Open Source Software: Management, Diffusion and Competition

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Abstract. The aim of this thesis is to contribute to the Open Source Software (OSS) research by a comprehending study of the factors that determine OSS diffusion, as well as the economic and social impact of this diffusion. The research focuses on the process of diffusion over time and assesses cause and effect relationships of the phenomenon. Firstly, it identifies and assesses the factors determining the diffusion and sustainability of OSS (cause). Secondly, it examines the effects of this diffusion at an economic and socio-political level (effect). At the economic level, the changes in markets structure and dynamics as a result of the OSS diffusion are analyzed. At the socio-political level, the study focuses on the effects in eGovernment and education.

The study grounds its results on a number of conceptual models that are based on a theoretical background with elements from the theories of technology acceptance and diffusion of innovations (DOI), as well as from social and economic theories. The models' evaluation is performed with the aid of rigorous methodological frameworks of mathematics and econometrics. Results can be a valuable input for both research and practice. For research, they provide with more accurate, a-priori estimations of the diffusion rate and the market competition. They also provide with the assessment of technological, social, economic and institutional factors that determine the OSS technology diffusion. As a result, they can become useful tools for strategic planning and policy making, in a continuously evolving and competitive environment such as the ICT market.

1 Introduction

OSS is an alternative model of software production and use, where source code is open for inspection, modification and distribution. OSS technology has introduced an innovative model of software development, based on self-organized communities that are open for participation to both users and developers. OSS innovation is twofold. First, the innovative method of organization and management of human and technology resources of OSS communities. Second, the OSS philosophy of open participation and the values of collaboration and sharing. According to Von Hipel, OSS is an innovation with a different value creation model, in which value is an outcome of collective intellect achieved through the OSS community [1].

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Over the last years OSS has moved to mainstream, creating a rapidly evolving ecosystem that provides with thousands of software solutions. From a managerial perspective, OSS offers critical advantages that have turned it to a competitive option to most organizations. As a result, most software production companies have reshaped their business models and strategies so as to include OSS development procedures. It can be deduced that OSS plays a critical role in the ICT markets. This, in turn, places research interest in OSS at a high level.

Although its technological aspects are the object of extensive research [2-6], many researchers have also stressed out the socio-economic changes caused by the emergence and rapid diffusion of OSS [1, 7, 8]. The multi-dimensional nature of OSS has attracted academics from different research fields, like software engineering, economics, sociology and even political economy [3]. Studies that have performed a thorough review on OSS [2-6], detected a severe gap in the literature concerning the diffusion process of OSS as well as the factors that underlie this diffusion. Also, very few studies have been found to examine the factors that determine existence and long-term sustainability of OSS products [9], which is closely related to its diffusion. This, in turn, calls for a comprehending analysis and study of the parameters that determine OSS diffusion and sustainability. Moreover, though the socio-economic aspects of OSS have been extensively discussed, important research questions like the impact of OSS on market structure and competition and the social effects of OSS, in relation to other open initiatives, like open government and education remain unresolved.

The aim of this thesis is to fill this gap in the literature and perform a holistic analysis on the OSS phenomenon in two aspects. First, to evaluate the factors that are critical to its diffusion and sustainability. Second, to evaluate the economic and socio-political effects of this diffusion. The methodologies and results of the studies implemented into the context of this thesis, are briefly presented in the following sections.

2 Sustainability of OSS

The study investigated factors that affect the long-term sustainability of OSS projects. For that purpose, the study thoroughly examined the development methodologies and processes of the SourceForge portal [10] and identified projects' characteristics that could affect sustainability. The empirical data were queried from a database that is provided by the University of Notre Dame (UND) for research purposes [11] and contains full SourceForge projects' activities. The proposed conceptual model is based on the Unified Theory of Acceptance and Use of Technology (UTAUT) [12] and the IS success model [13]. The model defines the metrics of the impacting factors based on project's characteristics and considers the performance of these metrics in three distinct time periods. The aim of using different time segments is the evaluation of the impact of the factors of one time period as a cause for the users' behavior on subsequent time periods. The model consists of a number of structural equations and evaluates the weight of impact of the different time-dependent factors on long-term sustainability. The methodology for the model's evaluation is the Structural Equation Modeling (SEM).

