Forecasting the Diffusion of a Mobile Service for Freight Distribution

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Abstract

Supply chain management supported by digital services is one of the most promising areas of research that have emerged in the last years since it has a tremendous potential to improve both operational and economic performance. In particular, distribution of freight is a field that lends itself to the application of the latest information and communication technologies to enable quick and safe ordering and delivering activities. However, in order to make new smart distribution services desirable for users and profitable for providers careful feasibility studies are necessary to evaluate possible strategies to make the diffusion time as short as possible and secure adequate profits.

The present work develops a System Dynamics model to capture the mechanisms of the adoption of a mobile service for the distribution of short life cycle products. The model integrates diffusion and supply chain management aspects and is used to devise appropriate policies the service providing company should implement to stimulate the growth of the community of users and to enable rapid business growth.

Keywords: mobile service, diffusion, freight distribution, supply chain management

Introduction

Smart distribution of goods is an increasingly researched issue as a fundamental component to help achieve a better sustainability and efficiency of supply chains (SC). Distribution involves the physical processes of storing and shipping products, as well as the information flows of product information and orders (Brewer *et al.* 2001). Whenever these processes integrate with real-time monitoring and control digital systems and with information and communication technologies (ICT), the distribution becomes an intelligent enabler of the SC efficiency. For instance, info-mobility services for monitoring and control of vehicle routing and freight dispatching are becoming fashionable tools to support planning and optimization of shipment along the SC. These systems, primarily based on mobile ICT, are proliferating in a variety of pilot and commercial applications in various environmental-sensitive SCs, such as for city logistics or for fresh organic food produced and distributed locally.

Such mobile ICT systems available for vertical applications, such as those for smart distribution, are attracting the telecommunication players because of their promising business potential. However, the dynamics of the diffusion of these innovative services is still unclear because it appears that the users' community growth mechanisms are largely affected by the capability of the mobile services to enhance inventory management, distribution efficiency, and user satisfaction combined with the service optimal pricing.

With the purpose of capturing the mechanisms of diffusion of a mobile digital service for smart distribution, we were challenged by a company in the ICT industry in a feasibility study to pre-evaluate the effects of info-mobility services on inventory and business performance in order to assess the community potential and determine the opportunity of launching the new smart distribution service.

To this end, a SD model was developed to capture the mechanisms of demand and inventory management, growth of the community of users, and revenue//business value creation for both the users and the ICT company.

In the following sections, we firstly review literature pertinent to the components of the SD model. Then, after gaining an understanding of the smart distribution service and methodology adopted for the research, the SD model is presented. Finally, results are discussed along with implications and conclusions.

Literature review

The present work is grounded on two main streams of literature: models explaining the diffusion of innovations and new products and models analyzing the dynamics of production-inventory systems and, in general, SCs. These fields will be explored with particular reference to the use of the SD methodology to capture cause, effect, and feedback loop mechanisms.

Innovation spread is widely described by S-shaped growth patterns (Cronrath and Zock 2007; Michalakelis *et al.* 2008; Wu and Chu 2010). At the beginning, a limited number of users adopt an innovation and form that critical mass that will play a key role in the subsequent diffusion process and in the achievement of the associated market saturation. Such early adopters are usually named innovators because their decisions do not depend on the rest of the community. At a later time, other users will adopt as a consequence of the interaction with innovators, according to a “word of mouth” process. This second category of adopters, defined as imitators, is also influenced by external factors such as advertising and other communication channels. “Word of mouth” and advertising make the demand for the innovation increase significantly and meet its maximum value; after that, it will decrease and equal zero when the market saturation point has been reached and all the prospective users have already adopted the innovation. As a consequence, the curve of the cumulated number of adopters first grows quickly, when the demand for innovation is rising, and then increases at a slower rate while approaching the market saturation (Figure 1).

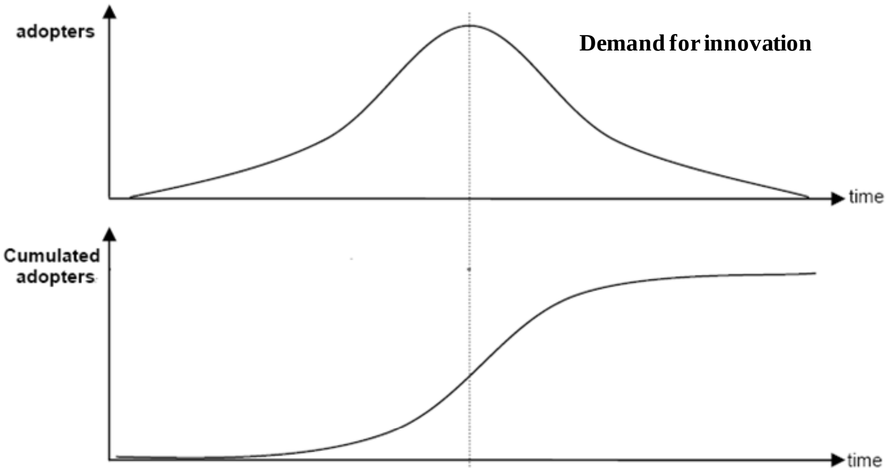

Figure 1: S-shaped growth pattern of diffusion (Adapted from Cronrath and Zock 2007)

Among the numerous models forecasting innovation diffusion available in literature, such as the Gompertz, Logistic, Bass, and Fisher-Pry models (Fisher and Pry 1971; Meade and Islam 2001), the one proposed by Bass (1969) has been extensively applied to new technologies.

The Bass model analytically represents the dynamics of the S-shaped growth: its original formulation as well as the subsequent extended forms has been used in retail services, industrial technology, agricultural, educational, pharmaceutical, and consumer durable goods sectors (Mahajan *et al.*1990). Several works can be found in the area of telecommunication and mobile phone markets. A common application of the Bass model is to study the diffusion of mobile telephony and communication infrastructures, such as for instance broadband, in single national contexts (Michalakelis *et al.* 2008; Chu *et al.* 2009; Wu and Chu 2010; Turk and Trkman 2012). Also, some pieces of research rely on the SD representation of the Bass model provided by Sterman (2000) to develop frameworks for identifying the economic and socio-cultural determinants affecting the capacity to adopt new Information and Communication (ICT) technologies, defining policies to stimulate the diffusion of ICT solutions, or forecasting the success of products either prior to their launch or during their lifecycle (Cronrath and Zock 2007; Dahan 2011). Given its characteristics and the existing application fields, the Bass model is particularly suitable to study the community growth for the case of services that are based not only on advanced telecommunication technologies but also on mobile phones as enabling devices.

The adoption pattern for a service to support SC operations also depends on SC performance related to inventory, orders, and deliveries. To this end, SD models of SCs have been reviewed. Following the SC model put forward by Sterman (2000), contributions focus on several issues affecting not only the manufacturing but also the service industry. The SD methodology has been applied to capture the interrelation between SC responsiveness and efficiency and to study the effects of strategies aimed at improving them (Minnich and Maier 2006). Responsiveness to demand variability has also been tackled by Gonçalves and others (2005) with the purpose of showing the effects of product availability on customer demand and proving the reinforcing feedback between demand fluctuation and the consequent adjustment of the production capacity for a semiconductor manufacturer. Furthermore, SD models have been developed to examine instabilities in the SC that are due to actions addressing the imbalances between supply and demand like price changes, promotions and the involvement of additional suppliers (An and Ramachandran 2005). SD proved to be beneficial in SC reengineering (Towill 1996) and to characterize the conditions under which the bullwhip effect can occur (Anderson Jr *et al.* 2005). Finally, SD models have been extensively used to evaluate the operational and economic performance of SCs (Sachan *et al.* 2005; Venkateswaran *et al.* 2011).

The literature review reveals that most of the current applications of the SD methodology are focused on either the innovation diffusion paradigm or the SC structure and behavior separately and the assessment of how the use of new technologies facilitating SC operations can improve performance is a topic that still needs further attention.

In order to contribute to such research gap, the present work proposes a SD framework combining the Bass model with an inventory management model to assess the operational and economic effects of the diffusion of a smart distribution service. The model has been tailored to the case of a service supporting order, inventory management and delivery of short life cycle products.

Research Objective and Methodology

A model is developed to understand the potential diffusion and impact of a mobile service to support efficient distribution of goods. The service is centered on a web application for smart phones that enables online product information, order placement, inventory control, and receiving/dispatching management. The intended users are part of the community of local producers, retailers and consumer of short life cycle products to be delivered in a small urban area with a minimum vehicle fleet.

In the designed service, all users share product, order, inventory, and shipment information and are charged a fee for transactions made through the online service, namely for receiving orders or dispatching deliveries. The service is connected to an intelligent vehicle real-time routing system for efficient transportation of freight.

The model is aimed at understanding the mechanisms of diffusion of such a service within the community of potential adopters and assessing the possible business for the service managing company.

A phased approach is used to carry out the research (Lyneis 1999). First, interviews are conducted with retailers to understand the business mechanisms. Then, a first SD model is created to capture the most important flows, state variables and feedback loops. Finally, a detailed SD model is calibrated and simulation results are analyzed to draw useful implications for the company to decide whether and how to develop the service.

The System Dynamics Model

The diffusion of the mobile digital service for smart distribution in a three echelon SC producing and delivering short life cycle products is studied. The upstream echelon of this SC is represented by producers that manufacture products and sell them to the retailers. The retailers, in turn, purchase products from producers and sell them to the final consumers that hereafter will be named just “consumers”. The modeled SC includes only those actors relying on the smart distribution service for placing orders upstream and delivering goods downstream.

The SD model is structured into six interconnected sub-models respectively investigating the adoption of the service by consumers and the associated order issuing, the dynamics of the diffusion of the service among retailers, inventory management by the adopting retailers and consumer satisfaction, the service diffusion among producers, the inventory management by adopting producers and retailer and producer satisfaction, and the revenue for the company from providing the service (Figure 2). The model has been developed using the Vensim® DSS software package by Ventana Systems. The simulations have been performed with Euler integration, with one-day time intervals and a simulation horizon of 156 weeks corresponding to about 3 years.

