THE EARLY-STAGE DEVELOPMENT OF TWO-SIDED DIGITAL PLATFORMS: A SIMULATION APPROACH

Research paper

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Abstract

Two-sided digital platforms mediate between two independent groups of users in a virtual marketplace. Firms such as Airbnb have impressively demonstrated the disruptive effects of business models relying on such platforms. In setting up a new platform from scratch, however, platform operators are confronted with a challenge that is often referred to as the chicken-and-egg problem, that is, the platform needs to attract groups of users on both sides, but users on either side will only join the platform if they expect sufficient users on the other side. Analysing the formation processes of the respective user bases is difficult due to the complexity of these processes, which are driven not only by measures set by the platform provider but also by word of mouth between (potential) users and normative social influence among them. In this paper, we introduce an agent-based model that can be used to simulate early-stage development of two-sided digital platforms and illustrate the model's applicability by means of a real case.

Keywords: Two-sided digital platforms, Chicken-and-egg problem, Agent-based simulation.

1 Introduction

Two-sided platforms have reached substantial economic relevance on a global scale. Such platforms have had an extensive effect on numerous companies in the past twenty years (Wan et al., 2017). Moreover, they have impressively demonstrated their disruptive potential in well-established global industries (Airbnb, for instance, is at the top of the CNBC disruptor 50 list; CNBC, 2017). According to the 'Best Global Brands 2016' ranking (Interbrand, 2017), fourteen of the one hundred most valuable brands create value through two-sided platforms. Sussan and Acs (2017) even go so far as to call the times we live in the 'platform age', linking the emergence of two-sided platforms to the rise of information and communication technologies that have decreased transaction costs while simultaneously increasing their scope of operation (Acs et al., 2002). Correspondingly, research into various aspects of two-sided platforms has also recently increased considerably, becoming rather widespread (Rayskin, 2017; Wan et al., 2017).

Despite the popularity and potential success of platform-based business models, launching a two-sided platform is still a perilous endeavour, with particularly high failure rates (Sussan and Acs, 2017). The challenges of founding these platforms can largely be attributed to the difficulty of reaching critical mass (Ruutu et al., 2017), that is, in order to get customers on one side on board, there must be a sufficiently large number of customers on the corresponding opposite side of the platform and vice versa (Caillaud and Jullien, 2003; Casey and Töyli, 2012). This dilemma is commonly referred to as the chicken-and-egg problem.

Early-stage two-sided platforms typically struggle to solve this problem and companies usually have only a single chance to do it right. Thus, finding and analysing proper strategies is of utmost interest to both practitioners and researchers. The main obstacle in this respect arises from the complexity of the formation processes during which the required user bases are established on both sides of the platform. These processes may involve several reinforcing feedback mechanisms resulting from multifaceted network effects (Ruutu et al., 2017) that are driven, for instance, by word of mouth (WOM) or normative social influence. While the literature describes several viable strategies to overcome the chicken-and-egg dilemma (for recent overviews see Parker et al., 2016, Wan et al., 2017, or Stummer et al., 2018), few tools are available to actually support decision makers in analysis of which of these strategies should be applied for a specific platform offering specific services for a specific market. Agent-based modelling (ABM) and subsequent simulation of platform development may be an exceptionally well suited approach for addressing this research question. However, as of yet, there is no satisfactory simulation model. Accordingly, the aim of this paper is (i) to develop a prototypical agent-based market model that can be used to analyse the platform adoption of heterogeneous agents during the early-stage development of two-sided platforms and (ii) to test this model empirically by means of a sample application.

The remainder of this paper proceeds as follows: Section 2 provides an overview of types of two-sided platforms and the motivation behind our choice of modelling a particular platform type; furthermore, we describe the difficulties of reaching critical mass due to the chicken-and-egg problem, outline strategies that may be suitable for overcoming this problem, and substantiate the suitability of agent-based modelling approaches. We then describe our agent-based model in Section 3 and the application case in Section 4. In Section 5, we present and discuss the simulation results, before summarizing our findings, limitations of our research, and further research opportunities in Section 6.