Results indicate that the ability to attract the users' interest initially and active users and developers in the next period are the two critical factors for a project's sustainability. The user's choice is influenced by the performance and productivity of the community. The final decision depends on the social influence exerted through dis-

cussions of community fora. The research has been submitted to the scientific journal 'European Journal of Information Systems (IS)' and is under review process.

3 OSS diffusion.

The research estimates the cross-country OSS diffusion and the factors that shape this diffusion at a country level. Taking into account the multidimensional nature of OSS, a new theoretical framework is proposed as a lens for the identification of the possible impacting factors. The framework consists of the theories of exogenous and endogenous growth and institutionalism. A country is conceptualized as a socio-economic system within which OSS growth occurs. The model is based on the idea that the forces of growth to an economic system comprise of institutional, endogenous and exogenous factors and is specified as:

$$OSS_{it} = F(X^{endog}, X^{exog}, X^{inst}) \quad (1)$$

Where OSS_{it} is the OSS growth rate determined by the three vectors of factors relevant to endogenous growth (X^{endog}), to exogenous growth (X^{exog}) and institutional theories (X^{inst}), for each country i, at time t. In this sense, growth is not restricted to economic development, but includes social, institutional and technological aspects. Into this context, two studies were implemented.

The first study examines the OSS diffusion process at a country level, under the prism of DOI theory and a parameterized diffusion model proposed by Dekimpe et al. [14]. The factors shaping the diffusion were drawn from the theoretical framework described by (1). The parameterized diffusion model allows for the comparison of diffusion parameters across countries and the evaluation of variables that may affect diffusion at different stages of the diffusion process. The model parameters are estimated and the significance of each of the factor is evaluated by a means of non-linear regression methods.

Research results indicated that a country's innovation level and human capital have a significant effect in all stages of diffusion. An important finding is also the different impact of the factors, depending on the diffusion stage. Technological infrastructure, economic status and institutions are more significant at the initial stage of OSS diffusion, while a nation's human capital and innovation activity are more important for subsequent stages. The research has been submitted to the scientific journal 'Information Technology and Management' and is under review process.

3.1 Diffusion of OSS: the case of the Apache web server

Previous research in OSS diffusion is very limited [15, 16]. Taking a case study approach, this study focuses on the diffusion process of a well established OSS, that is, the Apache web server. The study proposes a theoretical framework that consists of the DOI theory and the socio-economic theories as presented in (1) and aims to: (i) Estimate and forecast the market saturation of the Apache web server and provide with critical information for the interpretation of the diffusion process, namely the current stage of the market with respect to its saturation level and its inflection point. (ii) Evaluate the impact of socio-economic, country-level factors that affect the Apache's market saturation in different economic environments.

The theoretical framework is illustrated in Fig. 1. As shown, the research consists of two distinct steps. Firstly, the estimation of Apache's diffusion and market satura-

tion is based on the mathematical modelling drawn from the DOI theory, by means of a dynamic diffusion model [17]. The model assumes a time-variant market saturation, able to reflect the rapid diffusion of the web servers market. Secondly, a number of factors are evaluated for their impact on the Apache's market saturation. The factors are drawn out of the theories of institutionalism and exogenous and endogenous growth, as described in (1). The study's results are published in [18].

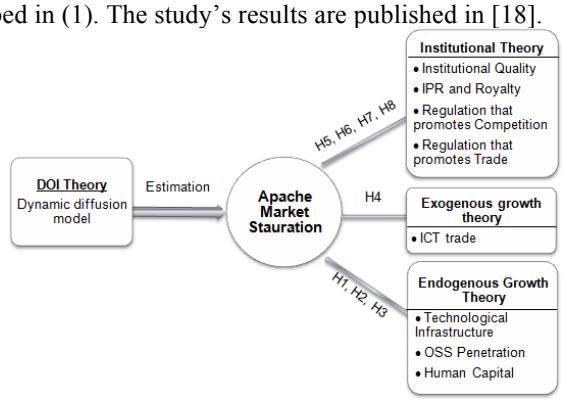

Fig. 1. Theoretical Framework

Estimation and forecasting of the Apache web server diffusion .