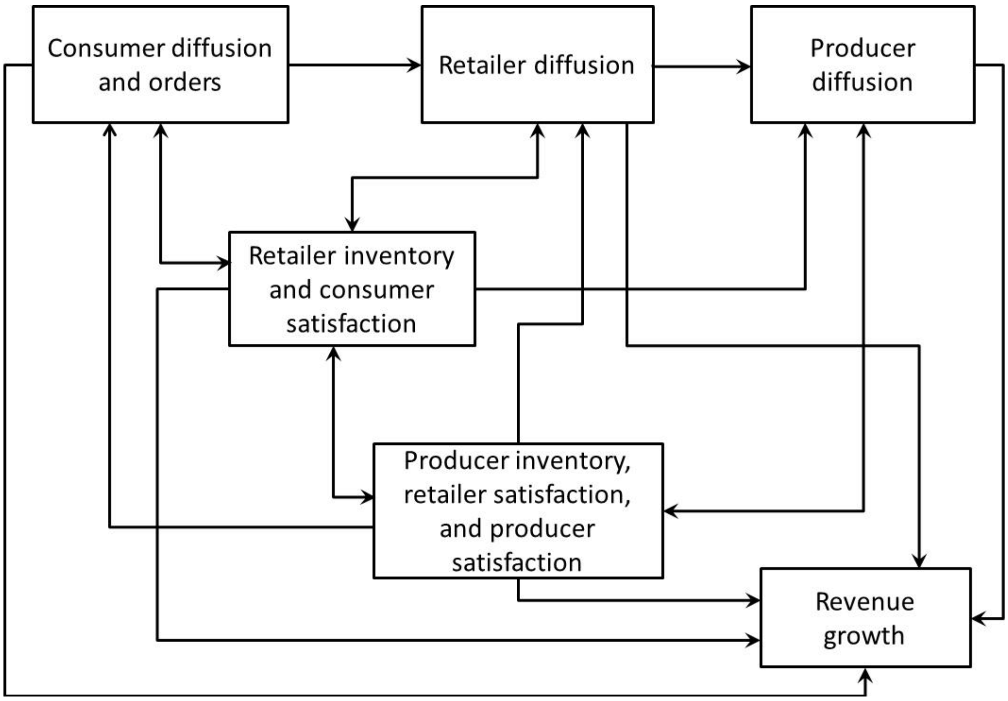

Figure 2: Block diagram as a representation of the SD model

The structure of the SD model is characterized by some main feedback loops explaining the mutual influences between the diffusion of the new service among the SC partners and the way they manage inventory and orders.

As far as consumers are concerned, a growth in the number of adopters increases their order rate to retailers and how successful retailers are in fulfilling the augmented orders, based on their inventory level and the replenishment orders placed with producers, determines the consumer satisfaction that may either accelerate or decelerate the growth of consumers through the "word of mouth" effect. In a similar way, an increase in the number of adopting retailers makes the total orders placed with producers go up and the performance of producers in fulfilling such orders will determine the retailer satisfaction. A high or low retailer satisfaction respectively stimulates or depresses the growth of the community of retailers that adopt by observing the level of appreciation of retailers that already use the info-mobility service.

Also, all the other variables remaining equal, the growing total orders to producers make the order rate to single producer go up that stimulates the adoption by retailers that are persuaded by producers about the possibility of increasing the volume of business with the new service.

Furthermore, the more the adopting producers, the more the products available to retailers and the more the retailer satisfaction that makes the number of adopting producers go up because of the word of mouth between retailers and manufacturers.
Finally, an increase in the number of producers, all the other variables staying equal, decreases the amount of retailer orders to single producers that in turn decreases the rate of producers choosing the new service because of good business chances given by relatively high retailer demand. This causes the number of adopting manufacturers to increase more slowly.
Following is the description of each SD sub-model.

“Consumer diffusion and orders” sub-model

This part of the SD model is based on the Sterman’s (2000) formulation of innovation diffusion according to Bass and aims to explain the dynamics governing the adoption of the smart distribution service by consumers (Figure 3). The stock of potential adopters (Potential Consumers) is decreased by the rate of consumers adopting the innovation (Consumer Service Adoption Rate) which in turn increases the stock of adopters (Consumers).
Consumers may adopt, thus entering the SC of the service users, as a consequence of either advertising or word of mouth. The present model assumes that advertising is performed by suppliers and by the service managing company, whereas word of mouth is pursued by customers and members of a same SC echelon.
Therefore, advertising to consumers may be carried out by both the service managing company and the retailers that have already adopted the distribution service. In the first case, it is usually a formal campaign, whereas in the second case it is most probably a simple verbal persuasion to place orders and receive goods supported by the service at issue because of their efficiency and easiness of use as perceived by the retailers. Word of mouth may be performed by other consumers that have already entered the community of users and are satisfied with the new service. The number of adopting consumers, together with the average number of orders per consumer in each single time step, determines the consumer order rate which feeds the stock of the consumers’ orders. It is important to highlight that the SD model is based on a standard order composition and does not consider the variability of the products that form an order.

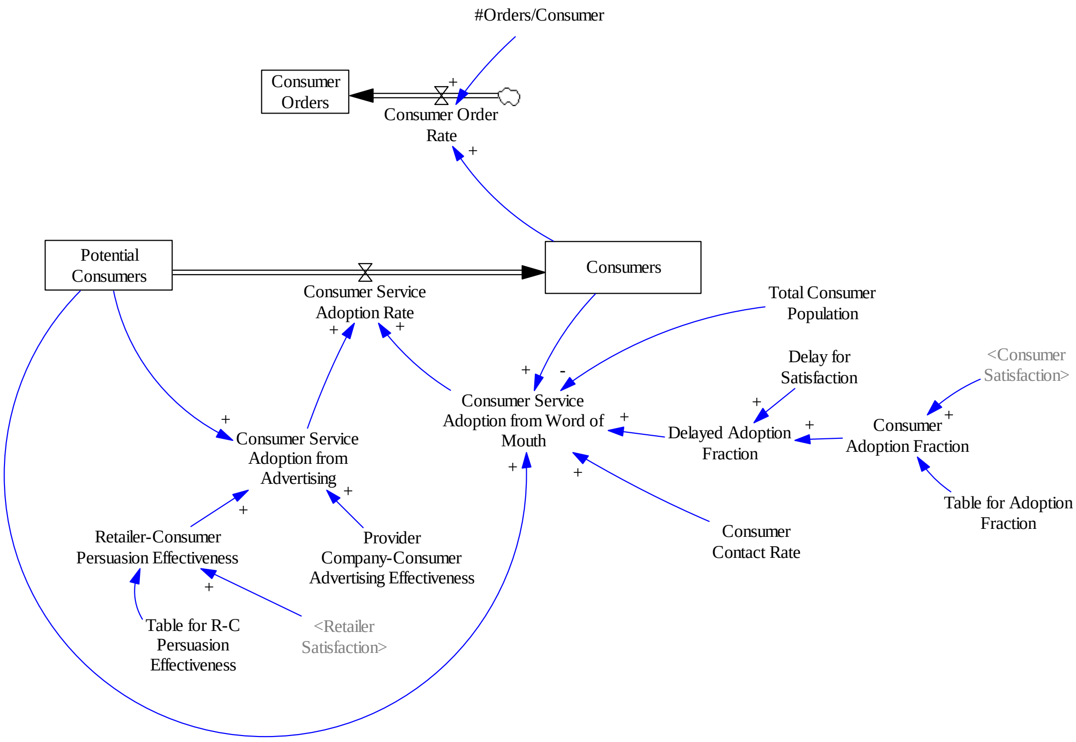

Figure 3: Consumer diffusion and orders

“Retailer diffusion” sub-model

The retailer diffusion sub-model is a modified version of the classical SD representation of the Bass model (Sterman 2000) to take into account the different ways a retailer may decide to adopt the mobile service for smart distribution (Figure 4). Also in the present part of the model the stock of potential adopting retailers (Potential Retailers) is decreased by the rate at which new retailers enter the community of users (Retailer Service Adoption Rate) that increases the stock of retailers that have already adopted (Retailers).

In general, a retailer approaches the service as an effect of either advertising or word of mouth. Advertising is performed by the service managing company and by the persuasion action of producers that have already adopted. In particular, the more the orders from adopting retailers faced by adopting producers, the more they will be encouraged to suggest new retailers to enter the community of users. The service adoption from word of mouth is made up of two components: the word of mouth of consumers towards retailers and the emulation adoption among retailers. Consumers that are satisfied with the new service will stimulate retailers to adopt them so that they can experience the purchase of products supported by the smart distribution system from a larger number of suppliers. Also, we have considered the emulation among retailers as a particular kind of word of mouth, though not explicit like the one carried out by consumers. In this case, the retailers observe the competitors that have already adopted, in particular their satisfaction with the service and their business volume expressed in terms of the orders from consumers, and they make the decision whether to enter the community of users.

