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Modeling and simulating Chinese cross-border e-commerce: an agent-based simulation approach

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ABSTRACT
Chinese cross-border e-commerce has become the largest in the world, overtaking US e-commerce and representing about 40% of total global e-commerce spending in 2018. This market is highly complex, uncertain, and poorly understood. Surveys and statistics have been used to characterise it, but new approaches are required to better understand its complexity. To address this gap, we present an agent-based model of Chinese cross-border e-commerce. For a realistic representation of the buyers' decision-making mechanism and some elements of their communication, including word of mouth (WOM), we use endorsements theory, and a survey is used to specify the model. The aim of the study is twofold: (1) to present an agent-based simulation (ABS) model of the Chinese cross-border e-commerce market; and (2) to illustrate the potential of the model to explore future possible configurations of the market and to guide stakeholders' decision making.

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1. Introduction

Chinese cross-border e-commerce has become the largest worldwide cross-border market, overtaking the US market (based on companies such as Amazon) and representing about 40% of the total global e-commerce spending in 2018; it is expected to reach double the size of the US market in the near future (AgencyChina, 2018; Li et al., 2018; Zhu et al., 2019). In the first half of 2015, China's online shopping sales reached US$253 billion, accounting for 10% of the country's total consumer retail sales in that period (Wikipedia, n.d.). Cross-border e-commerce can refer to online trade between a business, such as a retailer, and a consumer (B2C); between two businesses, such as wholesalers (B2B); or between two private people via a marketplace provided by companies (C2C). Chinese B2C cross-border e-commerce reached US$1.3 trillion in 2018, and the continuous development of B2C cross-border e-commerce has brought more development opportunities for enterprises, with competition becoming increasingly fierce (Z. Li & Guo, 2019).

These issues make it necessary to analyse Chinese B2C cross-border e-commerce. Thus, our paper focuses on B2C supported by Chinese online marketplaces or platforms, which we will call Chinese B2C marketplaces. Individual sellers in Chinese B2C marketplaces are businesses. However, the website owner is not the seller; rather, the owner is the marketplace company that offers a platform to sellers from which they can sell their products around the world. Homogeneity and characteristics of interchange are determined by the online market provided by the Chinese B2C marketplace, since there are numerous sellers and they are very diffuse.

Cross-border B2C e-commerce is highly complex. This is particularly so in the Chinese case, given that it has only recently started and is still undergoing a process of rapid expansion. Some additional elements of complexity in this market are: (1) that the owner of the marketplace is not the seller of products, and there are many individual sellers; (2) that the owner of the marketplace, the sellers, and the buyers are not necessarily in the same country, and are often not subject to the same jurisdiction; (3) that the sellers' behaviours cannot be fully controlled by the Chinese B2C marketplace; (4) that the quality of products in the Chinese B2C marketplace is relatively variable and uncontrolled; and (5) that buyers' trust in the marketplace and imitation among buyers depend on a large number of diffuse elements. As a result, the properties of these markets are very dynamic and emergent, which makes it particularly difficult to understand and characterise Chinese B2C e-commerce.

Given its high complexity, Chinese B2C e-commerce is a subject of growing interest. Previous statistical work has helped advance the characterisation of this market, while simultaneously illustrating its

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complexity and the importance of explicitly modelling shoppers' decision-making processes. Various studies have described cross-border e-commerce in general (Zhu et al., 2019) and Chinese cross-border e-commerce in particular (Li et al., 2018; Liu et al., 2017; Mou et al., 2017). These studies have identified diverse factors influencing Chinese B2C e-commerce, paying special attention to purchase intention and, more generally, to shoppers' decisions in these complex markets. Nevertheless, there is still much work required to characterise and understand cross-border e-commerce in general and cross-border Chinese B2C e-commerce in particular. Alternative approaches, such as social simulation, will complement statistical studies, as they make it possible to study systems virtually and experiment with models to understand them better. Additionally, simulation allows the exploration of scenarios of the possible future configuration of a system and its environment. In particular, explicit representations of the interacting agents, agent-based simulation (ABS), and their reasoning are helpful for the virtual study of interaction and decision making in Chinese marketplaces. ABS and scenario analysis permit us to study the dynamics of decision making and the possible "future words" of the Chinese marketplaces. Simulation studies in e-commerce are nevertheless scarce, and have been limited to the evaluation of business strategies using certain sorts of games, or process-based simulations. They have not yet included representations of agents' reasoning, nor have they been based on surveys, as will be explained in Section 2.2.

Here, we study Chinese B2C e-commerce via social simulation and, specifically, ABS (Squazzoni, 2012). By using virtual computational experiments applied to simulation models of social systems, and by extrapolating results from these experiments to real situations, ABS can increase understanding of those systems (Axelrod, 1997; Gilbert, 2010; Gilbert & Troitzsch, 2005; Moss & Edmonds, 2005; Squazzoni, 2012; Sun, 2006). ABS allows us to study dynamic and emergent properties of complex systems, such as Chinese B2C e-commerce, which is not possible using traditional statistical methods.

One of the approaches used to represent decision making in this community is endorsement theory (Cohen, 1985), which has been implemented and used in diverse research projects and modelling situations by Moss (1995) and several of his colleagues at the Centre for Policy Modelling in Manchester, UK, including Bruce Edmonds and Ruth Meyer (Alam et al., 2010). Researchers at the Centre for Policy Modelling created their own ABS language, a strictly declarative modelling language (SDML; see, Moss et al., 1998) that allows contextualised simulation and modelling. Nonetheless, this language has not received support or maintenance for several years, and is not available for new versions of operating systems (Windows, Linux, etc.). Moreover, the simulation languages that are available do not offer good facilities for realistic representation of agents' decision-making processes or contextualised knowledge (as suggested by Alam et al., 2010; Edmonds, 2003).

To address these shortcomings, we developed a model in Java (a general-purpose computer language; Leger, 2020)[1] to represent Chinese B2C e-commerce, which includes realistic consideration of buyers' decision-making mechanisms, based on the endorsement scheme and supported by survey data. Among the survey elements included are word of mouth (WOM) between buyers, which allows buyers to communicate (suggest) the names of Chinese marketplaces to other buyers; at each iteration, the marketplaces are better evaluated by the buyers (each buyer suggest the best evaluated marketplace). In this sense, a novelty of our work is the inclusion of endorsements, along with WOM, in a model of the Chinese B2C cross-border e-commerce market. To the best of our knowledge, no previous ABS models have employed endorsements or WOM to represent these kinds of markets. The present paper outlines the model we developed for Chinese B2C cross-border e-commerce and conducts a scenario analysis to explore future possible behaviours of interest for decision-makers in those markets.

This paper is organised as follows. Section 2 briefly reviews the relevant theoretical aspects, such as ABS and endorsements. Section 3 describes the simulation model, its configuration and validation, and the experimental design. Section 4 summarises and discusses the simulation results. Finally, Section 5 presents conclusions and recommendations for further research.

2. Literature review

We model Chinese cross-border e-commerce markets using ABS. The reasoning of the agents is represented by the endorsement mechanism, and their communication represents the WOM of real agents. This section briefly introduces this approach. First, we describe the modelled situation: cross-border markets. Second, we outline the use of the simulation in e-commerce. Finally, we explain the mechanism used to represent the agents' reasoning or decision-making process: the endorsement scheme and the notion of WOM.

2.1. Cross-border markets

E-commerce is a recent phenomenon that has appeared in the last few decades and is constantly evolving. In particular, Chinese B2C e-commerce has developed quickly and presents highly dynamic and emergent tendencies. An important characteristic of Chinese B2C e-commerce is that buyers and sellers interact in an online market offered by a company, referred to here as the Chinese B2C marketplace (e.g., AliExpress).

Chinese B2C e-commerce (Li et al., 2018; Liu et al., 2017; Mou et al., 2017; Zhu et al., 2019) has many uncertainties, some common to all cross-border e-commerce, and others specific to B2C markets. All cross-border e-commerce faces the impossibility of making a clear and confidential contract and the lack of a well-defined and easily accessible international tribunal and laws to protect buyers, especially given that buyer and seller are often not located in the same country, not subject to the same jurisdiction, use different currencies, and speak different languages.

