Simulation of tariff plan selection by online users using Agent Based Models

Aneesh Zutshi*, Tahereh Nodehi**, Ricardo Jardim-Gonçalves** and Antonio Grilo*
* DEMI, FCT, Universidade Nova de Lisboa,
** DEE, FCT, Universidade Nova de Lisboa,
aneesh84@campus.fct.unl.pt, t.nodehi@campus.fct.unl.pt, rg@uninova.pt, acbg@fct.unl.pt

Abstract—Online Businesses can be represented as a complex interaction of interconnected online users responding to the value proposition of an online company. We propose an Agent Based Modeling framework (DYNAMOD) that aims to explain these complex dynamics. This framework aids in the creation of simulation models that mimic the actual market behavior and perform business forecasting and decision support functions. Through a case study of the largest e-procurement provider in Portugal – Vortal.biz, we simulate their pricing model and its impact on user behavior and revenue.

I. INTRODUCTION

Understanding the new digital economy has been a challenge for companies that were tuned to the traditional ways of doing business and were armed with traditional product development and marketing philosophies. Today Digital Business managers often rely on experience and intuition to set up business models and pricing strategies. Though marketing surveys, have been traditionally used in gauging consumer willingness to pay, a big challenge is to predict business growth, customer adoption and customer response to specific business and pricing models [1], [2]. Online Businesses are complex interacting systems where online users interact and share opinions and experiences at a rate far greater than traditional brick and mortar businesses. These user opinions are shared through offline and online word of mouth (WOM) channels, in addition to various marketing channels. Customer Satisfaction is a key to spread of positive or negative WOM, which influences new customer adoption rate. System Dynamics have often been used to model consumer adoption [3]. However System Dynamics require the rules of the behavior to be written at a higher level, such as how the whole population of consumers will respond to a marketing activity rather than how a particular individual will respond [4].

Online businesses are examples of a complex system, where the behavior of individual users can be used to model the growth or decline of a business proposition [5]. This could provide an analytical approach to develop models that can be used by businesses as a decision support system. Such models can perform a range of objectives, such as making business forecasts, calculating the implications of a change in product pricing, optimization of different price plans, and simulating the impact of a change in the Business Model.

Agent Based Models have been chosen as the most appropriate tool to implement this complex systems approach. Agent Based Modeling is a new computational method through which macro-level consequences are explained through simplified representation of micro level interactions between agents that represent real life entities [6]. These autonomous agents represent online users with individual characteristics as well as independent internal decision making capabilities.

In this paper, we propose a Dynamic Agent Based Modeling Framework (DYNAMOD), that incorporates Agent Based Modeling (ABM) techniques to develop and test digital business models in a variety of online market scenarios. Further, this paper explores its applicability to forecast and simulate changes in the Pricing Models for the largest Portuguese e-procurement platform provider – Vortal.biz.

II. THE MODELING SCENARIO

Vortal.biz is the largest procurement platform provider in Portugal and has a market penetration close to 90% of its assessed potential market. Such a high penetration was possible due to the use of a freemium pricing model and the ability to attract a high percentage of large buyers. Vortal’s platform is an example of a double sided platform that tries to attract large volume buyers on one side and sell monthly subscription plans to various vendors on the other side. The buyers include both public and private entities. Contracts with buyers are often negotiated on a case to case basis with large discounts being offered to bulk buyers to make the platform more attractive for sellers. Sellers are offered the choice of choosing between a range of tariff plans. This paper only focuses on creation of an Agent Based Simulation Model for the sellers. This is firstly because contracts with buyers are more arbitrary in nature and hence difficult to model and secondly, in a short time period of one or two years, the number of buyers do not significantly change due to a saturated market penetration by Vortal. Hence the business may be modeled as a single sided platform despite being a double sided platform in reality.