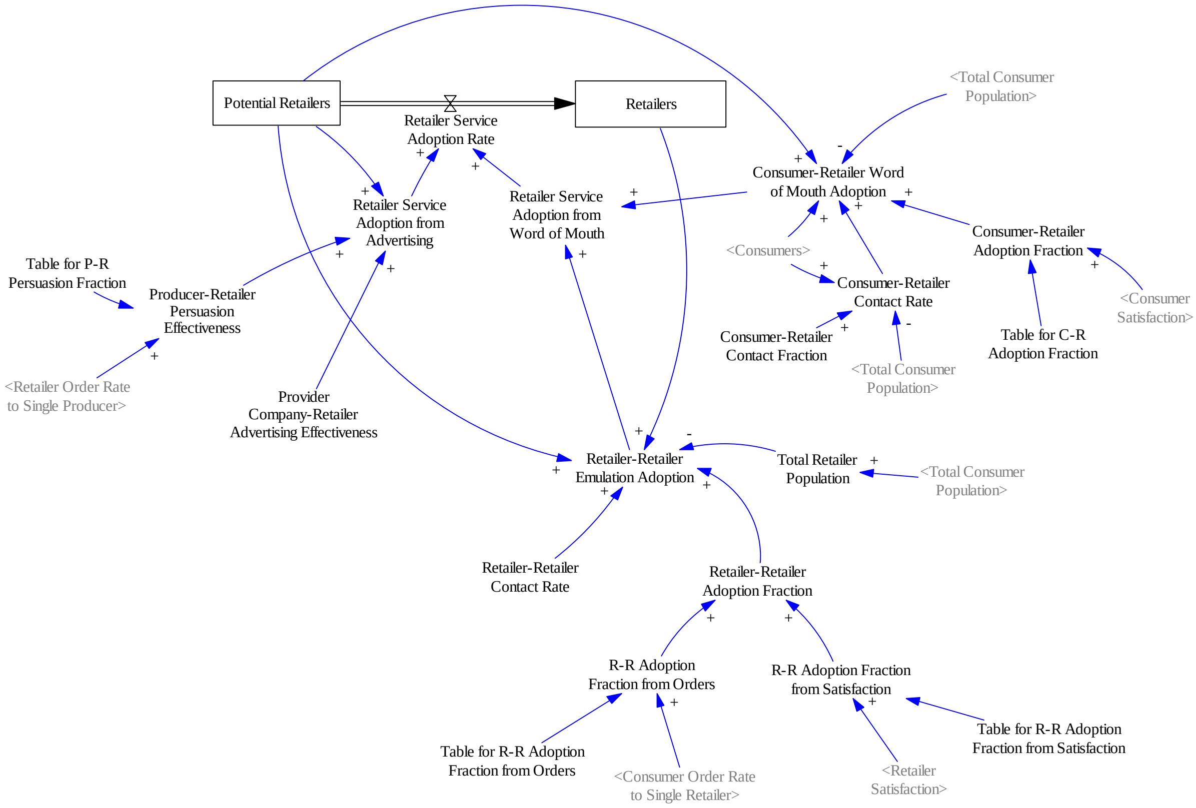

Figure 4: Retailer diffusion

"Retailer inventory and consumer satisfaction" sub-model

This part of the SD model aims to both describe the behavior of the inventory of retailers that use the info-mobility service and assess the consumer satisfaction based on the perceived service level and the associated price (Figure 5).

The SD model represents how the inventory performance of a single retailer changes as the number of service adopters increases; the Sterman's (2000) SC model has been taken as a reference. The unit of material in the studied SC is the order. The retailer stock (Single Retailer Inventory) is augmented by the flow of orders received by producers (Single Retailer Receiving Rate) and diminished by the flow of orders shipped to consumers (Single Retailer Shipment Rate). For the sake of simplicity, we assume that each retailer adopting the smart distribution service faces a same volume of orders (Consumer Order Rate to Single Retailer). In a similar way, each retailer places a same amount of orders with producers (Single Retailer Order Rate), receives a same amount of orders from them, and ships a same quantity of orders to consumers during a time step.

The consumer demand determines both the shipment rate according to the number of orders available on stock and the retailer orders to producers based on a forecast of future consumer orders. The forecast has been modeled as a first-order exponential smoothing of the present order rate.

Two components have been assumed to be relevant to consumer satisfaction: the service level experienced by the consumers when ordering products and receiving them from the retailer and the consumer sensitiveness to the price for accessing the smart distribution service (Zeithaml *et al.* 1993).

The variable Consumer Receiving Service Level is an indicator that combines the logistics performance with that of the proposed distribution service. As a matter of fact, its value is given by the product of Consumer Order Fulfillment Ratio, which measures how many orders are fulfilled in every time step, E-Order Service Reliability, which assesses the degree of reliability and security of the electronic system to place orders, and Consumer Receiving Timeliness and Efficiency, which evaluates the efficiency of receiving goods with the support of the smart distribution service.

The variable Consumer Sensitiveness to Pricing compares the price expected by consumers with the actual one. According to the applied pricing policy, each SC member is charged a unit fee every time he receives an order (Receiving Unit Fee) and every time he ships an order (Dispatching Unit Fee). In addition, he pays the WebApp Unit Price in order to download the software package allowing his smartphone to interact with the digital distribution system. Receiving Unit Fee, Dispatching Unit Fee, and WebApp Unit Price are constant and do not depend on the SC member using the service, being a producer, a retailer or a consumer.

Consumer Sensitiveness to Pricing ranges from 0 to 1 and it is defined as per equation (1). A value equal to 0 means extreme consumer sensitiveness to price while a value equal to 1 indicates scarce sensitiveness to price.

Consumer Sensitiveness to Pricing = (Expected Receiving Unit Fee/Receiving Unit Fee+Expected Web App Unit Price/WebApp Unit Price)/Max Consumer Sensitiveness to Pricing (1)

Max Consumer Sensitiveness to Pricing is defined as per equation (2):

Max Consumer Sensitiveness to Pricing = Max Expected Receiving Unit Fee/Min Receiving Unit Fee + Max Expected Web App Unit Price/Min WebApp Unit Price (2)

Thus, Consumer Satisfaction is a weighted sum of Consumer Receiving Service Level and Consumer Sensitiveness to Pricing:

Consumer Satisfaction = Consumer Receiving Service Level*(1-Weight of Pricing) + Consumer Sensitiveness to Pricing *Weight of Pricing (3)

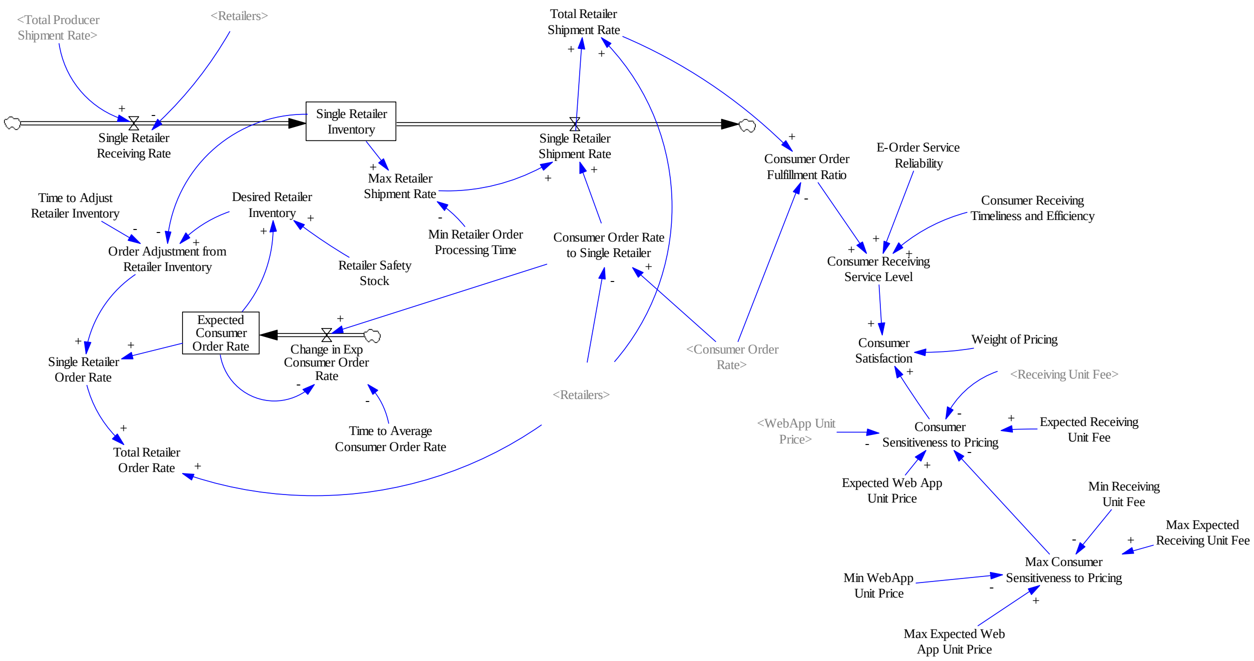

Figure 5: Retailer inventory and consumer satisfaction

"Producer diffusion" sub-model

The sub-model describing the diffusion of the smart distribution service among producers is very similar to the ones devoted to explain the dynamics of service adoption by consumers and retailers (Figure 6).

Producers may approach the service at issue as an effect of either advertising or word of mouth. Advertising is performed just by the service managing company having producers no upstream suppliers in the modeled SC. Word of mouth includes the action of retailers that encourage producers to become part of the community of users based on their level of satisfaction with the new service. A second form of word of mouth is represented by the emulation among producers: one producer observes the satisfaction and the volume of retailer orders of another producer that has already adopted and decides whether to become a service user.