Cross-border e-commerce, including Chinese B2C e-commerce, has been studied using surveys and statistics. Zhu et al. (2019) have described cross-border e-commerce in general, while Mou et al. (2017), Li et al. (2018), and Liu et al. (2017) have determined diverse factors influencing Chinese B2C e-commerce, giving special attention to purchase intention and to shoppers' decisions in these complex markets. More specifically, Mou et al. (2017) used online surveys to determine how the purchase intentions of online buyers in Chinese cross-border e-commerce are affected by positive valences (utilitarian benefits) and negative valences (pre- and post-contractual uncertainties). Recently, Zhu et al. (2019) developed a theoretical model of buyers' decision making by using the hierarchy-of-effects model and commitment-involvement theory, supported by an analysis of surveys from the B2C site DHgate.com. All these studies reveal not only the uncertainties of the market but also the importance of examining shoppers' decision-making processes, including agents' intentions, to better comprehend its behaviour.

Figure 1 illustrates how a Chinese B2C marketplace appears to a buyer. A brief consideration of the shopping process reveals additional aspects of the complexities of Chinese cross-border e-commerce. Some initial attributes important to the buyer are already visible on the main page (see, Figure 1a), including the variety of products, the quality of the page in terms of its agreeability, and the general presentation of the products. After the product has been chosen, the name of the seller (see the red arrow on the upper left of the image), as well as other attributes such as price, are presented (see, Figure 1b). Once the transaction has been made, the additional attributes relating to the process of sending the product to the buyer appear, including delivery time and the quality of delivery management. Thus, after receiving the product, the buyer can evaluate how realistic the promise of the seller has been in terms of the quality of the product and the delivery time and quality, which determines the buyer's confidence in the Chinese B2C marketplace. Finally, the buyer evaluates the entire shopping transaction, which can be compared with other experiences in Chinese B2C marketplaces, to decide about future shopping in the various marketplaces that he/she knows. Usually, buyers can rate their experience on the webpage by assigning a score that is then used by the website to publish an overall evaluation from each seller. This example shows how the great variety of sellers on Chinese B2C marketplaces increases the complexity of buyers' shopping decisions, in comparison with what happens on other e-commerce sites, where the main seller is the business that provides the website (e.g., Amazon).

Previous studies on e-commerce have shown the importance of factors that determine consumers' purchase intention to buy through a certain website. Table 1 illustrates aspects related to the Chinese B2C e-commerce marketplace that are important for a shopper's choice in that context. This description of cross-border markets, particularly Chinese B2C marketplaces, illustrates the situation of the interacting agents: buyers and shoppers.

2.2. Simulation studies in e-commerce

Though there are relatively few studies in e-commerce, three kinds of studies or applications of simulation in relation to e-commerce can be found, listed here in order of frequency: (i) games or applications to explore decision making and its consequences in controlled "business environments", including decisions at the strategic, tactical, and operational levels in diverse business situations, including e-commerce, which are useful for scenario exploration and teaching (Insight Maker, 2021; Marketplace Simulation, 2021; Parker & Swatman, 2001; Tabletto, 2021); (ii) processes and systems dynamic simulation applications exploring situations where e-commerce has been or can be implemented (Chen et al., 2006a, 2006b; Hristoski et al., 2015; X. Li & Kai-Ling, 2016); and (iii) social simulation applications investigating the dynamics of the system in relation to social constructs such as reputation (Letia & Slavescu, 2012). The last paper involves agents and uses formal logic to investigate theoretical issues; however, none of the studies has implemented a realistically situated simulation that includes surveys and agents' reasoning. The present research simulates not only the actions of many individual computer agents but also the actions of agents who can reason. It should also be noted that consumer surveys have been used in the literature to represent and validate the evolving situation in the field of modern e-commerce.

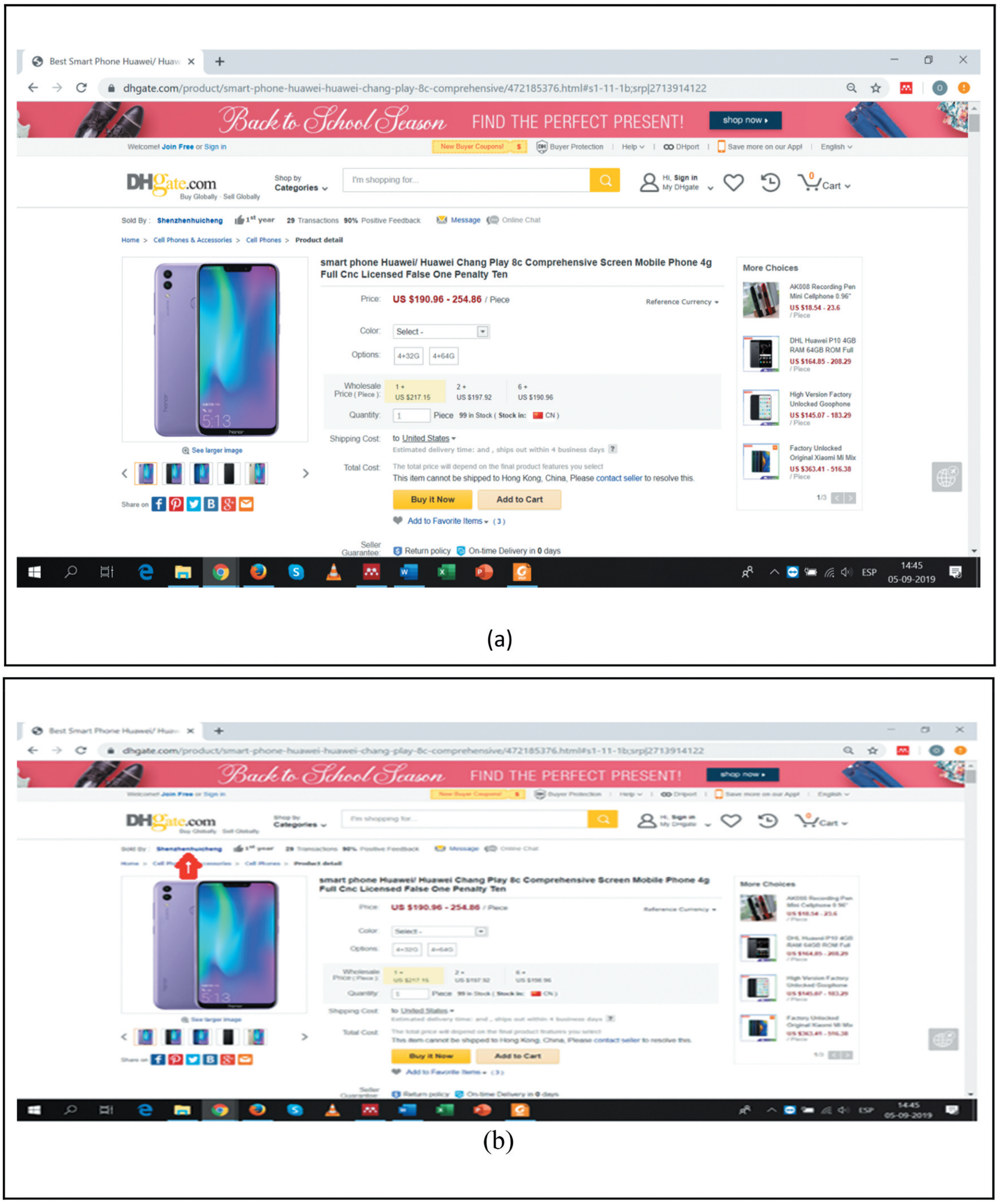

Figure 1. One of the most popular Chinese B2C marketplaces, DHgate.com. In (a), the options for the shopper are given; (b) presents details of the selected option, in this case a particular cell phone. Image (a) shows a set of general attributes associated with the web market, such as the variety of products, which involves a diversity of sellers not presented at this level. After a particular type of phone has been selected, image (b) shows more specific attributes of the shopping experience, including price and seller (indicated by the red arrow above the picture of a cell phone).

2.3. Agents' reasoning: The endorsement scheme

The importance of explicitly modelling agents' reasoning (decision-making) processes for a realistic representation of a social system was first emphasised by Herbert Simon and then developed in research on social simulation, including that of several of Simon's colleagues (Cohen, 1985; Cyert & March, 1963; Newell, 1990; Newell & Simon, 1976). Subsequently, cognitive architectures, theories, and software packages (e.g., SOAR, ACT-R, BDI) in relation to human cognition have been suggested and implemented (see, e.g., Newell, 1990; Newell & Simon, 1976). These classic cognitive developments are too complex to be implemented in an ABS context. However, a simplification of the original models allows us to represent the learning and evolution of the individual's mental models effectively using the endorsement mechanism, as explained by Cohen (1985) and

Table 1. Characteristics of a Chinese B2C marketplace that are important for a shopper and determine purchase.