A. Tariff Plans

The Sellers are offered a freemium tariff plan with the Universal plan as a basic free plan. Smart Plans offer 4 advanced features while Best Plans offer 4 more
advanced features. Universal (U), Smart-Gov (SG) and Best-Gov (BG) plans offer clients access to opportunities only from the Public entities while Smart-Eco (SE) and Best-Eco (BE) also offer opportunities for the Private as well as public entities. The Sellers are charged a Monthly Tariff based on the company size according to which four Tiers of Tariff are offered. However since the largest number of clients are in Tier 1, we will consider only Tier 1 in this simulation. Similar simulation models can be prepared for other Tiers.

B. Model Objectives

The model seeks to simulate the customer response to different plans and offerings in order to develop an agent based simulation model that can simulate the impact of changes in pricing of the various Tariff Plans. Also, the company was interested in viewing the attractiveness of offering users the option of using one of the premium features without upgrading to the higher tariff plan. Such a scenario was also modeled in this simulation. To summarise, the specific objectives of the model are as follows:

1. Simulate the upgrade of customers to newer tariff plans.
2. Simulate the subscription of a single feature instead of upgrading to a newer tariff plan.

III. THEORETICAL BACKGROUND

The development of the DYNAMOD model is based upon other previous research works in diverse areas. Some key concepts that have been applied in the model are discussed below

A. Use of Agent Based Models for Solving Business Problems

New tools and techniques are necessary to help model the complex nature of online products and services. Hence we need to develop a customizable simulation environment that can capture the dynamics of an online market, and provide Business Managers with tools to simulate and forecast, thus aiding to perfect their Business Model. Online markets can be represented as a network of interconnected online users which share positive and negative feedbacks and respond to different online products and services. If the behavior of individual agents can be sufficiently well modeled, then a natural candidate for representation is multi-Agent Based Modeling Techniques.

ABM is build on proven, very successful techniques such as discrete event simulation and object oriented programming [7]. Discrete-event simulation provides a mechanism for coordinating the interactions of individual components or “agents” within a simulation. Object-oriented programming provides well-tested frameworks for organizing agents based on their behaviours. Simulation enables converting detailed process experience into knowledge about complete systems. ABM enables agents who represent actors, or objects, or processes in a system to behave based on the rules of interaction with the modelled system as defined based on detailed process experience. Advances in computer technology and modelling techniques make simulation of millions of such agents possible, which can be analysed to make analytical conclusions [8].

The literature review reveals that applications of ABM have been made to model specific areas of Business. These include prediction of financial distress [9], product adoption [(S. Kim et al. 2011), [11], [12], [13]], consumer behaviour [[14], [15]], market share [16], Urban Management [17] and demand forecasting [18], [16] demonstrated the possibilities of predicting market share based on certain BM attributes of Frontier Airlines. [19] addresses the issue of capturing Internet behaviour to deliver relevant advertisements. ABM approaches can also be used for modeling user response to different sources of advertising. It can also be used to model response to identify the most critical target groups, complementing traditional approaches for the same [20].

[21] propose an Agent Based Model to simulate consumer decision making based on culture, personality and human needs and relates them to car purchase decisions. Tesfatsion introduced Agent-Based Computational Economics (ACE) as the computational study of dynamic economic systems modeled as virtual worlds of interacting agents. [22] have applied ACE to retail and wholesale energy tradings in the Power Markets. In this paper we extend the concept of Agent-Based Computational Economics, to develop DYNAMOD- An Agent Based Modeling Framework for online Digital Business Models.

IV. THE VORTAL ABM MODEL

A. The generic DYNAMOD Model

The Vortal Model is based on the customization of the DYNAMOD Simulation model that has been applied to a variety of online business case studies before. The DYNAMOD Framework has been developed based on the academic literature collected regarding the unique aspects of an online business. Its purpose is to provide researchers and companies engaged in online businesses with a tool for quickly developing Computational Modeling Systems that can represent their Business Models and their Business Environment, in order to perform advanced simulations for predicting business growth dynamics. DYNAMOD is based on Agent Based Modeling, which enables dynamic representation of the online marketplace. Every Buyer that is a customer for a product or service is represented as an Agent in DYNAMOD. These agents interact with each other and share information about new products and services. At the same time, they are influenced by Advertising and Social sites. The model captures these influences, and simulates their impacts in order to predict future scenarios.