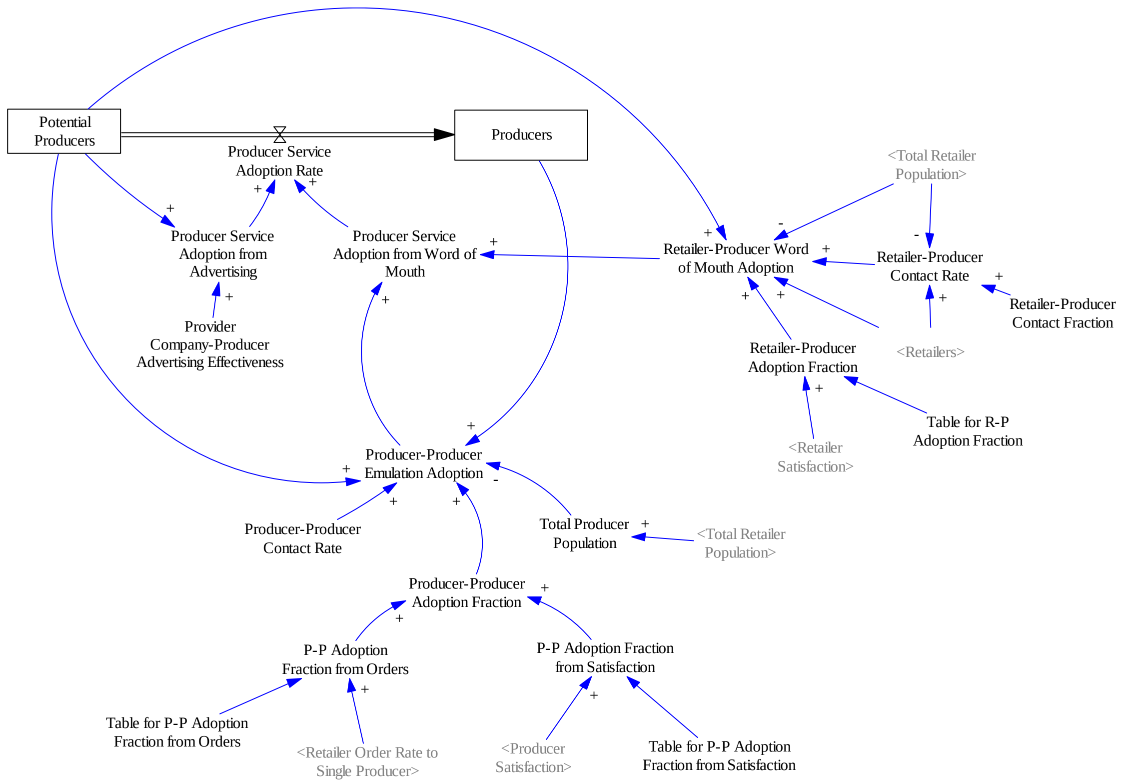

Figure 6: Producer diffusion

"Producer inventory, retailer satisfaction, and producer satisfaction" sub-model

The present sub-model deals with the inventory dynamics of producers using the smart distribution service and assesses retailer and producer satisfaction with such service (Figure 7).

Producers manage inventory in the same way as retailers. Again, the model represents how the inventory performance of a single producer changes with the number of service users. The producer stock (Single Producer Inventory) is increased by the flow of orders produced (Single Producer Production Rate) and decreased by the flow of orders shipped to retailers (Single Producer Shipment Rate).

Retailer Satisfaction is given by equation (4):

Retailer Satisfaction = Retailer Service Level*(1-Weight of Pricing) + Retailer Sensitiveness to Pricing*Weight of Pricing

(4)

Retailer Service Level is defined as the sum of Retailer Receiving Service Level and Retailer Dispatching Service Level. Retailer Receiving Service Level is calculated in a similar way as Consumer Receiving Service Level. Retailer Dispatching Service Level is determined as the product of E-Order Service Reliability, assessing the reliability and security of the electronic system to receive orders from consumers, and Info Routing Reliability, evaluating the reliability of the vehicle real-time routing system supporting product dispatching.

Retailer Sensitiveness to Pricing is defined similarly to Consumer Sensitiveness to Pricing:

Retailer Sensitiveness to Pricing = (Expected Dispatching Unit Fee/Dispatching Unit Fee + Expected Receiving Unit Fee /Receiving Unit Fee + Expected Web App Unit Price/WebApp Unit Price)/Max Retailer Sensitiveness to Pricing

(5)

Producer Satisfaction is calculated similarly to Retailer Satisfaction and is given by equation (6):

Producer Satisfaction = Producer Dispatching Service Level*(1-Weight of Pricing) + Producer Sensitiveness to Pricing*Weight of Pricing

(6)

"Revenue growth" sub-model

The revenue growth sub-model evaluates the revenue for the provider company produced by the diffusion of the smart distribution service (Figure 8). The revenue is a quantity that has been used in literature to study the economic benefits for mobile phone operators offering value added services such as data transmission, internet connection, location based, and TV broadcast services (Nejad Amiri and Kian 2008).

The SD model calculates the total cumulative revenue as the sum of the revenue from supporting the activities of receiving and dispatching orders (Subtotal Revenue) and the revenue from selling the software packages to connect the users' smartphones with the digital distribution system (Equation 7):

Total Revenue = Subtotal Revenue +WebApp Unit Price*(Consumers + Producers + Retailers)

(7)

Subtotal Revenue is determined by the sum of the revenue from the activities of receiving orders by consumers (Revenue Rate from Consumer Receiving), receiving orders by retailers (Revenue Rate from Retailers Receiving), dispatching orders by retailers (Revenue Rate from Retailers Dispatching), and dispatching orders by producers (Revenue Rate from Producer Dispatching). Each of these revenue components is given by the associated shipment rate multiplied by the pertinent service unit fee.

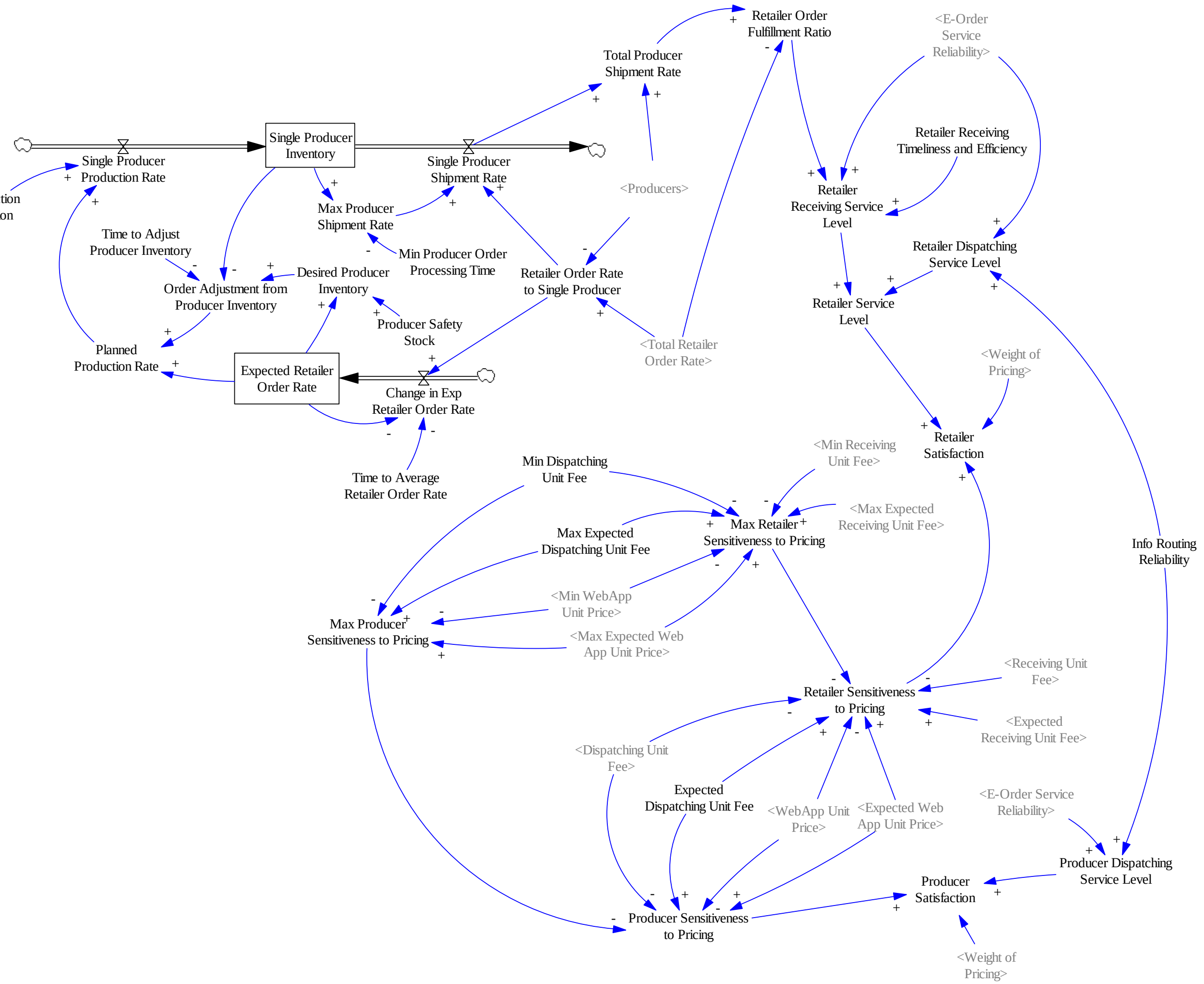

Figure 7: Producer inventory, retailer satisfaction, and producer satisfaction

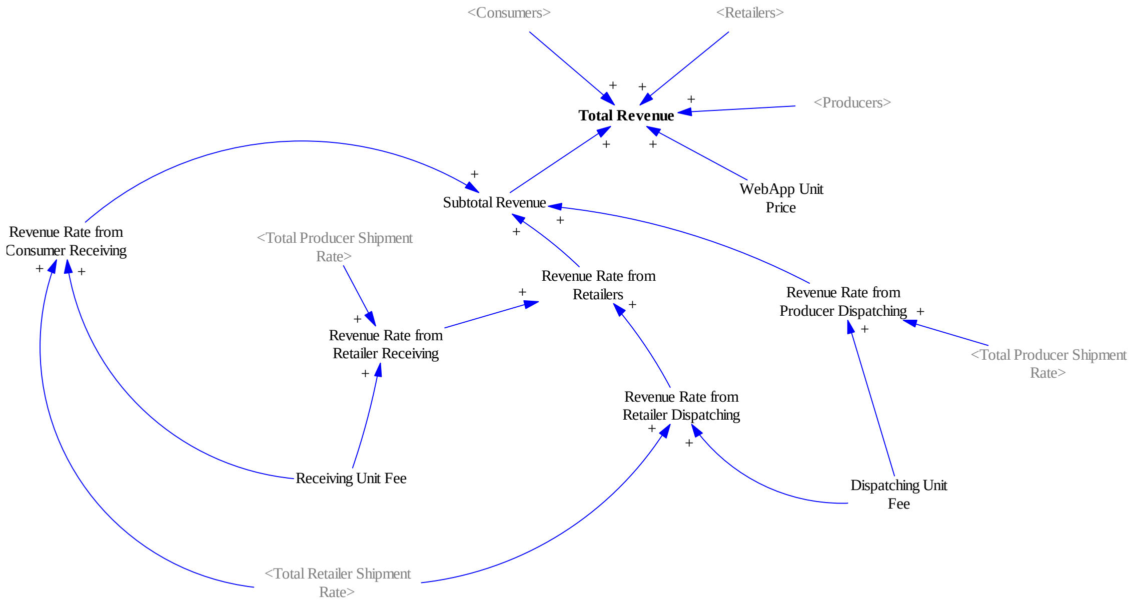

Figure 8: Revenue growth

Understanding the behavior of the system

In order to achieve an appropriate understanding of the behavior created by the structure of the system at issue, relevant feedback loops of the SD model are discussed. Particular attention has been given to the loops associated with the variables Consumers, Retailers, Producers, Single Retailer Inventory, Single Producer Inventory, Consumer Order Rate, Total Retailer Order Rate, and Planned Production Rate.