The diffusion process is estimated by the dynamic diffusion model proposed by Mahajan and Peterson [17]. The model assumes that the saturation level $\overline{\mathrm{N}}(\mathrm{t})$, is not constant, but a function of time and can be expressed as $\overline{\mathrm{N}}(\mathrm{t}) = \mathrm{f}(\mathrm{S}(\mathrm{t}))$, where S(t) represents the vector of all relevant exogenous and endogenous factors affecting $\overline{\mathrm{N}}(\mathrm{t})$. The proposed model takes into account the influence of one only factor, namely, the total market population growth (denoted by $P(t)$=S(t)) and assumes that the rate of increase in the market saturation with respect to the total market population, at any time t, is a constant. That is:

$$\frac{\mathrm{d}\overline{\mathrm{N}}(\mathrm{t})}{\mathrm{dP}(\mathrm{t})} = \mathrm{k}_2 \tag{2}$$

Integration of equation (2) yields (3), where k_1 is the integration constant and k_2 is the growth rate of market saturation with respect to total market population.

$$\overline{N}(t) = f\left(S(t)\right) = f\left(P(t)\right) = k_1 + k_2 P(t) \tag{3}$$

The final formulation of the dynamic model is given by:

$$\begin{aligned} &\frac{dN(t)}{dt} = \left(a + bN(t)\right)\left(\overline{N}(t) - N(t)\right) = \left(a + bN(t)\right)\left(k_1 + k_2 P(t) - N(t)\right) \\ &N(t = t_0) = N_0 = 0, \overline{N}(t_0) = f_0 \end{aligned} \tag{4}$$

where N(t) refers to the cumulative number of adopters at time t. Also, a and b are the parameters of innovation and imitation of the diffusion process, respectively. N_0 represents the number of adopters at time t_0 and f_0 is the initially estimated saturation level at time t_0 .The solution of the differential (4) gives the number of adopters of Apache, at each point of time t. Moreover, $P(t)$ can be estimated by the logistic diffusion model and thus is formed as follows:

$$\begin{aligned} &\frac{dP(t)}{dt} = \left(m_1 + m_2 P(t)\right)\left(\overline{P} - P(t)\right), \\ &P(t = t_0) = P_0 = 0 \end{aligned} \tag{5}$$

Where $\overline{P}$ is the population saturation level and the parameters m_1, m_2 are the parameters of innovation and imitation. The parameters $\overline{P}$, m_1, m_2 are estimated using the Nonlinear Least Squares (NLS) regression method. The estimation of a, b, k_1, k_2 is based on the discrete regression analogue of (4), as shown in (6) and NLS. The regression coefficients x_1, x_2, x_3, x_4, x_5 give the estimates for the model parameters.

$$N(t+1) = x_1 + x_2 P(t) + x_3 N(t) + x_4 N(t)P(t) + x_5 N^2(t), \quad (6)$$

$$x_1 = ak_1, x_2 = ak_2, x_3 = k_1 b - a + 1, x_4 = k_2 b, x_5 = -b$$

The cumulative number of Apache web servers, N(t), are extracted from Netcraft' s Web Server Survey [19]. The data span from the year 1996 to 2010 and are on a six months basis. The total population size, P(t), of the market corresponds to the total population of all possible web server adopters and its measure can be approximated by the number of Internet users. This can be justified by the fact that a potential web server adopter should firstly establish an Internet connection. The data for the Internet users penetration are derived from the United Nations (UN) database. The estimation of the parameters m_1, m_2, a, b, k_1, k_2 was derived by 24 observations, while the next 5 observations were used as a feedback sample to evaluate forecasting. To further evaluate the dynamic model's performance, the logistic model was used as a benchmark model. The evaluation of the estimation and forecasting is given in Table 1.