The model is customizable and extendible to implement a diverse set of Business Model components, and to make a variety of simulations. The model core consists of many interacting agents that represent a market. The model includes standard variables and logics
for implementing influence and satisfaction scores for each agent. This core component handles the simulation and interaction, and defines what constants are needed to initialize the key features of the model.

Other features are added to the model in the form of modules, as and when necessary, for different case scenarios. In the current scope of the model, four additional modules have been envisaged, namely Competitor Analysis, Pricing Analysis, Network Effects/Viral Marketing Effects, and Market Segmentation/Region Based Modeling.

Diffusion of Innovation literature has used two major forms of adoption functions [23]. In the Bass like model, adoption occurs through individual innovation or through peer imitation[24]. In the threshold model, each user adopts only when a certain threshold of its neighbors have adopted[25].

B. Formalization of the Simulation Model

Client Upgrades

The model tries to simulate the upgrade of users to higher tariff plan based on their willingness to pay. The upgrade choice for users is based on the assumption that a user will only choose to upgrade one level up at a time, and a user on a plan with access to public as well as private opportunities will not like to move to a plan that restricts opportunities for him to only the public opportunities. Hence, the Universal users may upgrade to Smart-Gov or Smart-Eco, Smart-Gov users may choose to move to Smart-Eco to expand their markets or may choose to move to Best-Gov plan if they would like to continue access to the same public opportunities but with enhanced features. Similarly users may upgrade from Smart-Eco as well as Best-Gov to Best-Eco. (See Figure 1)

![Figure 1. Client Upgrade Options](image)

To determine if a user is willing to upgrade to a higher plan or not, we need to identify the user willingness to pay for the higher plan. This was determined through sample online surveys where each user was asked about his interest and willingness to pay for the tariff plan options that he is most likely to upgrade to.

For each User Agent \( A_i \), the current plan, \( A_i[\text{plan}] = 0, 1, 2, 3, 4, 5 \) corresponding to Universal, Smart-gov, Smart-eco, Best-gov, Best-eco.

Willingness to Pay for an agent \( A_i \) currently on Plan n for Plan \( m \) = \( A_i[\text{WTP} - n - m] \)

Current Price for Plan \( n = \text{Price-}n \)

An agent with \( A_i \) on universal plan will upgrade to Smart-Gov if it is willing to pay more than the current price.

If \( (A_i[\text{WTP} - 0] >\text{Price-}n) \), \( A_i[\text{Plan}] = [0 \rightarrow 1] \)

In case an agent is eligible to upgrade to more than one higher plan, he will upgrade to the plan that he sees a higher value, ie, his willingness to pay is higher.

For any optimized pricing model, the company is interested in maximizing the Total Monthly Revenues.

\[
\text{Total monthly revenue} = R = nSG * \text{Price-1} + nSE * \text{Price-2} + nBG * \text{Price-3} + nBE * \text{Price-4}
\]

Where \( nSG, nSE, nBG \) and \( nBE \) are the number of Agents currently on plan Smart Gov, Smart Eco, Best Gov and Best Eco respectively.