First, the mechanisms governing the diffusion of the new smart distribution service are analyzed. The number of consumers adopting the service both sustains and depresses itself through multiple reinforcing and balancing feedback loops (Figure 9). Some of them are concerned just with the mechanism of consumer growth. For instance, as Consumer Order Rate increases as an effect of an increase in the variable Consumers, the augmented demand will tend to decrease the performance of retailers and the value of Consumer Order Fulfillment Ratio. As a consequence, Consumer Satisfaction and Consumer Service Adoption from Word of Mouth will go down, thus making the rate of new adopters go down (Loop 1). However, an increase in Consumer Order Rate also makes the orders to retailers and the consequent shipments go up, thus improving the order fulfillment ratio and the consumer satisfaction. This will make the word of mouth be more effective and the number of consumers adopting the service will raise (Loop 2). In other feedback loops the number of consumers that become adopters influences itself through the number of retailers that adopt the service. Let us consider the retailer adoption through the word of mouth operated by consumers. On the one hand, an increase in Consumers allows more people informing prospective retailers about the benefits of the distribution service and more retailers will choose the service. An augmented number of retailers increases the ability to fulfill the consumer demand and Consumer satisfaction will increase thus causing more consumers to adopt (Loop 3). On the other hand, when the number of the adopting retailers goes up, the consumer order rate faced by each of them diminishes and the shipment rate to consumers tends to decrease and with it the consumer satisfaction and the consumer adoption from word of mouth. So, ultimately, the number of adopting consumers will tend to increase at a lower rate (Loop 4).

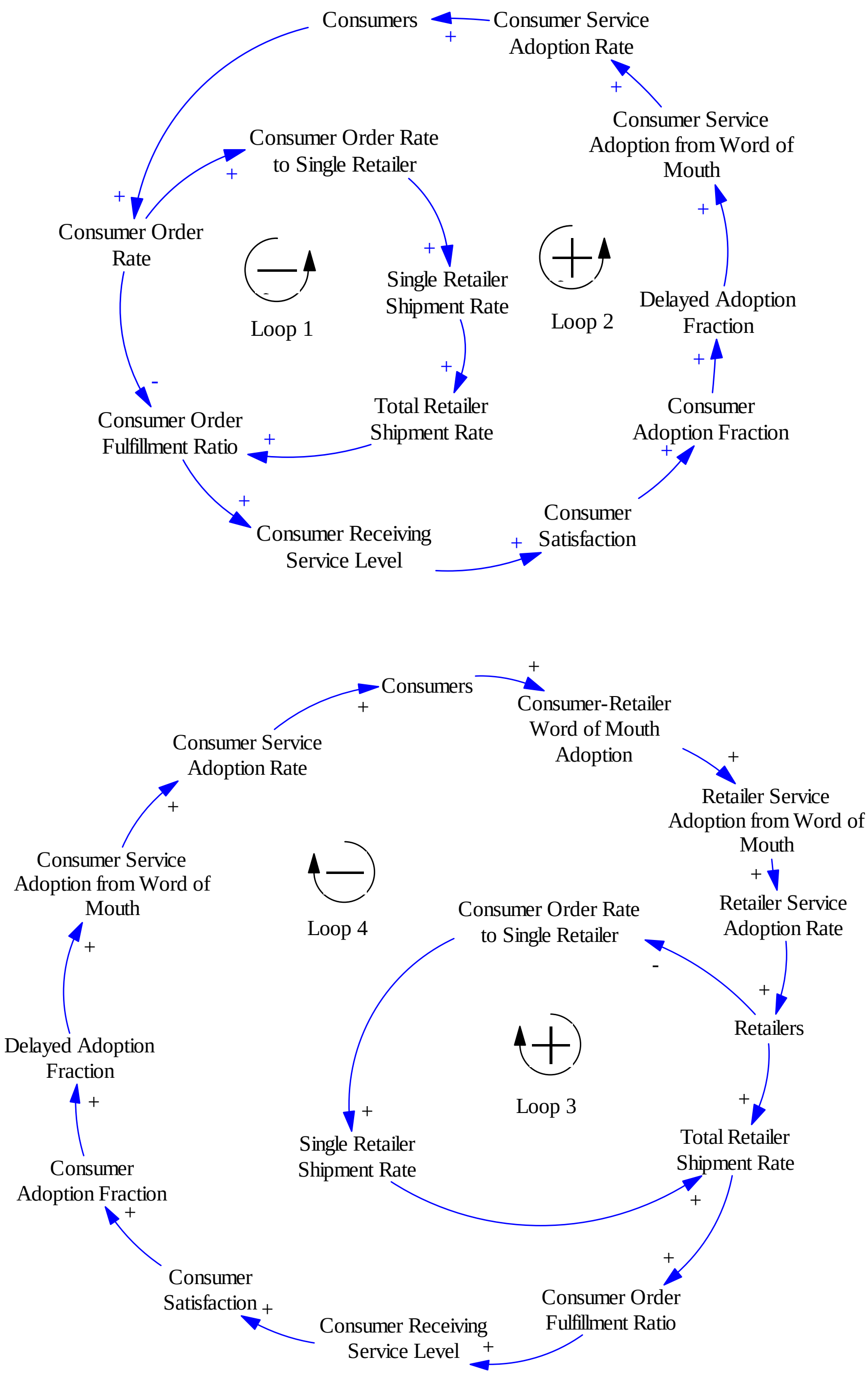

Figure 9: Dynamics of consumers' community growth

In a similar way, the feedback loops governing the adoption by retailers (Figure 10) and by producers (Figure 11) may involve the growth of the community either only in the SC echelon at issue or also in other links.

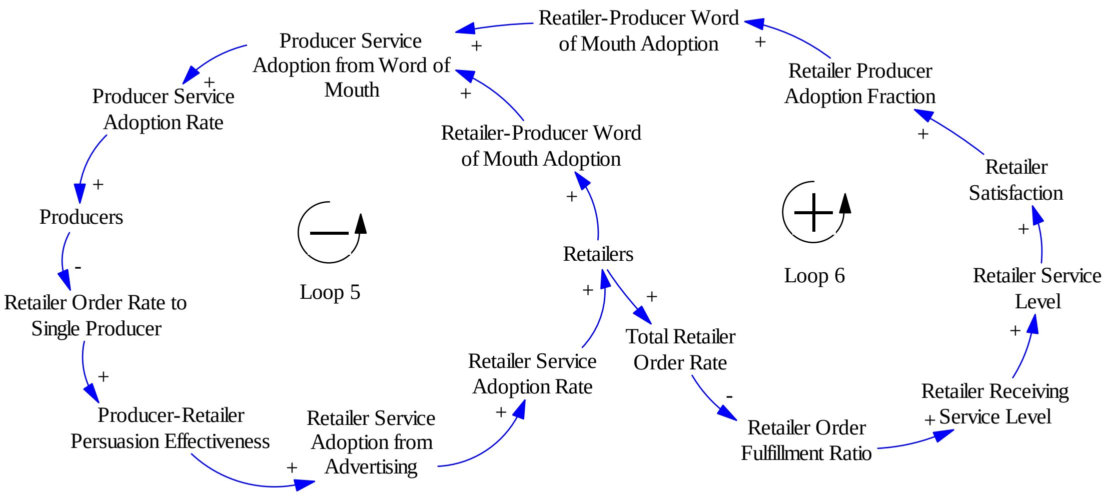

Figure 10: Dynamics of retailers growth

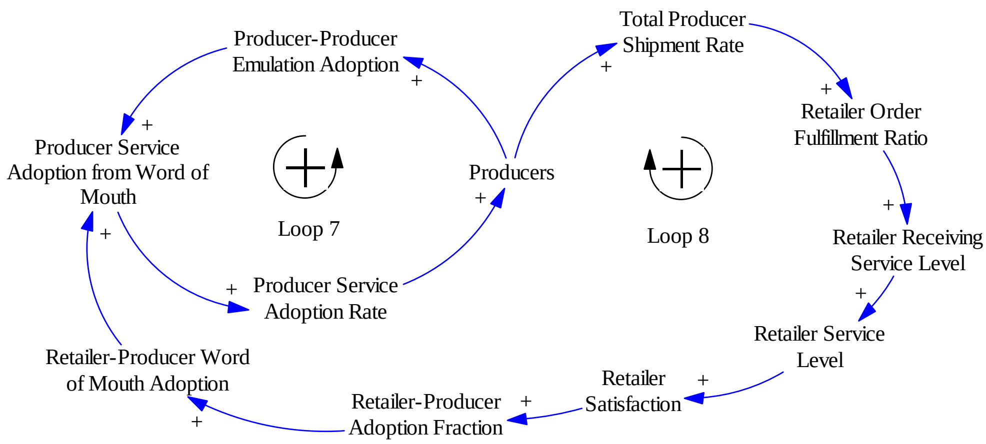

Figure 11: Dynamics of producers growth

Second, the interconnections between the growth of the community of users and the SC performance are investigated. The feedback loops explaining the behavior of the inventory levels of single retailers and producers show effects on the communities of consumers, retailers, and producers as well as on the dynamics of orders. Two examples are given in Figure 12. There exists a balancing effect of the number of adopting producers on the inventory level of single retailers. As Single Retailer Inventory goes up less products will be purchased from producers and each producer will experience a reduced business (reduced Retailer Order Rate to Single Producer) which decreases the number of new producers willing to adopt the smart distribution service because of the promised profitability. In this way, the producer shipment rate increases slowly and also the inventory levels of the retailers (Loop 9). A reinforcing effect of the number of adopting retailers on the producer inventory can also be identified. An increase in Single Producer Inventory has positive effects on the producer shipment rate to retailers and on the associated inventories. This in turn contributes to raise the retailer shipment rate towards consumers which causes Consumer Order Fulfillment Ratio and Consumer Satisfaction go up, and new retailers are stimulated to adopt by consumers' suggestion. An increased number of adopting retailer makes Retailer Order Rate to Single Producer increase and Planned Production Rate and Single Producer Inventory growth as a consequence (Loop 10).