Table 1. Evaluation of the estimation and forecasting results

	Estimation		Forecasting	
	Observations: 24		*Observations:* 24	
	Dynamic Model	*Logistic Model*	*Dynamic Model*	*Logistic Model*:
R^2	0.98	0.98	0.988	0.81
MSE	9.4	9.21	15.4	78.3
MAPE	1.3	2.145	1.068	2.808

The above table shows that the statistical measures (R^2, MSE and MAPE) confirm the dynamic model's effectiveness in fitting, for both estimation and forecasting. It can be elicited that both the dynamic and logistic models effectively estimate diffusion, yet the dynamic model has a superior forecasting ability as compared to the logistic. This is mainly due to the time variant market potential, which captures the growth of the market and shifts the diffusion curve up to higher values. Graphically, the diffusion curves are illustrated in Fig. 2.

In addition, the inflection points of both the logistic and dynamic models were calculated. As shown in Fig. 2, there is big difference in the estimations with the logistic model showing that Apache has reached the inflection point at t*= 23 (year 2007), while the dynamic model is predicted to reach the inflection point at t*=38 (year 2014) and which is a much more realistic value. The shading parts of the figure correspond to the forecasted values of the diffusion. It can be deduced that the low value of the constant saturation level $\overline{N}$ (estimated at 112.81 million) of the logistic model shapes a downward slope that increases the gap between the last observations of the data. On the contrary, the time variant saturation level (estimated at 167.52 at t=38) of the dynamic model shifts the curves up resulting in much better fitting, especially for the forecasted values (time segments 25-29).This confirms the necessity for a non-constant market saturation for the rapidly diffused Apache web server. Findings suggest that Internet penetration has a positive impact on the market potential for Apache and that the growth of Apache has not yet reached its maximum rate (inflection

point). As a result, the diffusion curve and the market potential are still at a growing stage.

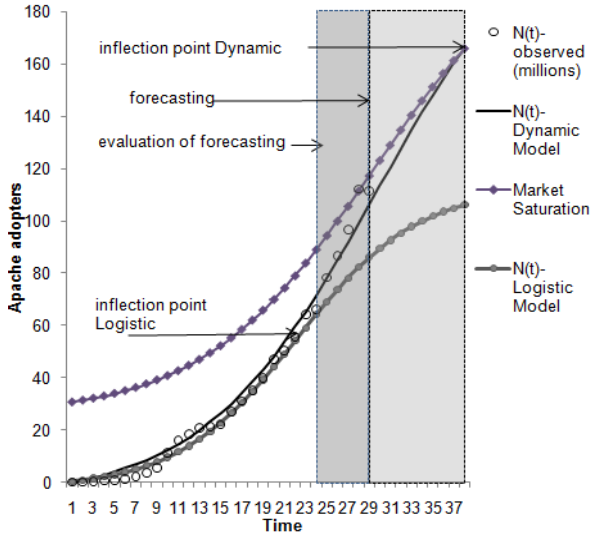

Fig. 2. Diffusion curves and forecasting for Apache

Socio-economic factors that determine the market potential for Apache.

Taking into account the theoretical framework in (1), the model assumes that market saturation depends on institutional, endogenous and exogenous factors and is specified as:

$$\bar{N}^i(t) = F(X^{it}, Y^{it}, Z^{it}, \vartheta^i) \quad (7)$$

where X^{it} is a vector of all factors relevant to endogenous growth theory, Y^{it} a vector of all factors relevant to exogenous growth theory, Z^{it} a vector of all factors relevant to institutional theory, for each country i, at time t. In addition, ϑ^i a country specific variable, which determines developed and developing countries. Market saturation $\bar{N}(t)$ of the Apache web server is the dependent variable, explored in terms of possible influencing factors. The expected market saturation $\bar{N}^i(t)$ for each country i, can be estimated by equation (3), that is,

$$\bar{N}^i(t) = k_1 + k_2 P_i(t) \quad (8)$$

where Pi(t) is the number of Internet users for each country i and the parameters k_1, k_2 have been estimated with the dynamic model. By substituting the values of Pi(t), k_1, k_2 in (8), the expected market saturation for each country is obtained. The factors are evaluated for their impact on the Apache market saturation, by means of a panel data analysis of 25 countries selected so as to represent different regions and economic status. The choice for the possible influencing factors was grounded on certain hypotheses. The statistical tests performed for the econometric model that derived out of (7) showed evidence of endogeneity, thus the Two Stage Least Squares (2SLS) regression with Generalized Method of Moments (GMM) and Heteroscedasticity and Autocorrelation (HAC) errors was the most effective method.