C. Optional Features

Vortal was interested in using this model to simulate the impact of additional revenue generation models. One of the possibilities included the introduction of users to chose one optional premium feature from a higher plan without needing to upgrade to a higher plan. The features are listed as follows:

\{f1, f2, f3, f4\} are offered in plans SG, SE

\{f5, f6, f7, f8\} are offered in plans BG, BE

A user at plan U does not have access to any of the features. He may chose to subscribe to f1 or f2 or f3 or f4 but not to more than one of them at the same time. Similarly one of f5, f6, f7 or f8 is available to a user of SG or SE Tariff plan. Features must be priced in a way such that they do not cannibalise the upgrades to a higher tariff plan. The set of possible monthly prices for the eight features are:

\{f1, f2, f3, f4\} can have the following prices \{€40, €60, €80, €100\}

\{f5, f6, f7, f8\} can have the following prices \{€30, €40, €50, €60\}

An agent with \( A_i \) on universal plan will upgrade to f1 if it is willing to pay more than the current price of f1. If this is true the flag f1 for the agent \( A_i \) is set to 1.

\( (A_i[\text{WTP-0-f1}] >\text{Price-f1}) \), \( A_i[\text{f1}] = [0 \rightarrow 1] \)

The users willingness to pay for different features were again collected through the sample survey. User’s willingness to pay for each of the features were evaluated and a distribution of the same was used for programming the agents in the simulation model. If an agent’s willingness to pay is higher for more than one feature, and he is not ready to make the switch to a higher tariff plan, then the feature for which his willingness to pay is the highest shall be adopted to. If he has the same willingness to pay for more than one feature, then the order of utility for features according to the overall utility of various features based on the sample survey.

D. Data Collection for the Vortal Model

An Agent Based Model mimics the real life consumer opinions and preferences and uses these to simulate the larger business scenario. To gauge user opinions, preferences and willingness to pay for various tariff plans, we conducted an online questionnaire to gauge the user satisfaction, influence from various sources of advertising and willingness to pay for upgrade to a higher plan. The questionnaire was sent to 7000 randomly selected clients. The total number of respondents were 365 (U – 290, SG- 37, SE -19, BG- 15, BE-4) which is a
response rate of more than 5%. The distribution of respondents according to the maximum willingness to pay for an upgrade is shown in

Similarly, the willingness to pay for each of the 8 features was obtained from the respondents and arranged according to the current tariff plan that they are currently on. These were fed into the Simulation Model for the purpose of simulating user adoption of feature based pricing.

E. NETLOGO – The Agent Based Modeling Tool used

The DYNAMOD model is generic and can be modeled using any modeling language. However we have used NETLOGO 5.0.3 as the development environment to model this case study. This provides us with an extensive library to program the agent behavior, environmental constraints and the modeling parameters. It also provides us with a graphical interface to review the simulation results.

NetLogo is a freely downloadable, agent-based software package that was created at the Center for Connected Learning and Computer-Based Modeling (CCL), directed by Uri Wilensky, at Northwestern University. NetLogo utilizes a simple programming language and a convenient user interface allowing models to be easily simulated and evaluated. The software application is designed to be easy to use yet is broadly utilized by academics in the social, computer, and “hard” sciences. NetLogo is extremely flexible. Interactions not only among autonomous agents, but also between agents and the simulated environment, can be specified.

![Figure 2. Netlogo ABM Model Interface](image)

DYNAMOD Models are based on output of time series data, so that customer adoption and preferences are modeled over a period of time. The concept of time is modeled in NetLogo as an arbitrary unit (referred to as a “tick”) that is left to the model developer to define. In our model, a tick is recorded after every consumer agent makes a random “walk” within the simulated environment. These consumer movements are what enable interactions with other consumers or brands. The total number of time units per iteration, as well as how many units represent a single year, can be modified by the user to best represent a specific study context. Figure 2 shows the Netlogo Model for this case.

V. MODEL VALIDATION

To validate the model we obtained the actual number of users for each price plan in the end of 2012 and 2013 from Vortal (TABLE I). We initialized the model to have different agent types based on the number of users on different tariff plans in 2012. The user willingness to pay were attributed to the agents based on the survey results.