Figure 12: Inventory dynamics

Finally, the order rate of consumers and retailers towards the respective suppliers as well as the planned production rate of manufacturers impact on the community growth of in three SC echelons, on inventory levels, and on the orders issued by other SC members. Figure 13 depicts a couple of feedback loops capturing such dynamics. Loop 11 details the reinforcing effect of the number of adopting retailers on the consumer order rate. As Consumer Order Rate goes up, the rate of orders served by each retailer increases, thus promising a profitable business to prospective retailers. The number of adopting retailers increases so that the consumer demand may be more easily fulfilled. This makes the number of consumers and the associated order rate further increase. Loop 12 is quite straightforward from a conceptual point of view but highlights the interconnection between orders and inventory levels in different SC echelons. When Total Retailer Order Rate goes up, each producer will face an increase volume of orders and will raise the production orders. The inventory levels of producers will increase, thus allowing the shipments of more products to retailers and causing a growth of the inventory levels of retailers which in turn will decrease the order rate to producers.

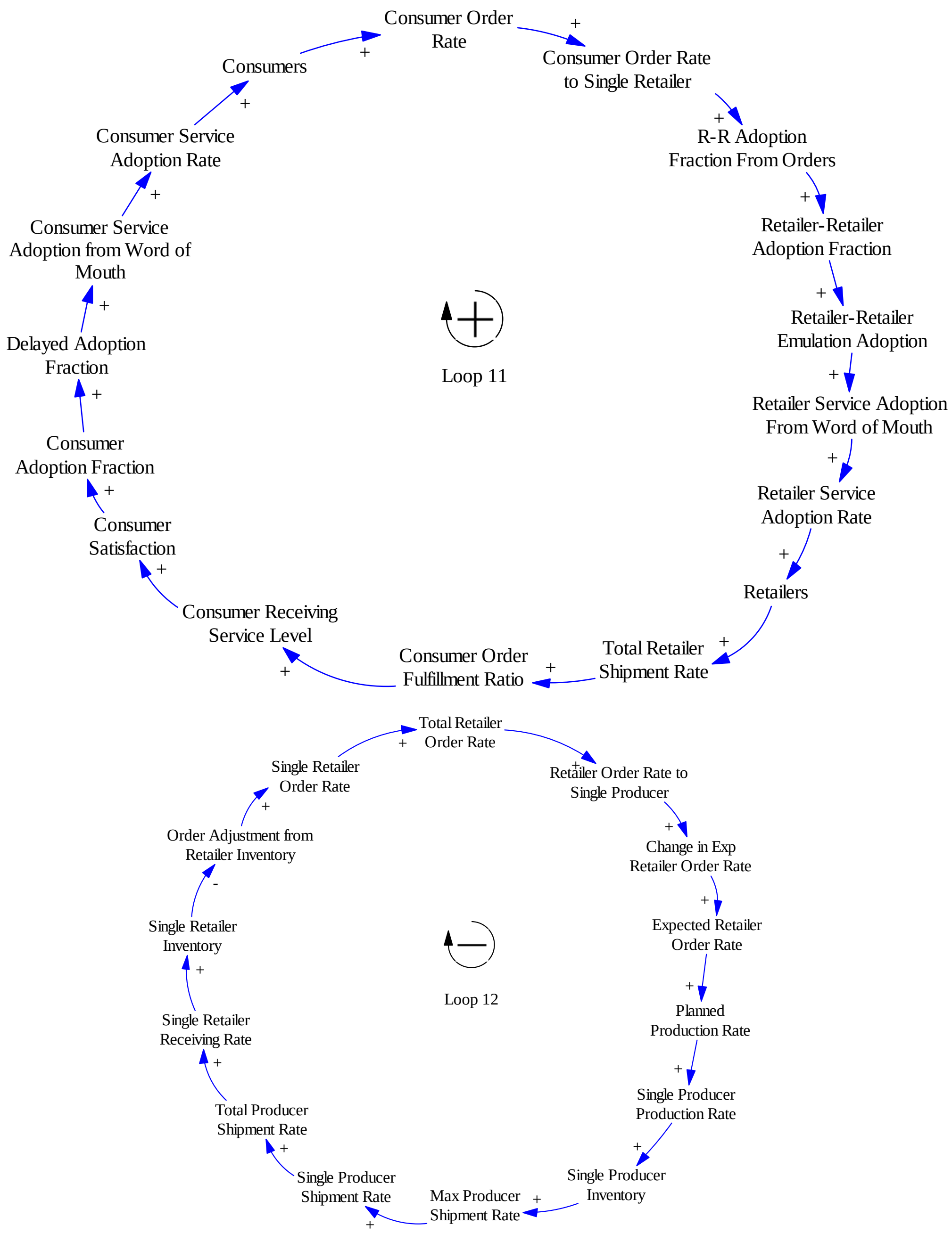

Figure 13: Order dynamics

Calibration

The calibration of the model's parameters and lookup tables is based on interviews carried out with some current market players. Table 1 shows some of the input data used for model calibration and setting of the base case variables.

Variable	input			Unit
	min	average	max	
Total population				
Total consumer population		75,000		Users
Total retailer population		750		Users
Total producer population		3,750		Users
Contact rates				
Consumer contact rate	0	0.2	10	1/time
Consumer-retailer contact fraction	0	0.4	10	1/time
Retailer-retailer contact rate	0	0.2	10	1/time
Retailer-producer contact fraction	0	0.1	10	1/time
Producer-producer contact rate	0	0.01	10	1/time
Adv effectiveness				
Provider company-consumer advertising effectiveness	0	0.001		1/time
Provider company-retailer advertising effectiveness	0	0.001		1/time
Provider company-Producer advertising effectiveness	0	0.001		1/time
Orders&inventory				
# orders/consumer		0.2		order/ time
Minimum retailer order processing time		0.2		Time
Minimum Producer order processing time	0.2	0.6	1	Time
Pricing				
Receiving Unit Fee	0.001	0.01	1	€
Dispatching Unit Fee	0.001	0.03	1	€
Web app unit price	0.001	0.1	15	€/user

Table 1: Input data for the calibrated model

Simulation Results and Sensitivity Analysis

Base Case

A base case simulation is run with the calibrated input data given in Table 1. The base case simulation results in the mobile service been adopted by the total populations of consumers, retailers, and producers in 12.6, 10.2, and 82.3 weeks respectively. Such results are robust against changes in the lookup tables variables.

The base case provides evidence of a SC in equilibrium with steady inventory levels. The average weekly orders per consumer are kept constant. The inventory behavior is a determinant, both directly and through the consumer's satisfaction variable, of adoption by the SC players. Figure 14 depicts the trend of the retailer's inventory level for the base case.

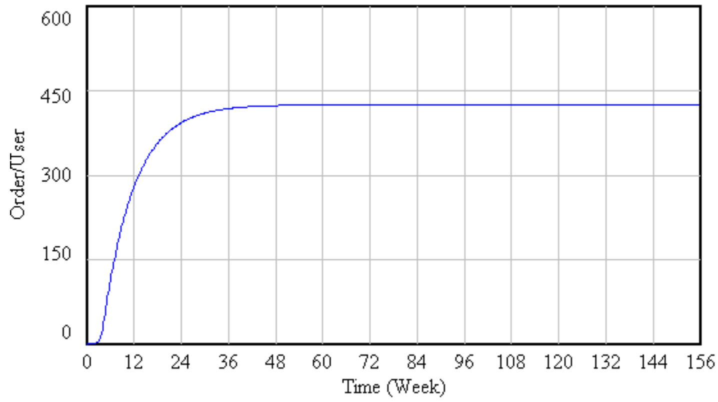

Figure 14. Graph for the 'Single Retailer Inventory' variable over time

A sensitivity analysis is carried out on the base case with the purpose of testing the model's robustness and supporting policy making.

Efficiency and Reliability of the Service

Here we analyze the parameters associated with the efficiency and reliability of the business that most affect the adopters' growth dynamics. The involved variables are the E-Order Service Reliability, Consumer Receiving Timeliness and Efficiency, Retailer Receiving Timeliness and Efficiency e Info-Routing Reliability.

Any univariate sensitivity analysis conducted with random triangular distribution (0; 0.5; 1) reveals that none of these parameters has influence on the retailers' community. rather, the retailers' community growth is dominantly affected by the persuasion that producers activate based on the business volume generated and expressed by the Retailer Order Rate to Single Producer. In fact, it happens that as the values of Table for F-R Persuasion Fraction vary, the retailers' population saturation point moves in the order of one and a half year, while the consumers and producers points of saturation vary in the range of three to four months only.