Regression results are presented in Table 2. It can be deduced that the diffusion of Apache depends on both endogenous and exogenous to a country factors, namely technological infrastructure, level of skills and education and ICT trade. The institutions and rules and laws of an organized society were also found to positively affect the growth of the Apache technology. On the contrary, regulation that promotes com-

petition does not appear to have any impact. Finally, Apache saturation levels are higher in developed versus developing countries, an outcome which is in accordance with other technological innovations and the problem of digital divide.

Table 2. 2SLS GMM regression results for $\overline{N}(t)$

Second regression: ln($\overline{N}(t)$)				**First regression: IQ**		
No of Observations:112				**No of Observations:**112		
F(9, 102)= 86.76***				**F(11, 100)**= 66.87***		
Vars	**Coef.**	**S. Err.**	**z**	**Coef.**	**S. Err..**	**t**
lnphone	0.570	0.049	11.72***			
ICTexp	0.085	0.035	2.43**			
ICTtrade	0.015	0.003	4.32***			
HCI	0.011	0.007	1.91*			
lnOSS	0.190	0.040	4.73***			
educ	0.088	0.034	2.58***			
B_R	0.021	0.023	0.91			
OECD	-0.411	0.158	-2.60***			
cons	-5.901	0.785	-7.52***			
IQ	0.280	0.131	2.14**			
lnroyalty				0.179	0.039	4.63***
TradeBar				0.137	0.043	3.16**
IPR				0.094	0.023	4.08***

Notes: Significance levels: * = $p < .10$, ** = $p < .05$ and *** = $p <. 01$.

4 Economic impact of OSS diffusion.

The research focused on the impact of OSS on ICT markets structure and competition and consists of three studies. Initially, ICT market characteristics and dynamics were explored and analyzed in relation to the OSS special economic attributes that affect competition [20, 21]. The first study identifies and discusses the new dynamics formed in software markets due to the emergence of OSS. The impact of OSS in competition is further evaluated by applying the Herfindahl-Hirshman concentration index (HHI) on market shares data in three widely used software market segments, that is, web servers, web browsers and operating systems. HHI results indicated that though markets exhibit concentration, there are clear upward trends in competition. Market analysis showed that OSS has changed the strategies of most dominant software companies towards the creation of new OSS business models. This, in turn, has created new market entries and raised competition and market dynamics [22].

Further investigation and analysis of the OSS business models (OSS BM) was conducted in the second study. The objective of this study is to provide with a comprehensive and generic OSS BM framework that explicitly defines its structural elements, describing the deeper structure of what firms, adopting an OSS strategy, actually do. The study following the structured-case methodological approach [23] conducted two research cycles. In the first cycle, a sample of 100 popular OSS related firms instances is considered as ‘pilots’ organizations, in order to explore the different

possible business models cases. The instances were chosen so that to represent all three aspects of ICT markets, i.e. software, hardware and services sectors.

The second research cycle aims to validate, evaluate and further improve the initial findings by means of data collected from questionnaires and a workshop with eighty two participants, experts from the Greek OSS market and Academia. The research cycles revealed new concepts, dimensions and building blocks of the ontological OSS BM. The elements that differentiate OSS BM from the classical business models are the way of organizing production, the different OSS licenses, the innovative models of profit and the OSS community. The taxonomy of OSS BM was derived by a vertical analysis of the structure "*offered value*". Research results were published in [24].

4.1 Analysis of the operating systems market dynamics and competition

A deeper research in the effects of OSS in markets structure and equilibria was conducted in the field of the operating systems market. The study considers a highly concentrated market, the desktop (DT) and laptop (LP) operating systems sector, in order to provide some insights of the potential of OSS even in the case of high market concentration.