Factor	Definition	Studies that have shown its importance in e-commerce
Reputation of the Chinese B2C marketplace	Extent to which buyers believe a Chinese B2C marketplace is professionally competent or honest and benevolent (Doney & Cannon, 1997)	Teo & Liu, 2007
Company size	Company overall size and market share position (Doney & Cannon, 1997)	Teo & Liu, 2007
Website appearance	Visual attractiveness of a website (Liao et al., 2006)	Liao et al., 2006
Website content quality	Characteristics of the website content in general, such as content usefulness, completeness, clarity, conciseness, and accuracy (Al-Qeisi et al., 2014)	Liao et al., 2006; Ranganathan & Ganapathy, 2002
Website technical quality	Extent to which appropriate technologies have been adopted by the web retailer (Liao et al., 2006)	Liao et al., 2006; Van der Merwe & Bekker, 2003
Security of the web	Dependability and assurance of a retailer's online transaction system, which enables transactions through the Internet to be secure and successful (Teo & Liu, 2007)	Ranganathan & Ganapathy, 2002; Teo & Liu, 2007
Privacy	Willingness of consumers to share information over the Internet, allowing purchases to be concluded (Belanger et al., 2002)	Belanger et al., 2002; Ranganathan & Ganapathy, 2002
Consumer reviews	Any positive or negative statement made by potential, actual, or former customers about a product or company that is made available to a multitude of people and institutions via the Internet (Hennig-Thurau et al., 2004)	Chevalier & Mayzlin, 2006
Cost saving	Availability of low prices on the website	Escobar-Rodríguez & Bonsón-Fernández, 2017
Product offerings	Assortment or range of goods available from a retailer (Jarvenpaa & Todd, 1996)	Chen & Tan, 2004
Product quality	Expected standard of product excellence (Jarvenpaa & Todd, 1996)	Chen & Tan, 2004
Service quality	Overall customer evaluations and judgements regarding the excellence and quality of e-service delivery in the virtual marketplace (Santos, 2003)	Chen & Tan, 2004
Previous experience on the website	Transaction performance in previous purchases on the website	Fang et al., 2014
Previous experience with Chinese websites	Transaction performance in previous purchases on Chinese websites	Fang et al., 2014
Word of mouth	Face-to-face conversation between consumers about a product or a service experience (Sen & Lerman, 2007)	Hwang, 2010

Moss (1995). An example of an endorsement would be the label "high reputation" observed by a buyer in a Chinese B2C marketplace.

Since these initial applications, the notion of endorsement has been further developed and applied in a range of contexts. Important conceptual advances and revisions in terms of its usefulness and implications for virtual research in social interaction (e.g., to add contextualised knowledge) have been offered by Alam et al. (2010) (see also, Edmonds, 2003; Moss, 2000; Moss & Edmonds, 2005). In a study of e-commerce and value chains, Taylor (2006) used endorsement to describe and model the attitudes, perceptions, and patterns of behaviour of real trading actors, including consumers, using qualitative data. Barthélemy (2006) employed endorsement in a model of household water demand to process information in accordance with observations of real situations, including individually weighted subjective value. Werth (2010) made fruitful use of endorsement to represent the reasoning process for sellers and clients in relation to the evidence given by the interviewed stakeholders. Terán et al. (2007) employed endorsement to model the decision making and learning of diverse actors (e.g., colons, the state) in a forest reserve, and thereby to characterise the landholding distribution of colons.

Further developments have applied endorsements in models of the decision making of agents to investigate the factors that influence complex social interaction in water management in emergent metropolitan areas (Galán et al., 2009, 2008). Alam and Meyer (2010) applied endorsement to the evolution of dynamic social networks in a model of HIV/AIDS in a town in South Africa, observing that social ties are based on abstract labels (e.g., similar age or same gender). Geller and Moss (2017) used endorsements to represent the agents' reasoning process about preferences in models of power and authority. They developed a model of a characteristic agent based on interviews and indirect data, which allowed them to differentiate dimensions of reasoning and implement them in a "natural way"; that is, it permitted the use of mnemonic tokens found in the evidence, thereby overcoming the lack of statistical data. Finally, as noted above, an extension for representing endorsements was added to the 5.2 version of NetLogo (GitHub, 2021; Meyer, 2021; NetLogo, 2021).

2.4. Word of mouth

The phrase word of mouth (WOM) is used to refer to oral communication, or as the Free Dictionary puts it, "informal oral communication: *rumors spreading by word of mouth*" (Lang & Hyde, 2013; The Free Dictionary, 2020a). More specifically, WOM refers to information passing viva voce from person to person, which can be as simple as saying what day it is, or as complex as oral storytelling (Wikipedia, 2020b). The marketing literature uses the term to refer to conversation between consumers about products and/or brands (Sen & Lerman, 2007). Accordingly, in this study, WOM refers to situations in which individuals make purchases on Chinese B2C marketplaces and share their buying experience with other consumers.

An important characteristic of WOM concerns the source that transmits the message. The marketing literature has distinguished between strong ties, where the source of information has a close relationship with the receiver (for example, they are friends or relatives), and weak ties, where the source of information and the receiver have a more distant relationship (for instance, they are acquaintances; Brown & Reingen, 1987). Previous studies have shown that consumers are more likely to share their experiences of products and brands in the context of strong ties (Wirtz & Chew, 2002), and that strong ties allow greater influence among consumers than weak ties (Brown & Reingen, 1987; Koo, 2016). Therefore, in this paper WOM refers to communication about experiences in relation to Chinese B2C marketplaces between consumers who have a close relationship or a strong tie, as in such cases communication is more likely to take place and more likely to be influential. WOM can occur in face-to-face conversation or via the Internet (when, for instance, consumers express their opinions on social networking sites; Hennig-Thurau et al., 2004; Sen & Lerman, 2007), and a consumer might share his/her experience with a product with a close friend either face to face or through WhatsApp. Accordingly, in this study WOM represents interaction between buyers in the form of either (i) direct face-to-face interaction, or (ii) indirect social media interaction, e.g., by using WhatsApp or Facebook.

3. Simulation model and experimental design

ABS involves simulation of the interaction of several computational entities representing agents of socially real or ideal systems (Squazzoni, 2012), in our case the set of shoppers and the set of sellers on Chinese marketplaces. This section presents a model of Chinese B2C marketplaces in the Spanish context, and the experimental design for a relevant scenario analysis using survey data. In Section 3.1, we describe the context, characteristics, and relevant results of the survey. In Section 3.2, we explain how, on the basis of the survey data, we configured the basic model to represent a real case. In Section 3.3, we describe the validation of the model. Then, in Section 3.4, we present an analysis of scenarios that characterise and explore several possible configurations of the model. These scenarios represent situations of interest for stakeholders of Chinese B2C marketplaces (e.g., real Chinese B2C marketplaces, as well as sellers and buyers in these marketplaces). The results are presented and discussed in Section 4. A brief description of the model in ODD (Overview, Design concepts and Details) terms (Grimm et al., 2020) is given in the Appendix.

3.1. Survey

We conducted an online survey to obtain the necessary information to develop the simulation. Specifically, we ascertained consumers' perceived importance of the website characteristics that determine their purchases in Chinese B2C marketplaces. We also obtained consumers' perceptions regarding the extent to which certain Chinese B2C marketplaces fulfill these characteristics. The participants were individuals who had previous shopping experience in or were familiar with some of the Chinese B2C marketplaces.

To obtain accurate information for the simulation, we developed a questionnaire based on previous work, thereby maintaining the correspondence between existing theories and our research results (Eldabi et al., 2002). Characteristics of Chinese B2C marketplaces in relation to purchasing were obtained from previous studies (see, Table 1), and scales were adapted from the literature to measure them (see, Table 2). Long questionnaires are problematic in terms of increasing modal responses and decreasing extreme responses, which can affect the quality and validity of the data (Vriens et al., 2001). To avoid this issue, we used a relatively small number of items to evaluate each Chinese website (generally one item per characteristic; see, Table 3).