The E-order Service Reliability is the parameter with the greatest influence on the consumers' community growth, while other factors, such as Consumer Receiving Timeliness and Efficiency, Retailer Receiving Timeliness and Efficiency, and Info Routing Service Reliability have a very small influence on the dynamics of consumer adoption.

The multivariate sensitivity analysis on E-Order Service Reliability, Consumer Receiving Timeliness and Efficiency, Retailer Receiving Timeliness and Efficiency, and Info-Routing Reliability confirms the relatively insensitive retailers' population growth dynamics. On the contrary, a large variability affects both consumers and producers growth when such parameters are all less than 100% so that a very long time might be necessary to disseminate the usage of the mobile service among producers (Figure 15).

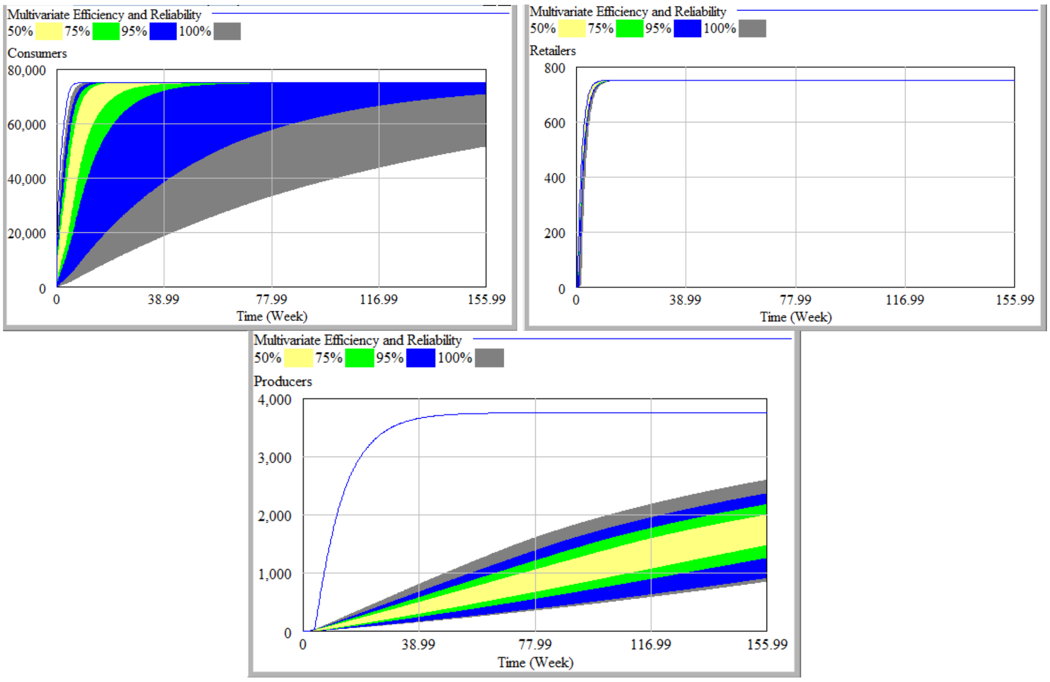

Figure 15. Multivariate Sensitivity Analysis on Efficiency/Reliability Parameters

Pricing

Here we analyze the influence of pricing policies on service adoption dynamics and the corresponding relative importance compared to the parameters of efficiency and reliability of the service.
The analysis of Weight of Pricing indicates that retailers are not price sensitive in determining their degree of satisfaction, while consumers and producers are indeed sensitive to pricing. In fact, the consumers' adoption is influenced by advertising, which is in turn affected by the Retailer satisfaction and thus by Weight of Pricing. Similarly, adoption from producers is influenced by the Retailer Satisfaction and Producer Satisfaction, which are subsequently affected by Weight of Pricing (Figure 16).
Whatever the value of the Weight of Pricing, the consumers' total population saturates within the three-year simulation period (156 weeks). On the contrary, the diffusion among producers largely depends on the importance given to the price of the mobile distribution service.
Also, the low pace growth of adopting producers due to a higher Weight of Pricing does not affect the retailers' community growth. Rather, it stimulates a fast community increase because the persuasion by producers has a high level of influence. Indeed, the persuasion is directly proportional to the producers' business level, which is expressed as the share of retailers' demand addressed to a single producer. As a consequence, the lower the number of producers, the greater the persuasion.

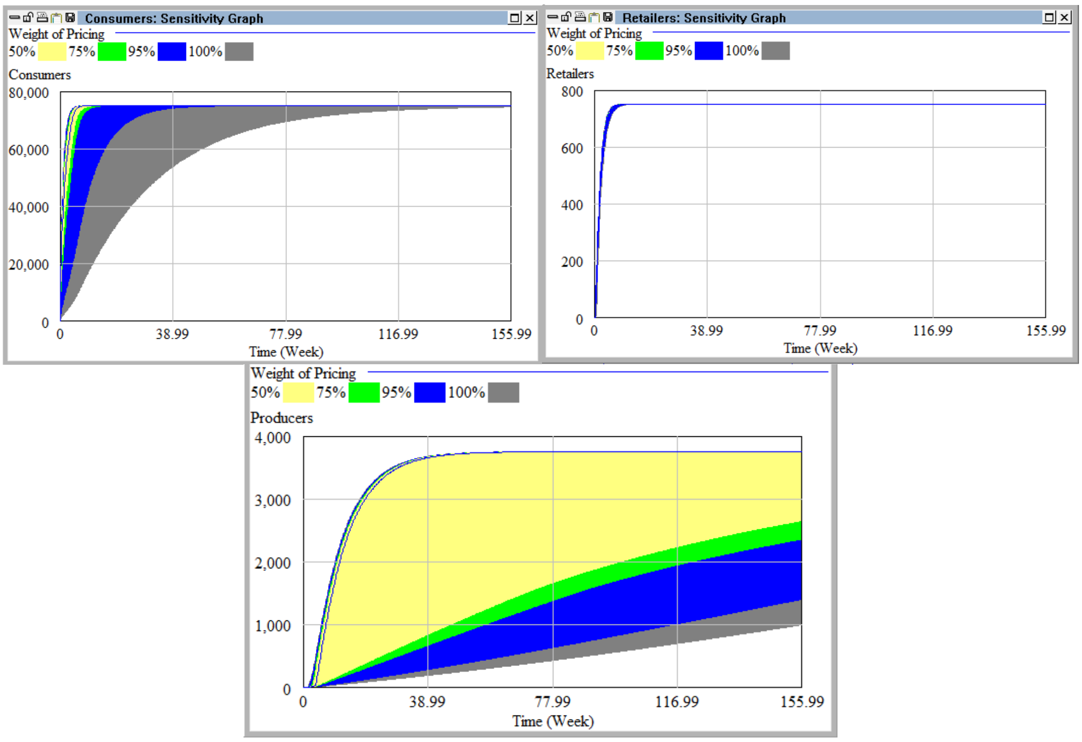

Figure 16. Univariate Sensitivity Analysis on Weight of Pricing

The dynamics of all populations growth does not result to be sensitive to the variation of the service fees, although all players are set to be extremely sensible to pricing. Of course, same results are confirmed with no price sensibility. This might be justified by the fact that efficiency and reliability of professional services are a better adoption incentive than low cost. As an example, Figure 17 illustrates the sensitivity of population growth to the Dispatching Unit Fee.

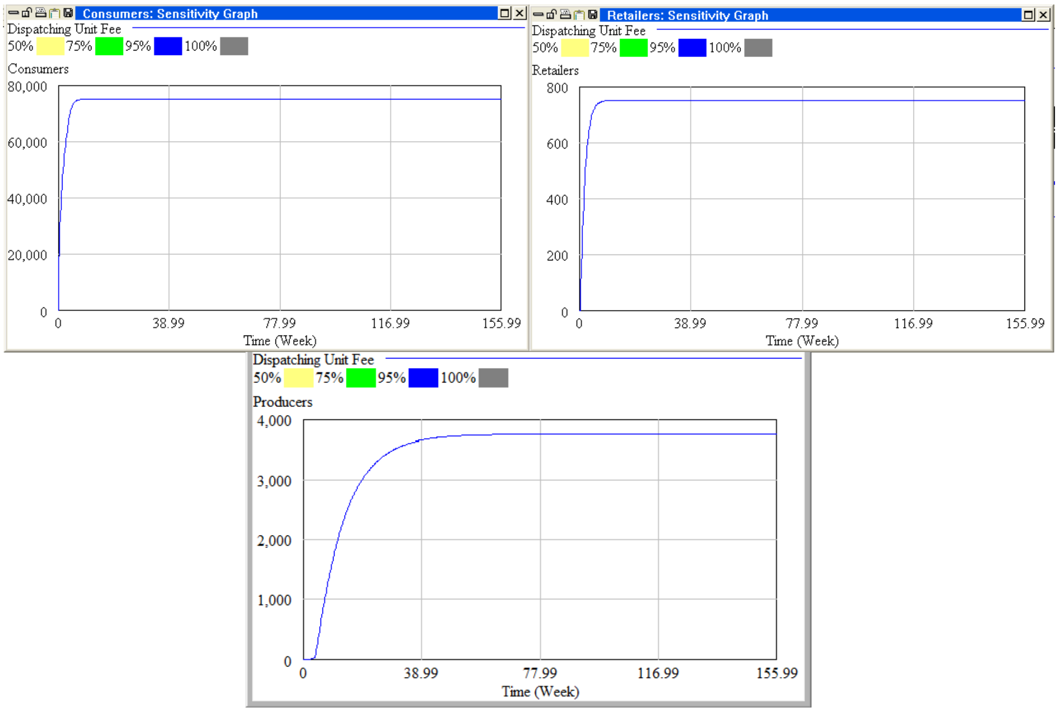

Figure 17. Univariate Sensitivity Analysis on Dispatching Unit Fee

Figure 18 presents the projected total revenue when the three service fees vary. In particular, it is shown that revenue growth is much more sensible to the variation of the Receiving Unit Fee e di Dispatching Unit Fee than to variation of the Web App Unit Price.