2 Background

2.1 Types of two-sided digital platforms

Research on two-sided markets and platforms has been booming since the beginning of the century (Rochet and Tirole, 2006; Roson, 2005). The literature contains several suggestions for classifying two-sided platforms: Wan et al. (2017) divide platforms into five types, namely, e-commerce, online community, payment cards, software, and video console; Smith and Gai (2017) propose a classification along the dichotomy of transmission versus transformation (depending on how non-transparent and distorting the role of the intermediary is); and Obstfeld (2005) suggests a division along the lines of how joined or separate the two sides of a platform are kept. We ultimately follow the approach by Evans (2003), who distinguishes between market makers, audience makers, and demand coordinators. Market makers, such as eBay, connect two distinct groups, enabling them to make transactions; audience makers, such as Facebook, provide advertisers with a target group-specific audience by providing content attractive to the desired target groups; and demand coordinators, such as credit cards, neither sell 'transactions' nor 'messages' but 'make goods and services that generate indirect network effects across two or more groups' (Evans, 2003).

To determine which platform type has been most discussed in recent studies and should thus be considered in our agent-based model, we conducted a systematic literature review. Due to their prevalence in the current literature on two-sided platforms, we selected market makers as the subject of our simulation.

2.2 Difficulties in reaching critical mass

Recruitment of users in the early phase of two-sided platforms is challenging due to the chicken-and-egg problem mentioned above: the growth of members on one side of the platform is inhibited by too few members at the other side and vice versa (Caillaud and Jullien, 2003; Casey and Töyli, 2012; Evans and Schmalensee, 2016). Once a critical mass has been reached, platform adoption is accelerated through self-reinforcing network effects (Arroyo-Barrigüete et al., 2010).

Network effects may arise from users on the same side, the other side, or both. So-called same-side network effects occur when users' decision to adopt a platform is influenced by the number of (other) users already active on their side of the platform and can be either positive (e.g. in the case of multiplayer games, in which a greater number of players increases the willingness to join the platform) or negative (e.g. in real estate, in which a higher number of buyers results in rising prices, which makes it less attractive for further buyers to join; Rayskin, 2017). However, typically, the second type of network effect–cross-side network effects–drives the success of two-sided platforms, as well as being a major challenge for early-stage platforms to attract a sufficient number of participants on both sides. These cross-side network effects arise from users on one side of a platform expecting a minimum number of users on the other side as a prerequisite for joining (Katz and Shapiro, 1986). Cross-side network effects are often asymmetrical; for example, the number of credit card transactions increases faster with rising numbers of merchants than with similar increases in numbers of cardholders (Evans, 2003). In practice, it is usually easier to increase demand by boosting supply than to increase supply by boosting demand (Chu and Manchanda, 2016). Thus, it is worth noting that stimulating or neglecting one side can attract or deter the other side, and the impact of supporting one side can depend on which side is subsidised. In recent empirical work, Schirrmacher et al. (2017), examined launch strategies of new (start-up) digital platforms. Most notably, they distinguish between platforms with switching users and non-switching users, respectively, which determines whether the platform should be open to both sides from the beginning or should start with one side and only later also offers access for the second side.

2.3 Strategies for initial user generation

In their review of recent literature in the field, Wan et al. (2017) describe five common strategies to increase platform adoption: pricing, openness, integration, differentiation, and envelopment. Most prominently, pricing options are proposed in the literature as an effective measure to attract platform members (Eisenmann et al., 2011; McIntyre and Srinivasan, 2017) and thus to reach critical mass (Evans, 2009). Such a strategy may work if pricing stimulates virtuous circles of platform growth, but a failed pricing strategy (e.g. fees that are keeping away relevant users from at least one side) might also lead to platform failure (Casey and Töyli, 2012; Eisenmann et al., 2006; Parker and Van Alstyne, 2005). When it comes to choosing the right pricing strategy for an early-stage platform, the above-mentioned asymmetry of cross-side network effects becomes relevant, because subsidising one side may ultimately attract both sides to adopt the platform (Casey and Töyli, 2012; Parker and Van Alstyne, 2005). Thus, not only the right price level but also the right price structure (i.e., which side is charged with which share of the targeted transaction fee) can affect platform adoption (Rochet and Tirole, 2006). Which side of the market is subsidised can differ between platform categories; market maker platforms usually subsidise the demand side (Parker and Van Alstyne, 2005). The second strategy for overcoming the chicken-and-egg problem, namely, openness, is concerned with the accessibility of the platform in terms of who is allowed to register and consequently use it, while the third strategy, integration, influences which complementary products are offered on the platform. A fourth strategy often considered promising for early-stage platform growth is differentiation. This strategy may be implemented by increasing platform quality over that of competitors (e.g. video consoles investing in the improvement of their features; Wan et al., 2017; Zhu and Iansiti, 2012) or by attracting and winning over especially influential users (so-called marquee users, e.g., firms offering particularly interesting products or influencers such as popular bloggers); the latter might be achieved by exclusivity contracts (Eisenmann et al., 2006; Pepall and Richards, 2001). The last strategy, platform envelopment, strives for reaching the critical mass by piggybacking on an already successful platform (Eisenmann et al., 2011)