The Chinese B2C marketplaces that were evaluated in the questionnaire were identified in a pre-test: AliExpress, LightInTheBox, MiniInTheBox, DealExtreme, Banggood, DHgate, Delfind, Wish, and Alibaba. For each platform, we checked whether it provided consumer product reviews. Participants were asked to give the names of and evaluate any other Chinese B2C marketplaces that they know and have bought from, stating how often they buy on these platforms, how many people they have frequent contact with (in order to measure their strong ties), and how often they share information with them. Finally, their sociodemographic information was obtained.

Participants were recruited from a Spanish online consumer panel. The sample consisted of 414 individuals who fulfilled the characteristics of Spanish Internet users in terms of sex, age, and place of residence. These steps were taken to ensure the representativeness of the sample (Malhotra et al., 2017).

3.2. ABS model for Chinese B2C e-commerce

The data to configure the model were taken from the survey. The model project, which is publicly available (Leger, 2020), was implemented on Java (1.8.0_11)

Table 2. Measurement of characteristics of a Chinese B2C marketplace.

Variable[a]	Items	Source
Reputation of the Chinese B2C marketplace	The company is well known. The company has a good reputation in the market. The company has a reputation for being honest. The company has a reputation for being fair. The company has a reputation for being consumer-oriented.	Doney et al., 1998
Company size	The company is very large. The company is one of the industry's biggest suppliers on the web.	Kini & Choobineh, 1998
Website appearance	Website attractiveness Website organisation	Aladwani & Palvia, 2002
Website content quality	Finding contact information Finding company information Finding product details Finding customer policies Finding customer support Presence of visual presentation aids (graphics, audio, video)	Aladwani & Palvia, 2002; Ranganathan & Ganapathy, 2002
Website technical quality	Ease of navigation Search facilities Absence of broken links Absence of "under-construction" pages	Aladwani & Palvia, 2002; Van der Merwe & Bekker, 2003
Security of the website	Availability of secure modes for transmitting information Provision for alternative, non-online modes for financial transactions Opportunity to create individual accounts with log-on ID and password Provision for PayPal payment Website provides a security seal	Ranganathan & Ganapathy, 2002
Privacy	Gathering of personal information	Ranganathan & Ganapathy, 2002
Consumer reviews	Provision of star ratings of the products Provision of consumer reviews of the products Provision of consumer reviews of the vendors	Self-developed
Cost saving	Obtaining the best prices for products Getting a better price–quality relation Saving money	Jensen, 2011
Product offering	Great range of products on the website Finding hard-to-find products on the website	Jarvenpaa & Todd, 1996
Product quality	Finding quality products	Jarvenpaa & Todd, 1996
Service quality	Speed of delivery Ease of returning merchandise	Liu & Arnett, 2000
Previous experience on the website	Previous experience purchasing on the website	Self-developed
Previous experience with Chinese websites	Previous experience purchasing on Chinese websites	Self-developed
Word of mouth	Friends and relatives' experience purchasing on Chinese websites	Self-developed

[a]Individuals were asked to what extent they consider these characteristics important when buying on a Chinese B2C marketplace (1 = of little importance, 7 = very important).

Table 3. Measurement of consumers' perceptions of a Chinese B2C marketplace.

Variable	Items	Source
Reputation of the Chinese B2C marketplace	Company reputation (1 = bad reputation, 7 = good reputation)	Self-developed
Company size	Company size (1 = small, 7 = large)	Self-developed
Website appearance	Website attractiveness (1 = little attractive, 7 = very attractive) Website organisation (1 = little organised, 7 = very organised)	Aladwani & Palvia, 2002
Website content quality	Website content quality (1 = low quality, 7 = high quality)	Self-developed
Website technical quality	Functioning of the website (1 = bad functioning, 7 = good functioning)	Self-developed
Security of the website	Security of the web at buying (1 = little security, 7 = high security)	Self-developed
Privacy	Privacy at gathering of personal information (1 = low privacy, 7 = high privacy)	Ranganathan & Ganapathy, 2002
Cost saving	Product pricing (1 = expensive, 7 = cheap)	Self-developed
Product offering	Variety of offered products (1 = little variety, 7 = high variety)	Self-developed
Product quality	Quality products (1 = low quality, 7 = high quality)	Jarvenpaa & Todd, 1996
Service quality	The speed of delivery (1 = slow, 7 = fast) The ease of returning merchandise (1 = difficult, 7 = easy)	Liu & Arnett, 2000
Previous experience on the website	Previous experience purchasing on the website (satisfaction)	Self-developed

under the IDE Intellij Idea, and executed mainly on a MacOS Catalina, 3.1 GHz Dual-Core Intel Core i5 with 8GB of RAM.

Given that buyers use endorsements for learning, contextual modelling is required, which involves retrieving accumulated data that represent their experience (beliefs). To do this, at each iteration buyers access data for the previous time steps of the simulation ("historical data access"). As mentioned above, although this process was possible in SDML, a simulation language that is no longer available (Edmonds, 2003; Moss et al., 1998), it is not easily implementable in currently accessible languages such as Repast or NetLogo; because of this, workshops have addressed the possibility of adding this kind of facility in NetLogo (Centre for Policy Modelling, 2019). An extension is available for the 5.2 version of NetLogo (Meyer, 2021), but not for the most recent versions of that simulation language. It is possible to develop models where agents require access to historical data during the simulation in languages such as Repast and NetLogo, but the task is not straightforward because of the multiple configurations needed to include both the endorsements and e-commerce concepts. In addition, computing systems that have to be tightly configured are error-prone, since the developer will make many coding decisions without fully understanding the implications (for example, the white box principle; Kiczales et al., 1997). For these reasons, we chose to develop a software application adapted to our current and future needs (we are planning to create related simulation models representing cross-border e-commerce in future research).

The model consists of four elements: environment, agents, iteration time, and rules.

3.2.1. Environment

The environment consisted of a set of six (computational) agents of the Chinese B2C marketplace type and a set of m (computational) agents of the buyer type (representing online shoppers). For the simulation, m was set to 50. The five better-known Chinese marketplaces (AliExpress, LightInTheBox, Banggood, Wish, and Alibaba) were selected, alongside "Others", an agent representing the remaining, less well-known marketplaces (i.e., those known by fewer than 10% of buyers). Table 4 shows the percentage of shoppers who know each of these Chinese marketplaces, and their proportion of unique buyers (that is, buyers who have bought in the marketplace at least once).

Table 4. Percentage of buyers who know and have bought at least once in each marketplace.

Marketplace	Percentage of buyers in the sample who know the marketplace	Number of buyers who know the marketplace where the marketplace has a total of 50 buyers in the simulation	Proportion of buyers who have bought at least once[a]
AliExpress	92.27	46.1	0.626
Banggood	10.14	5.1	0.041
Wish	41.30	20.7	0.180
Others	14.25	7.1	0.068
LightInTheBox	11.59	5.8	0.024
Alibaba	42.51	21.3	0.061

[a]The total represents the number of buyers who have purchased in each marketplace at least once; therefore, a buyer who has purchased in three marketplaces is counted three times.

3.2.2. Agents

There are two types of agents: Chinese B2C marketplaces and shoppers. Shoppers learn from their experience via endorsements (as they observe characteristics of the marketplaces, such as variety), and they adapt their behaviour during the simulation. Chinese B2C marketplaces do not learn, and they maintain similar behaviour throughout the simulation. As indicated above, we simulated six marketplaces and 50 buyers.

3.2.3. Iteration time

The iteration period is the length of time between two sequential shopping instances.

3.2.4. Rules

The rules implement the following features of the system.

(a) The initial state and structure of the system. For example, the rules create the agents with their variables, including the two values, low and high, of the 13 possible attributes of the marketplaces (Table 3, right column), and the buyers' endorsement scheme.

