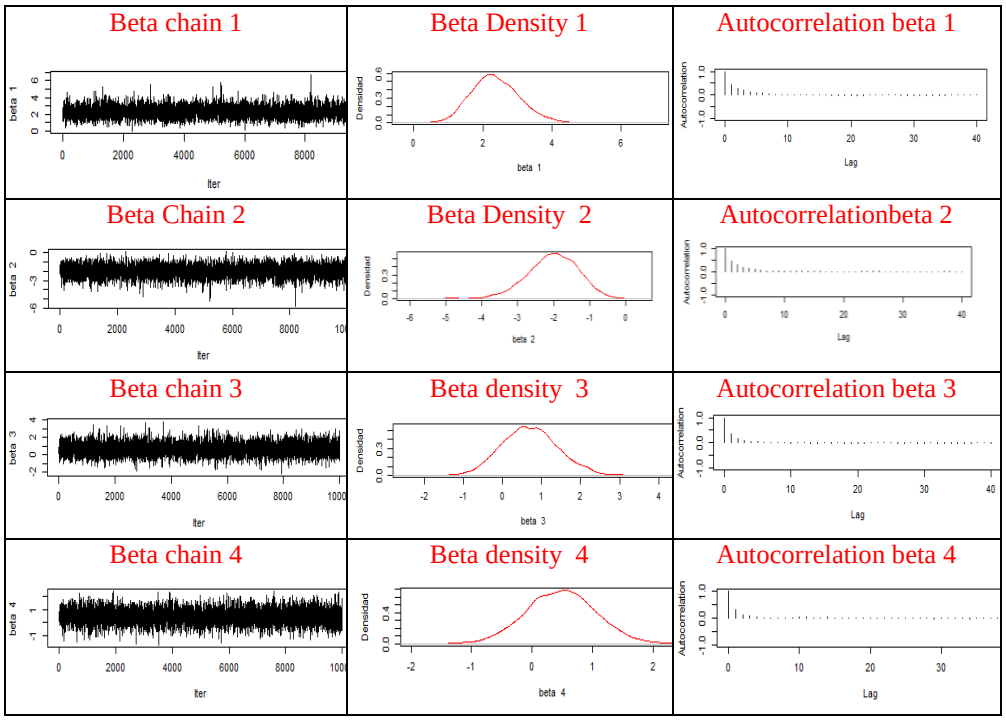

Fig 1. Chains, kernel density and autocorrelograms of the parameters.Program used R (Free Software)

4 Discussion and Conclusions

Table 2 shows the conclusions obtained from this study, indicating the general differences between family and non-family enterprises, and their comparison with the theoretical and three dimensions studied: strategy, organization and climate within the innovation process.

On the other hand, it is important to emphasize that the Bayesian generalized linear modeling methodology, in particular Bayesian logistic models, is an alternative statistical tool to deal with problems related to innovation management in family and non-family enterprises, where there is little data available Potential sources of error and where latent

variables are being measured. We found convergence and a good acceptance rate of the a posteriori samples for all parameters of the model.

Tabla 2. Differences between the Family and Non-Family Companies in the innovation process

Strategy	**Radical versus incremental innovation** - According to the description of the innovations generated by the family companies, these are usually of an incremental rather than radical nature, therefore, the theory is fulfilled. Family businesses focus on incremental innovations, while non-family firms are more often involved in new radical innovation projects.
	Focus on closed front Focus on open - Within the companies of the graphic industry studied, the first vision regarding the "opening" of the innovation process is maintained, which shows that family companies are much more likely to draw on external sources of knowledge and technologies during the activities Of innovation. Above all, this strategy is highly used by family companies aimed at improving processes that allow them to optimize resources. Since they are a little more closed in the development of innovations related in products. While unfamiliar companies take a much more closed and inward approach.**[18]**, it is considered that the family companies are of Analytical type, since they are in the search and adaptation of the new knowledge to The needs of the customer [19].
Organization	**Functional Organization vs. Multifunctional Equipment** - This variable is not scrutinized thoroughly through the survey, although it seems that its innovation processes were sufficiently formalized by giving a high relevance both to internal and external R & D activities, - Faced with R & D personnel: non-family companies have a higher percentage of doctors dedicated to R & D activities by 20%, compared to 13% for families. In the same way, it can be observed that non-family companies in terms of professionals (Engineers, Designers, among others) devote a greater proportion in R & D activities by 41%, compared with family members by 36%. But in technical personnel, it was found that family companies spend more people on R & D activities by 21% compared to non-family by 14%.

The innovation management of goods considered as tangible products according to these data and analysis methodology, is influenced by the family characteristics and the main product type of companies in the graphic design sector. Non-family businesses dedicated to book production are more likely to develop innovation activities in goods, you could say that these companies invest a greater amount of effort in the acquisition of technology and tangible gods.

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