<table>
<thead>
<tr>
<th></th>
<th>U</th>
<th>SG</th>
<th>SE</th>
<th>BG</th>
<th>BE</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>8227</td>
<td>431</td>
<td>218</td>
<td>46</td>
<td>51</td>
<td>8973</td>
</tr>
<tr>
<td>2013</td>
<td>7888</td>
<td>679</td>
<td>458</td>
<td>167</td>
<td>115</td>
<td>9307</td>
</tr>
</tbody>
</table>

The model is allowed to run till it reaches the closest to the real value of number of SG users in 2013. Hence the real value of SG in 2013 is used to determine the average number of steps that constitute a one year period for the simulation model. The model was run 1000 times to monitor the stochastic variability of the results. This enables us to visualize a probability distribution of the forecasts. The average number of steps the ABM took to just cross the number 679 of SG users in 2013 was 60. The 60 steps represented a time scale of one year and the model was run 1000 times for 60 steps and other parameters were measured. Hence, we shall use the forecasts for agents on other tariff plans to validate the accuracy of forecasts of the model for 2013 (Figure 3).

The price of the optional features were set at the maximum possible value, ie, €100 and €60 for the first four and last four features respectively. The simulation results showed that in one year, an average of 11.48 users and 8.96 users subscribed the f2 and f7 features respectively. There were no subscribers for any of the other features. Thus this price point was set too high. We shall discuss further how an optimization of prices can be achieved using genetic algorithms.

The model represents a highly saturated market condition, where there is a high market penetration. Already all major vendors in Portugal are using the Vortal Platform. The model forecasts a strong shift from the free users of Vortal towards becoming paying customers as well as customers upgrading from the “Smart” Plans to the “Best” Plans. It further closely forecasts the percentage of users in various plans with an error of less than 1% in all the cases. However this error is negative across all the paid plans thus showing a small bias where the model predicts a lower willingness to pay than in reality. This bias may be corrected in future research work by implementing other means of gauging willingness to pay other than direct questionaires, for example, Vickery Auction [26]. The prediction capabilities of this model cannot be compared with any other existing forecasting tool, because no forecasting tool enables future prediction when only one set of data for the current period exists [27]. The DYNAMOD model is not just a forecasting tool, but rather a toolkit that enables us to capture the underlying business scenario in the form of user satisfaction and willingness to pay end enables us to make future forecasts based on a variety of what-if scenarios.
VI. CONCLUSION AND FUTURE WORK

The objective of the DYNAMOD Modeling Framework is to model the complex dynamics of online users and how they respond to the value proposition of a Digital Business. Through a complex system approach we propose an Agent Based Modeling Framework that can be used as a basis to develop customized Agent Based Models for different online business scenarios. This framework models the most common features of online markets, such as Word of Mouth, Network Effects, Price Sensitivities, Viral Marketing and various sources of User Influences. In this paper we apply this model to develop pricing models for a B2B procurement platform provider.

We demonstrate how user willingness to pay can be measured and used to initialize an ABM model that can then be used to forecast how users will react to different combinations of pricing for different plans and features. We also demonstrate the use of this tool to test the revenue implications for new business scenarios, such as the introduction of new feature based pricing options. This approach provides us with a useful tool to test and optimize business and pricing decisions before they are finally implemented.

The DYNAMOD framework captures the key characteristics of online businesses, however each business is unique and hence this modeling framework must be customized to include specific Business Requirements and Modeling Objectives. The framework also provides a structured approach to developing questionnaires to gauge sample user behavior. Since user behavior changes over a period of time, we are in the process of developing a Decision Support Toolkit that can conduct automated periodic surveys to update user responses and thus adjust the behavior of the agents used in the model to improve accuracy of long time intervals, and alert management about changes in key metrics like customer satisfaction, word of mouth, in addition to simulating its impact.

The complex systems approach is novel in terms of viewing the Business Model of a company and the online networks of users as one complex system, where overall behavior can be understood by capturing individual level behavior. We believe this approach could open up new opportunities for digital entrepreneurs and business managers, and deepen academic understanding about how online businesses work.

REFERENCES