(b) The simulation dynamic for the iteration steps (time iterations). The simulation is run for each iteration, from 1 to n, where n is the maximum number of iterations. (Here, n was set to 200, but results were collected for iterations 101 to 150, as Section 3.3 explains). At this stage, we have the agents' interaction at each step of the simulation: sellers showing their attributes (such as quality), and buyers' shopping and endorsing (learning). Thus, for iterations 1 to n, we have:

(b.1) The actions of Chinese B2C marketplaces. At the actual iteration time, each marketplace presents at random the levels (states) of the 13 categorical variables indicated in the left column of Table 3, which represent the characteristics important for the buyer's choice. These features were obtained from previous studies on e-commerce (see, Table 1). We assumed that each attribute has only two possible states: low and high. The probability of each possible state was calculated from the survey based on the frequency an attribute receiving low or high valuations from the interviewee. Thus, the frequency for low was obtained by counting the number of answers in the survey in the interval [1, 3.5] (a half of the whole interval: [1, 7]), and the probability for low was calculated by dividing this frequency by the total number of answers. The probability for high is the complement of the probability for low.

(b.2) Actions of buyers. At the actual iteration time, a buyer uses the endorsement scheme to calculate the endorsement value for each marketplace the buyer knows, and then probabilistically choses a marketplace in accordance with these endorsement values (the endorsement value is the probability weight for each marketplace, as explained in Section 3.2.5). After shopping at the chosen marketplace, the buyer endorses the marketplace by adding to its list of endorsements the attributes the marketplace has shown in the present iteration, thereby updating its memory with the new experience. Finally, to simulate WOM in the Spanish context (as explained below), the buyer shares with other buyers (12 buyers chosen at random) the name and attributes of the best marketplace it knows (the one with the highest endorsement value). Because of bounded rationality, of all the information a buyer receives from the 12 other buyers, in the next iteration it considers only one suggested seller (chosen at random).

As mentioned, the model is based on the Spanish context, and its configuration takes into account the following relevant facts. In Spain, there are about 20 million Internet shoppers of whom around 70% (i.e., 14 million) have purchased from a Chinese marketplace. The survey indicates a mean of the frequency of face-to-face interaction of 4.93, out of a total of 7; thus, the probability of an agent sharing information face to face with others is 4.93/7. As the average number of other purchasers know to a buyer is 17 (as shown by the survey), in each iteration a person shares information with 4.93/7*17 buyers, that is, with approximately 12 buyers. In some of the simulation experiments, we assume that shoppers interact with other shoppers to share information about Chinese B2C marketplaces by WOM every iteration, giving their opinion to another 12 shoppers. Because of bounded rationality, a shopper considers only one of the suggestions received (chosen at random).

3.2.5. Example application of the endorsements scheme

The endorsement mechanism forms part of the rules of the ABS. It establishes how buyers choose among different websites at each time-period of the simulation. Among the attributes of Chinese B2C marketplaces that buyers consider when making their choices are the reputation of the marketplace, product quality, privacy, and the security of the website. In our simulation, these are categorical variables that take one of two values (high or low), which define all the possible endorsements. We have 15 variables or categories, giving a total of 30 possible values or attributes that a Chinese marketplace can show. These attributes include highReputation, lowReputation, highProductQuality, lowProductQuality, highPrivacy, LowPrivacy, highSecurityWeb, and lowSecurityWeb. As an example, suppose that in several interactions an agent has perceived on a certain Chinese B2C marketplace the following attributes: highReputation, lowQuality, highPrivacy, and highSecurity. These will determine the beliefs of the agent about the marketplace. Endorsement theory (Moss, 1995) tells us how to determine the importance of this marketplace for the buyer by using the weight of these attributes, that is, the buyer's intention to buy in that marketplace.

For the results reported in this paper, these weights were obtained from the survey as a function of the importance of the attributes of the marketplaces for the interviewed buyers. They were calculated as follows. Each endorsed attribute can take the value high (considered positive or satisfactory) or the value low (considered negative or dissatisfactory) in accordance with how it appears to the buyer. Simon (1998) indicated that agent satisfaction is usually in a range of values above zero, and that dissatisfaction is in a range below zero: "Most people consistently register either slightly below zero (mild discontent) or a little above (moderate satisfaction)" (p. 29). For each attribute that the buyer takes into account (e.g., product quality), we calculated the mean value given in the survey. The range of the answers in the survey is [1, 7], with 4 being the neutral central value. This neutral value corresponds to a weight of the endorsement of 0. Consequently, the range of weight of the endorsements is [−3, 3]; the maximum value of the weight given to an endorsement is 3, and the minimum value is −3. The value of a positive endorsement for an attribute is defined as the distance from the mean of the attribute to the central value; for example, as the mean of importance of "product quality" is 6.25, the positive endorsement (for a satisfactory experience: high product quality) is established as $6.25 - 3 = 2.25$. All the means were larger than the neutral state of the variable (4). Following Simon's (1998) suggestion that a dissatisfactory experience is represented by values lower than those of a satisfactory experience, the corresponding value for a negative experience is taken as the negative value of one-half of the value for the satisfactory case; for example, in the event of low product quality, the endorsement is $-2.25/2 = -1.125$.

For the above listed attributes, the endorsement schemata is as follows:

[[highReputation 1.94] [lowReputation −0.97] [highProductQuality 2.25] [lowProductQuality −1.125] [highPrivacy 0.78] [lowPrivacy −0.39] [highSecurityWeb 1.65] [lowSecurityWeb – 0.825]]

The higher the weight of the positive case of the attribute, the greater its importance for the buyer. The formula for evaluating the endorsements and determining buyer i's indicator of shopping intention at the website j at time t (IdBuyer(i, j, t)) is as follows (Moss, 1995):

$$IdBuyer(i,j,t) = \sum_{ei>0} b^{ei} \sum_{ei<0} b^{|ei|} \quad (1)$$

where b is the base of the endorsement scheme, a value usually in the interval [1, 2], and ei are the values of the endorsements (beliefs) buyer i has for website j at time t. If at a certain iteration time an agent has only the endorsements highReputation, lowProductQuality, highPrivacy, and highSecurityWeb (the buyer's actual beliefs), then the memory of the agent will be as follows:

[[highReputation 1.94] [lowProductQuality −1.125] [highPrivacy 0.78] [highSecurityWeb 1.65]]

Assuming that b takes the value 1.2 (the value used in the simulation), we have the following indicator for this agent of the option represented by the Chinese B2C marketplace (with which the agent has interacted):

$$\begin{aligned} IdBuyer(i,j,t) &= 1.2^{1.94} - 1.2^{|-1.125|} + 1.2^{0.78} \\ &\quad + 1.2^{1.65} \\ &= 2.7005 \end{aligned}$$

We assume that this buyer has experiences with two other Chinese B2C marketplaces, which the buyer has endorsed, and evaluates them at time t, obtaining the following values for shopping intention: 2 and 4 (sum of the IdBuyers: 2.7005 + 2 + 4 = 8.7005). Finally, the buyer will choose among the three websites with probabilities in proportion to these IDs (i.e., with probabilities of 2.7005/8.7005, 2/8.7005, and 4/8.7005, respectively).

As explained above, after each shopping experience, the buyers actualise the endorsements in accordance with their experiences, exchange endorsements (in the form of WOM communication), evaluate the Chinese B2C marketplaces using the endorsement mechanism, make a choice among the Chinese marketplaces using the results of the evaluation, and buy again. Different buyers can have different endorsement schemes, and types of buyers can be defined according to the endorsement scheme they use. However, in line with the results of the survey, our model contains only one type of agent.

3.3. Validation of the model

This section qualitatively validates the model. We show that the order of the Chinese B2C marketplaces given by the simulation is very similar to that obtained from the survey for the variable of interest: the number of buyers who have bought at least once in a particular Chinese B2C marketplace ("SalesUniquePerMarket"). For the survey, this order was determined using the data shown in the fourth column of Table 4.

Simulation results were analysed for two cases: when buyers sharing opinions about the marketplaces was not allowed (the NoWOM case), and when this was permitted (the WOM case, enabling buyers to know new markets). Figures 2,3 present the results. The base of the endorsement scheme was set to 1.2. Although we simulated 200 iterations, we collected the simulation data for 50 iterations, which represents approximately 8 years (assuming that a complete shopping experience took 2 months). We obtained the data after the simulation had stabilised – that is, after the buyers had learned – starting at iteration 101. We performed 30 replications for each experiment (the NoWOM case and the WOM case). Figures 2,3 present the mean values of SalesUniquePerMarket and the standard deviation of the mean at each iteration time for the two cases.