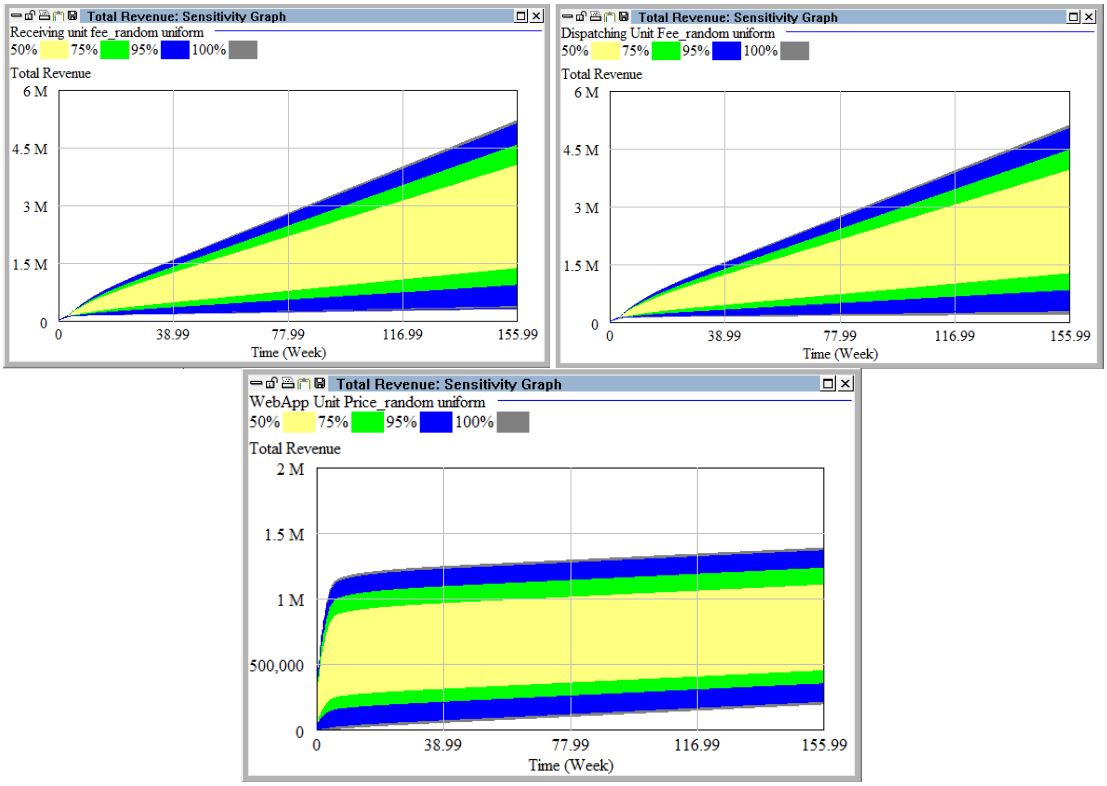

Figure 18. Effects of service fees on Total Revenue

Advertising

Provider Company-Consumer Advertising Effectiveness, Provider Company-Retailer Advertising Effectiveness e Provider Company-Producer Advertising Effectiveness are the variables associated with the level of advertising from the service provider.
Provider Company-Producer Advertising Effectiveness is an important parameter for the producers’ adoption rate because its variation determines significant changes to their saturation period as shown in Figure 19.
Also, given high values to the Provider Company-Producer Advertising Effectiveness, the community of producers itself would drive the diffusion across the SC. Table 2 shows that, when Provider Company-Producer Advertising Effectiveness equals 1, the saturation time span increases along the SC from producers to consumers.
On the contrary, the Provider Company-Producer Advertising Effectiveness has lower impact on the consumers and retailers growth dynamics.

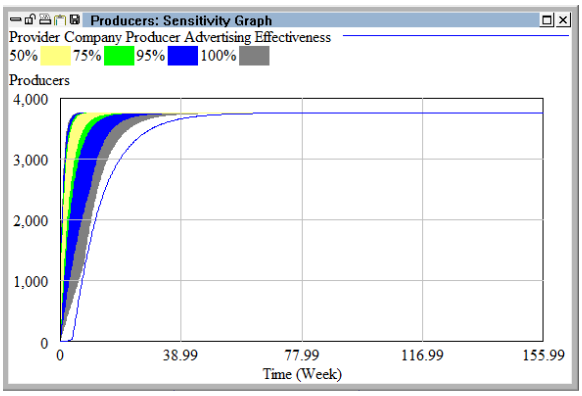

Figure 19. Effects of Provider Company-Producer Advertising Effectiveness on producers' growth

Producer saturation (weeks)	Retailers saturation (weeks)	Consumers saturation (weeks)
7.4	14.6	15

Table 2

Moreover, the Provider Company-Consumer Advertising Effectiveness has just a small influence on the consumers' population growth (Figure 20) and no impact on the retailers and producers.

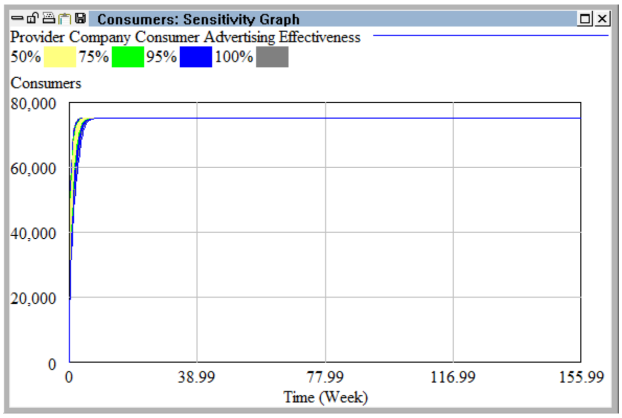

Figure 20. Effects of Provider Company-Consumer Advertising Effectiveness on Consumers

Likewise, the Provider Company-Retailer Advertising Effectiveness has just a small influence on the growth dynamics of retailers and producers (Figure 21) and no power on determining the growth of the consumers adopting the service.

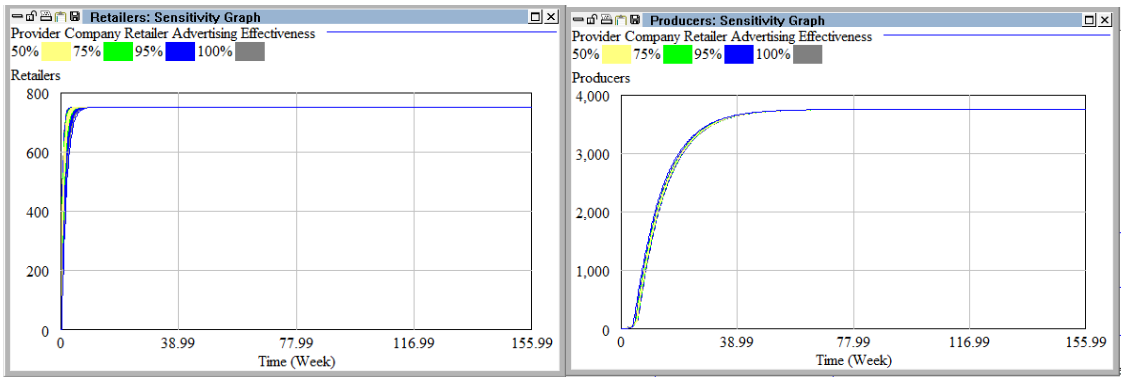

Figure 21. Effects of Provider Company-Retailer Advertising Effectiveness on Retailer and Producers

Interpretation of results

The results of sensitivity analyses help in policy making to stimulate the rapid diffusion of the service among potential adopters and allows to draw implications on the business model.

First, the efficiency and reliability of the mobile service designed for placing and managing orders as well as for tracking and routing of deliveries are the most important aspects to catalyze and speed up adoption, especially by producers and consumers. On the one hand, adopting producers would activate persuasion upon retailers; on the other hand, satisfied consumers would facilitate adoption from word of mouth and stimulate adoption by additional retailers.

Second, the pricing policy results not to be determinant in addressing the dynamics of service adoption by the SC players because the cost of service is perceived to be rather inexpensive for this kind of service and to offer a large potential for economic return from accrued business growth. Therefore, the service providing company can adjust its pricing policy according to the expected dynamics of revenue growth, especially for what is related to receiving and dispatching fees.

Finally, advertising efforts should be addressed primarily towards stimulating producers' adoption in order to maximize the effect of their persuasion on retailers' adoption and, in turn, on consumers. The advertising spending results to be most effective whenever spent downstream along SC, that is from producers to consumers. On the contrary, if the population of consumers is the advertising target, the upward SC contamination would be less effective. In short, producers and consumers are the communities of potential adopters that drive the diffusion of the mobile service and stimulate from both sides the adoption by retailers. A lower level of competition between retailers might be a factor to facilitate business development and revenue growth. In fact, a lower the number of retailers generates a high order rate per retailer, which activates emulation from other retailers to reach a similar high business volume. In the meantime, producers, which are subject to a quicker adoption rate, are likely to carry out their persuasion action towards the retailers.

Conclusion

SD model-based policy making is used as a support for a service providing company to understand the factors that might be having influence on the dynamics of growth of a mobile service business to enable smart distribution of freight. Simulations result to be a useful methodology and tool for measuring the impact of various levers on the business. In particular, it is uncovered that it could be appropriate to activate just service contracts with just a few early adopting retailers. In the meantime, advertising efforts should be targeted to producers and a high level of reliability and efficiency of the service should be assured from consumers and producers to enable adoption by new retailers. In turn, the Retailer Satisfaction would contribute to increasing the consumer and producer communities growth.

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