Based on concepts of population dynamics and organizational ecology, the study analyzes the evolutionary and competitive dynamics of the three leading players of the market, namely the OSS Linux, the partly-OSS Mac OSX and the proprietary Windows operating systems. Market evolution is estimated and forecasted by applying the Lotka-Volterra competition (LVC) model, which describes the competitive interaction of species for a common supply [25, 26]. The model's parameters were estimated by applying genetic algorithms, which are adaptive heuristic search algorithms based on the mechanisms of natural systems and genetics.

The main assumption of the methodology was to consider the three software products as interacting species competing for a common source, the market itself, expressed in terms of market shares. The empirical analysis showed that, at the equilibrium, all operating systems will coexist, while the highly concentrated market will tend to become less oligopolistic. Regarding the dynamics of the market, it was shown that Mac OSX has the highest growth rate and is less affected by the competition with the other systems, while is more affected by its own growth dynamics. An indirect mutualism effect, where the partly OSS Mac OSX is ultimately benefited by the existence of Linux, could also be deduced. Windows on the other hand experiences a decrease in its share, as it faces intense competitive pressures by both Linux and Mac OSX, with Linux being its main opponent. Results show that Linux shares are raised mainly due to Windows users that churn to Linux. However, the low growth rate of Linux is not expected to increase substantially, at least under the current market conditions and Windows will retain its leading position.

The above results add to the issue of the impact of OSS on competition. Firstly, OSS has a direct impact by the emergence of quality OSS such as Linux, which can offset the monopolistic behavior of the software market. Even in the highly concentrated DT/LP OS market, Linux not only survives but also raises its shares. Secondly, OSS allows for the creation of new business models, like the partly OSS that enable successful entrance in the market. The partly OSS Mac OSX paradigm shows that Mac OSX, though a late follower, has successfully entered a highly concentrated market.

As one step further, the study performs a sensitivity analysis of the possible effects on market behavior, induced by a rise in Linux adoption. Such a rise could be attributed to an organizational change of policy towards Linux adoption, as for instance in the public sector, following a governmental initiative. In this case, the Lotka-Volterra model is reformed to accommodate different adoption levels of the Linux operating system. Results demonstrate the effects of such policy on market concentration, according to different levels of Linux adoption. Findings also reveal useful implications for practice, in terms of the role of OSS and its derivative partly-OSS products in markets with high concentration. The main outcomes, which also define the importance of contribution of the proposed methodology, are the estimation of the modeled system dynamics, the provision of forecasts regarding market equilibrium and the estimation of the "churn effect", which reflects the level of users' switching among the operating systems. The model also provides information on the survival or extinction of each species due to the competition effects and the market structure at the equilibrium. he research has been published in [27].

5 Socio-political impact of OSS diffusion.

OSS ideology carries the notions and values of freedom, transparency and openness, active participation, cooperativeness and sharing that has created a new philosophical stream. The principles of OSS have extended beyond the software and inspired other forms of "open" initiatives, such as open standards, open access, open content, open science, open education, open government, open innovation and more. This thesis examines the impact of OSS in two sectors that have been highly affected by this openness: eGovernment and education.

5.1 OSS and eGovernment.

The relation of OSS diffusion and eGovernment maturity is examined at a national level, under the prism of the theoretical framework of the socio-economic theories of institutionalism, exogenous and endogenous growth, as presented in (1). The theoretical framework was deemed appropriate for two reasons. Firstly, because it was successfully applied for explaining OSS diffusion. Secondly, because the endogenous growth theories and institutionalism have been widely used in the case of eGov. Into this context, three distinct conceptual models were created and evaluated by means of econometric methods on secondary, cross-national data.

The two of the models focus on the impact of OSS on eGov maturity and use FGLS regression to statistically evaluate the corresponding models. Both models agree that OSS diffusion has a significant impact on eGov maturity. It can be concluded that OSS exerts a positive impact in eGov policies, like transparency, democracy and citizens' active participation, which are the characteristics of the eGov's higher maturity levels. The first model's results were published in [28], while the second's in [29].