Before analysing the mean of SalesUniquePerMarket given in the upper parts of Figures 2,3 we consider the confidence interval for each value of this mean. Table 5 gives the upper bounds for this interval, indicating that the maximum size of half of the confidence interval is 2.16 (the size of the whole interval being 4.32). This allows us to conclude that the differences between the means shown in the graph for an iteration (period) larger than or equal to 110 (see, Figures 2,3) at each iteration point are significant, given that such differences are larger than 2*1.23 (2.46). The exceptions are the differences between Banggood and Others for the NoWOM case (Figure 2) and between Banggood and Alibaba in the WOM case (Figure 3). Thus, considered from point to point, the tendency of SalesUniquePerMarket for Banggood is similar to that of Others in the upper part of Figure 2, and similar to that of Alibaba in the upper part of Figure 3.

The order of the marketplaces in the two simulated cases, WOM and NoWOM, is very close to that obtained in the survey, as Table 6 shows. (The order in the survey is obtained from Table 4, and that for the simulations from Figures 2,3) We observe that in both cases (WOM and NoWOM), AliExpress obtained a much higher value than the other marketplaces; Wish had the second-highest value, outperforming the marketplaces below it in the order by a significant margin; and LightInTheBox had the poorest performance. Only those marketplaces with values somewhat similar in the survey – Banggood, Others, and Alibaba – changed order in Table 6, which was expected. These observations permit us to qualitatively validate the simulation model.

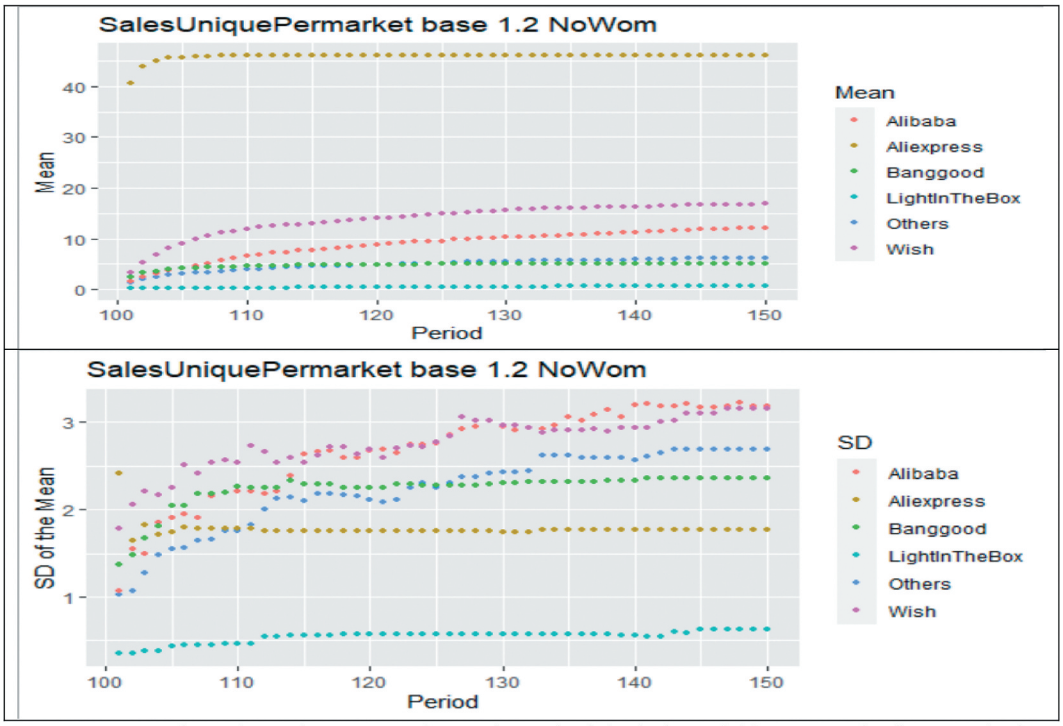

Figure 2. Mean for SalesUniquePerMarket and standard deviation of this mean. The first graph gives the mean of the variable SalesUniquePerMarket for each Chinese marketplace. In this case, buyers did not suggest Chinese marketplaces to the other buyers (i.e., WOM was not implemented), 30 replications were performed, and data were collected from iteration 101 onward (i.e., after the simulation had stabilised). The second graph gives the standard deviation at each iteration point of the means shown in the first graph.

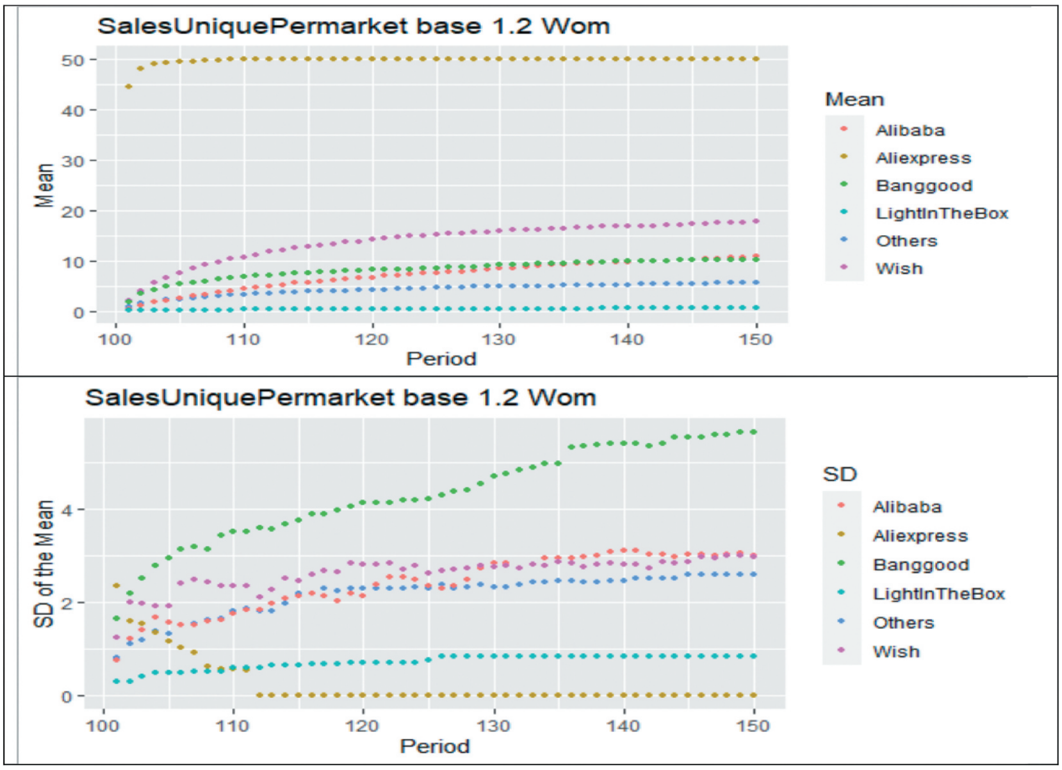

Figure 3. Mean for SalesUniquePerMarket and the standard deviation of this mean for the WOM case. The first graph shows the mean of the variable SalesUniquePerMarket. In this case, buyers suggested Chinese marketplaces among themselves (i.e., WOM was implemented), 30 replications were made, and the data were collected from iteration time 101 onward (i.e., after the simulation had stabilised). The second graph gives the standard deviation at each iteration point of the means shown in the first graph.

Table 5. Upper bound of the standard deviation.

Order in the survey	Upper bound[a]	Half of the upper bound
NoWOM and WOM cases for all marketplaces, except Banggood	2.46	1.23
WOM case for Banggood	4.32	2.16

[a]The table gives the upper bound of the size of the confidence interval for the standard deviation of the mean of the variable SalesUniquePerMarket for the NoWOM and WOM cases. The confidence interval of the mean at each point is given by the *t*-student distribution. To calculate the interval, we used the standard deviation of the mean given in the lower parts of Figures 2,3. We then calculated the maximal value of the size of the confidence interval using the maximal values of the standard deviations given in the same figures. We call this maximal value SDmax. In the NoWOM case in Figure 2, SDmax takes the value 3.3. A half of maximal amplitude of the confidence interval with α = 0.05 is, therefore, $t - value * SDmax/\sqrt{n}$ (*n* taking the value 30). Using the values $t = 2.0423$, SDmax = 3.3, and $n = 30$, the max of half of the amplitude of the interval is 1.23. The other values shown in the table were calculated in a similar way.

Table 6. Order of Chinese marketplaces for the variable SalesUniquePerMarket.

Order in the survey	Order in the simulation, NoWOM case	Order in the simulation, WOM case
AliExpress	AliExpress	AliExpress
Wish	Wish	Wish
Others – Alibaba	Alibaba	Alibaba – Banggood
Others – Alibaba	Others – Banggood	Alibaba – Banggood
Banggood	Others – Banggood	Others
LightInTheBox	LightInTheBox	LightInTheBox

3.4. Experimental design: Scenario analysis

This section defines several scenarios, or configurations, of the model that are of interest to stakeholders, especially the stakeholders of Chinese B2C marketplaces. We investigated the behaviour of the simulated Chinese B2C market in Spain (looking at the tendencies of the variable of interest, SalesUniquePerMarket) to determine what happens in the market if certain factors of the initial configuration are varied. The varied factors were the strategies of the Chinese B2C marketplaces (that is, the probability of their attributes, such as the quality of service and/or product). The scenarios are as follows.

Scenario (0). The market continues to develop in the same way. This scenario allowed us to identify and discuss interesting behaviours and tendencies. In particular, it confirmed that AliExpress was the most successful Chinese marketplace, followed by Wish. An interesting question concerned which key factors Wish should copy from AliExpress to improve its performance (see the first column of Table 2 for the whole set of attributes). The subsequent scenarios focused on answering this question as an example of the usefulness of scenario analysis for examining business strategy.

Scenario (1). Wish copies the entire strategy of AliExpress (i.e., Wish copies all the attributes of AliExpress).

Scenario (2). Wish copies the attributes "product quality", "service quality", and "product offering" (see, Table 2) so that they have levels similar to those of AliExpress.

Scenario (3). Wish copies the qualities of AliExpress's webpage: "website appearance", "website content quality", "website technical quality", and "security of the website".

Scenario (4). Wish copies "product offering", "product quality", and "service quality", as well as the attributes of AliExpress's webpage (i.e., a combination of Scenarios 2 and 3).

Scenario (5). Wish copies the attributes associated with the reputation and size of AliExpress, namely, "reputation of the Chinese B2C marketplace", and "company size".

Scenario (6). Wish copies the attributes associated with the reputation and size of AliExpress, as well as the quality of its webpage (i.e., a combination of Scenarios 3 and 5).

4. Results

This section presents the main results of the simulation for the scenarios defined above. As explained above, there were two goals: to better understand the current situation (Scenario 0, presented in Section 4.1); and, according to the results obtained for the current situation, to investigate future possible behaviours of interest for stakeholders (Scenarios 1–6, presented in Section 4.2). Rather than exploring the scenarios exhaustively, we sought to demonstrate the usefulness of scenario analysis based on the developed model. Thus, for the second set of scenarios, we investigated possible strategies that the marketplace Wish might implement to improve its performance, in terms of imitating the behaviour of the marketplace AliExpress.

4.1. Scenario 0: The current situation

The analysis of Scenario 0 is based on the graphs in the upper parts of Figures 2,3 where the behaviour of the system is presented for 50 iterations, representing about 8 years of real time. The following observations are valid for both the WOM and NoWOM cases.

- As the figures show, the system was very dynamic. With the exception of LightInTheBox, it was in continual change and continued to increase the number of customers (i.e., the SalesUniquePerMarket variable), even in the NoWOM case in which buyers did not recommend marketplaces to each other.

- AliExpress increased its market until it reached its maximal value; it expanded until all the buyers had purchased on it. At the other extreme, LightInTheBox barely increased its market, and buyers seemed to be dissatisfied with it.
- AliExpress continued to dominate the market. Only AliExpress reached its maximum market size; in the near future (8 years), the other Chinese marketplaces would obtain only a fraction of the market.
- Even when Alibaba had a share of the market larger than that of Wish (see the first two columns of Table 4), Wish thereafter maintained a better level of SalesUniquePerMarket than Alibaba.

These trends hold when we perform sensibility analysis with certain variations of the input to the simulation, specifically changes of 5% and 10% (increase and decrease) in the number of buyers who know each marketplace (values given in Table 4).

Finally, in terms of comparing the WOM and NoWOM cases, when WOM was permitted, AliExpress and Wish maintained their good performance, and Banggood improved to reach the same level of SalesUniquePerMarket as Alibaba. The company with the worst performance was LightInTheBox. Thus, we expect AliExpress, Wish, and Banggood to be the marketplaces with the best performance in future, since in real markets WOM is always present.

4.2. Scenarios 1–6: How Wish can imitate AliExpress to improve its performance

The results for the variable SalesUniquePerMarket are shown in Figure 4. Scenario 1 shows the best performance that Wish could achieve by copying all the attributes of AliExpress. To discover the best strategy for Wish to improve its performance, the subsequent scenarios investigated the behaviour of the system when Wish copied specific aspects of AliExpress's strategy (for descriptions of the scenarios, see, Section 3.4). The value Wish obtained for that variable in the final simulation step (150) for each scenario is given in Table 7. We can see that, in all scenarios, AliExpress tended to dominate this virtual "world" across a broad range of parameters and simulations.

As Figure 4 and Table 7 show, the best performances by Wish, after Scenario 1, were Scenario 6 (22.97), followed by Scenarios 4 (21.93), 5 (21.67), and 3 (21.40) (with little difference between them), and then Scenario 2 (18.73). This indicates that the most important factors responsible for the difference between AliExpress and Wish, and for the success of AliExpress, are, in order of importance: (1) reputation and size of the company; (2) attributes relating to the quality of the webpage; and (3) product offering and quality of service and product. In practice, the most important factors, namely reputation and company size, cannot be imitated or copied. Thus, the best immediate strategy for Wish would be to improve its webpage.

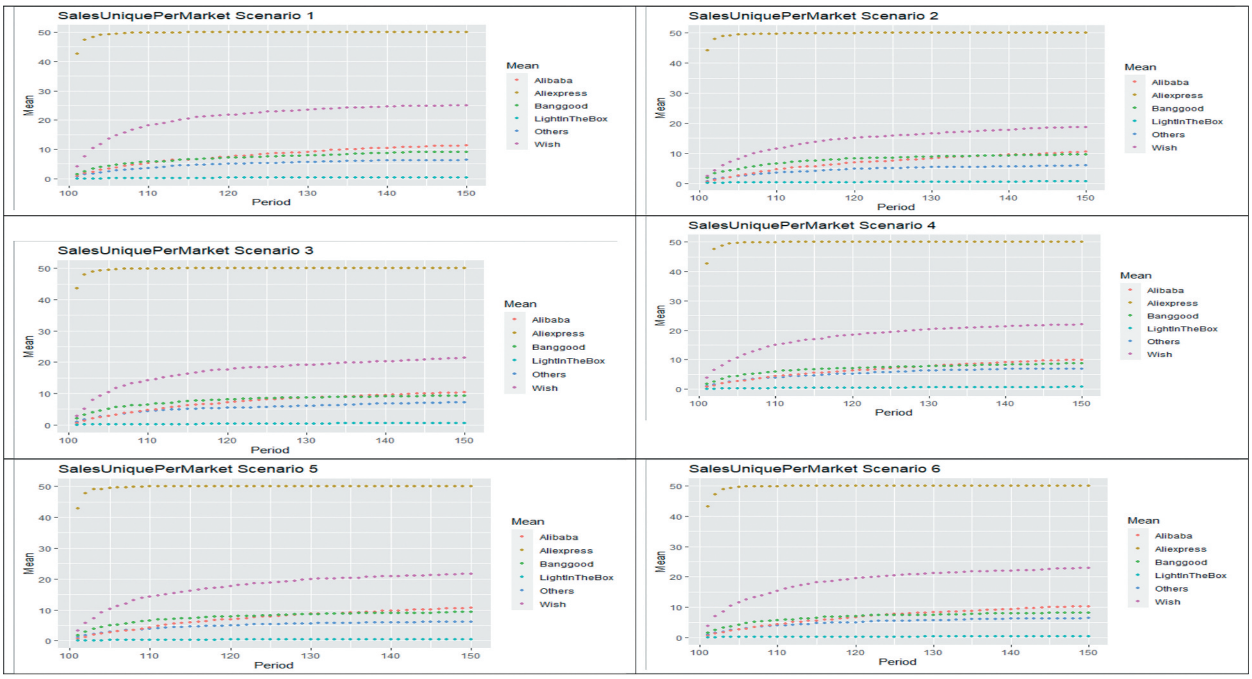

Figure 4. Values of SalesUniquePerMarket for Scenarios 1–6. Wish's best performance, after Scenario 1, was in Scenario 6, followed by Scenarios 3–5, with Scenario 2 as the worst case.