Taking one step further, the third model investigated the simultaneity in the relation of OSS diffusion and eGov maturity. The model consists of two structural equations that express OSS and eGov mutual effects and is evaluated by means of a Simultaneous Equations Model and 2SLS regression. Results validated the positive impact of OSS diffusion on eGov maturity, yet rejected the assumption of a simultaneous relation. This research has been submitted to the scientific journal 'Technological Forecasting and Social Change' and is under review. Findings also provide with interest-

ing information on the impact of innovation on OSS diffusion and other country level factors that affect eGov maturity. These include institutional (governance effectiveness, freedom of the press, regulatory quality and the quality of institutions) and economic factors (ICT trade). Social development, however, exhibits the highest impact suggesting that higher levels of living and education are essential conditions for effective eGovernment.

5.2 OSS and education.

In the education field, OSS has gained wide acceptance. A number of well known and established OSS communities and organizations have created software properly configured for education purposes. However, the success story for OSS, is the online education (E-learning) and the electronic Learning Management Systems (LMS) and Content Management Systems (CMS), with highly diffused software (e.g. Moodle, Sakai). A combination of open content and E-learning is the Open Educational Resources (OERs).

The study, reviewing the literature identifies factors that impact the diffusion of OSS in the education field, that is, the usual OSS advantages, like quality, cost-effectiveness and compatibility. However, there are some additional factors, like the ability for course customization by teachers and students, the low system requirements and the different levels of learning. Especially, important are the fast diffusion of knowledge through the OSS communities, the encouragement and promotion of collaborative and open way of learning, the promotion of open content and open education. The successful implementation of open content initiatives has lead to the development of a new education model, the open education. It can be concluded, that the role of OSS in the digitalization of education is twofold. Firstly, it provides with cost-effective, yet qualitative education software. Secondly, its philosophy sets the stage for new education models based on open standards, collaboration and active participation of both students and teachers.

6 Conclusions

The study contributes to the OSS research by the creation and development of new methodologies for the estimation and evaluation of the OSS diffusion process and the underlying critical factors, as well as the social and economic implications of this diffusion. Results, as explicitly described in the previous sections, revealed that OSS diffusion mainly depends on a country's technological infrastructure, innovation and education levels and social development. Also, the continuous attraction of users and developers in OSS communities, ensure its sustainability. For the economic impact, findings suggest that OSS plays a critical role on markets and competition, creating new business models and structures. All prediction models applied into the context of this thesis, were quite favorable to OSS, with steadily increasing trends of adoption. Finally, the positive relation of OSS and eGov verify its socio-political implications.

The research conducted for this thesis provides with useful input for both research and practice. For research, it brings in a new theoretical framework for the study of OSS diffusion that consists of three socio-economic theories: endogenous and exogenous growth theories and institutionalism. Into this context, it has developed methodologies for (i) the estimation of the international Apache diffusion and the factors that

impact market saturation, (ii) estimation of the cross-national OSS diffusion and the impacting factors at different stages of the diffusion process. It also implemented a conceptual model that is able to evaluate the critical factors for OSS sustainability.

Finally, it developed methodologies for the analysis and evaluation of the economic and socio-political impact of OSS. These include (i) the assessment of the OSS impact on market structure and competition, (ii) the creation of a competition model that estimates and forecasts the concentration, dynamics and the future market equilibrium of the operating systems market, (iii) the development of a holistic conceptual framework that provides with insights into the critical ontological elements of OSS BM and a taxonomy of the various OSS BM with an assessment of their risks and opportunities, (iv) the creation of models for the evaluation of the relation of OSS with eGovernment.

For practice, research results can become valuable input for strategic planning and policy making, as they provide with more accurate, a-priori estimations of the diffusion rate, the market competition and equilibrium, in a continuously evolving and competitive environment such as the ICT market. They also provide with the evaluation of the factors that constitute to the diffusion and sustainability of OSS, which are important information for organizations in designing their strategies. For the enterprises, which are planning to encompass OSS into their business models, the proposed OSS BM framework can become a useful tool. The conclusions for the relation of OSS diffusion and eGov maturity could also be taken into account at a political level, as they involve the assessment of technological, social, economic and institutional country level factors.

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