Table 7. Final values of the means of SalesUniquePerMarket for Wish when copying AliExpress.

Scenario	Attributes copied by Wish from AliExpress	Final value of SalesUniquePerMarket
1	All attributes	24.966667
2	Quality and product offering attributes	18.733333
3	Webpage attributes	21.400000
4	Quality, product offering, and webpage attributes	21.933333
5	Reputation and company size attributes	21.666667
6	Webpage, reputation, and company size attributes	22.966667

For all the simulations, the variance of the mean of SalesUniquePerMarket was similar to that of the simulations reported in Section 3.3. The low variance strengthens the validity of our results.

The analysis of scenarios has shown how difficult it is for Wish and the other marketplaces to match the unique sales that AliExpress has achieved, i.e., to challenge its dominance. The virtual market shows strong stability in favour of AliExpress. Further research should examine that stability more closely, performing a more exhaustive scenario exploration to determine the extent of this tendency, and investigating whether the difficulties are due to an intrinsic (i.e., structural) constraint of the model. Future work should also include other markets, such as Amazon and auction markets.

5. Conclusions and implications for future work

To better understand and deal with the complexity of Chinese cross-border e-commerce markets, this paper presents an agent-based model of this market in Spain, showing how we can research the model's behaviour by developing a set of scenarios useful for stakeholders' decision making.

Two types of actors are represented in the model: a set of buyers, and a set of Chinese B2C marketplaces. The behaviours of these kinds of actors were designed in accordance with the results of a survey. On the one hand, the agents representing the marketplaces deterministically show the attributes important for buyers, as revealed by the survey. How probabilistically a marketplace presents its attributes is its strategy. This kind of agent does not learn during the simulation, corresponding to a situation in which marketplaces do not change their strategies. On the other hand, the agents representing the buyers learn as they purchase, in accordance with the importance the agents give to the attributes shown by the marketplaces. Here, learning was represented in terms of the endorsement scheme (with the survey providing the required data).

The model was qualitatively validated, as the order of the marketplaces given by the number of unique sales per market (the SalesUniquePerMarket variable) in the simulation was very similar to the order in the survey. The order in the survey was determined in two ways. In one, buyers were allowed to use WOM to suggest successful marketplaces; in the other, WOM was not allowed.

The order of the marketplaces in the simulation indicates their effectiveness or success. The most successful marketplace was AliExpress, followed by Wish. We developed several scenarios to explore the most important attributes that Wish should seek to copy from AliExpress in order to improve its performance. The resulting order of importance of the attributes was: (1) reputation and size of the company; (2) attributes associated with the quality of the webpage; and (3) the quality of product and service. Reputation and company size cannot be copied. Thus, in order to improve its performance, Wish must improve the attributes related to its webpage. Nevertheless, AliExpress is likely to dominate the virtual "world" across a broad range of parameters and simulations.

The model therefore not only enables us to better understand Chinese B2C cross-border e-commerce and its behaviour in Spain, but also demonstrates the usefulness of the scenario analysis of the model for decision making and the design of business strategies.

Future research should focus on two main areas. First, it should abstract the theory behind the model and examine more closely the tendency found in the scenario analysis (the strong dominance of AliExpress). The use of more exhaustive scenarios will enable us to determine whether there is a structural constraint that prevents the tendency from being overcome. Second, it should develop broader models that include non-Chinese marketplaces, such as Amazon, thus allowing a deeper comprehension of cross-border e-commerce in Spain and worldwide.

Endnotes

1. We justify the development of this model in Java in Section 3.2. The model can be downloaded at https://github.com/pleger/ABME-market.

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Appendix

Overview	Purpose and patterns	The research and model address the problem of modelling and supporting decision making in cross-border marketplaces. The paper shows how social simulation and, in particular, agent-based simulation (using endorsements) can be successfully and realistically applied, based on survey data, to represent agents' interactions in cross-border e-commerce. The model represents buyers' shopping (interactions between buyers and marketplaces and between buyers via WOM), which allows us to observe the performance of marketplaces, measured as the number of buyers that have bought at least once in the marketplace. This informs and supports stakeholders' decision making by modelling a specific case: Chinese B2C cross-border e-commerce in Spain.
	Entities, state variables, and scales	Table 4 shows the main entities and variables (e.g., agents and environment) included in the model.
	Process overview and scheduling	In Section 3.2, the paper describes the dynamic components of the model, including the rules and actions that agents can take.
Design concepts	Design concepts	*Emergence and learning*. The number of actors does not change during the simulation. Emergence occurs in the buyers' decision-making mechanism (endorsements), as it evolves in accordance with the buyers' preferences and the marketplaces' attributes, improving the behaviour of the buyers. Overall behaviour of the marketplaces was shown by the number of buyers who have bought at least once in a particular Chinese marketplace (SalesUniquePerMarket). The tendency of this variable indicates the performance of the marketplaces, and the outstanding behaviour of some of these can be considered as surprising or emergent by stakeholders and researchers (see, Section 3.2). The (implicit) objective of the buyers, while learning, is to increase satisfaction by buying in the marketplace whose characteristics are closer to their preferences, as represented by the weights they give to the diverse attributes of the marketplaces according to the levels of the endorsement scheme. However, adaptation and objectives are not explicitly included in the model. They occur implicitly as buyers learn via the endorsement scheme.*Prediction*. There is no prediction in the model. We assume that the model is good at exploring scenarios that help stakeholders to learn about possible developments of the real system, but not at predicting. Moreover, the agents do not make any predictions.*Sensing*. Buyers know the attributes of the marketplaces when they interact with them while shopping. Marketplaces do not "sense" their environment. Their behaviour changes stochastically during the simulation as they vary the attributes of their page, quality, etc., from iteration to iteration. Buyers communicate with each other via WOM (for more details, see Section 3.2).*Interaction*. Buyers interact with each marketplace. At each shopping interaction and at each time step, the buyers endorse the marketplace in accordance with the attributes shown, and the marketplaces present attributes stochastically (as explained in Section 3.2). Interaction among buyers also takes the form of WOM.*Stochasticity*. Stochasticity is implemented only when marketplaces present their attributes in accordance with their frequency in the survey, as explained in Section 3.2.4 (a). We assume a uniform distribution.*Collective*s. There is no grouping in the model. Buyers and marketplaces act individually.*Observation*. The variable observed in the simulation was the number of buyers who have bought at least once in a particular Chinese marketplace (SalesUniquePerMarket). This variable was observed for each time step, and then a mean was calculated for each marketplace at each iteration time step for 30 replications of the experiment. In Section 3.3, by observing the mean of this variable, we show that the order of the Chinese B2C marketplaces given by the simulation is very similar to that obtained from the survey, which allows us to make a qualitative validation. This variable also permits us to determine the position/order of the marketplaces for several scenarios of interest to inform stakeholders' decision making and help them to take better decisions.
Details	Initialisation	This includes the number of users (buyers) and friends of every buyer, number of periods of the simulation, number of periods of the learning process, attributes of a Chinese B2C marketplace (see, Section 3.1), and endorsement variables that represent information about previous transactions that the agents can retain (experience for learning; see, Section 3.2). The initialisation is loaded in the simulation software using Excel (the file is accessible at https://github.com/pleger/ABME-market).
	Input data	This includes the number of times that buyers buy in marketplaces, the weight of the buyers' endorsements, and the probabilities of the marketplaces' attributes. For each period and buyer, all values are saved in an Excel file, which we analyse according to scenario conditions. When the simulation ends, the file contains the complete history of each buyer's data in the simulation for the variables of interest.
	Submodels	The submodel (application) describes how, for each period of the simulation, a buyer decides to buy in a certain Chinese marketplace and then makes the transaction. To reach the decision, each agent receives information from friends (other agents) and evaluates its historical transactions in each marketplace accordingly (using endorsement attributes presented in Section 3.1 and in line with the reasoning explained in Section 3.2). Finally, the buyer selects the best marketplace evaluation to share with its contacts (at each iteration step).