2.4 Agent-based modelling

To substantiate the usefulness of ABM as a tool for analysing early-stage development of two-sided digital platforms, we checked the properties of the underlying setting as proposed by Rand and Rust (2011), who put forth one necessary condition (temporal aspects), one sufficient condition (adaptive agents), and four indicative conditions (medium numbers, local and potentially complex interactions, heterogeneity, and rich environments) for the use of ABM. We found all conditions to be met.

Some prior works have already examined two-sided platforms with the help of simulation. Casey and Töyli (2012) and Ruutu et al. (2017), for example, utilized system dynamics models, but these–quite naturally–cannot account for the heterogeneity of potential platform adopters. Other works have already used agent-based simulation and thus allow for heterogeneity, but most either focus on a later development phase (i.e., they skip the critical early-stage in which the chicken-and-egg problem arises; e.g., Heinrich and Gräbner, 2018) and/or account for only one side of the platform (e.g., Ozer and Anderson, 2015). These are interesting works, but they differ from our model, which focuses on the early phase of an innovative platform established in a new market (in contrast to a mature and/or oligopolistic market) and analyses the interplay between both sides of the platform. It is noteworthy that for such highly innovative platforms as those investigated herein, rarely face competition with other platforms as a major issue in the early phase. However, they face other challenges, such as making potential adopters (on both sides) aware of the existence of the platform or prompting them to give the novel platform-based business model a try.

The agent-based simulation approach most like our own is probably that introduced by Meyer (2012). Still, there are major differences. The research question addressed by Meyer is not whether or when agents choose a platform but which of several platforms they choose. Adoption in this model accordingly is based on being informed about a platform, not on needing the service it offers. Thus, the model by Meyer manoeuvers around the chicken-and-egg problem of acquiring early-stage adopters. Procedurally, a given fraction of potential adopters automatically become adopters, biasing the process in favour of an S-shaped adoption curve following the established diffusion model introduced by Bass (1969); while word of mouth takes place, it is only as an additional stimulus. Our model, in contrast, considers the needs of potential adopters and allows for heterogeneity of agents beyond the classification into adopters and potential adopters as in the model by Meyer (2012).

Finally, several models by Huotari and various coauthors address the question of which platform (out of two) is chosen and how the adopters' decision can be affected (Huotari, 2017; Huotari et al., 2017) or how complementors should best be managed (Huotari and Ritala, 2017), which is different from the concern of our research with whether and how a (probably monopolistic) platform with an innovative mediation service (as in the application case) wins over adopters from both sides in an early-stage of the platform development process. In a related paper, Huotari and Ritala (2016) investigate setting up a platform in stages (i.e., first offering a subscription-based service and then switching to an advertising-based model) as a way of overcoming the chicken-and-egg problem; this would allow the newly founded platform to start with an already existing user base on one side. While this is also interesting, it requires handling one side of the future platform yourself for some time, which is hardly feasible for a typical market maker platform, such as that addressed in our research.

3 The Model

We will now introduce an agent-based model that can be used to analyse early-stage development of a two-sided digital platform, as visualised in Figure 1. It should be noted that in this version of the model, we focus on platforms that provide novel services; this is typically applicable to most settings as platform innovations are often disruptive (Sussan and Acs, 2017) and therefore usually face no existing competitors (at least not in the early development phases). Modelling a market in which several platforms are striving to set up similar services and thus pursuing the same target groups of potential users would certainly be an interesting avenue for enhancing this model but is beyond the scope of this paper.

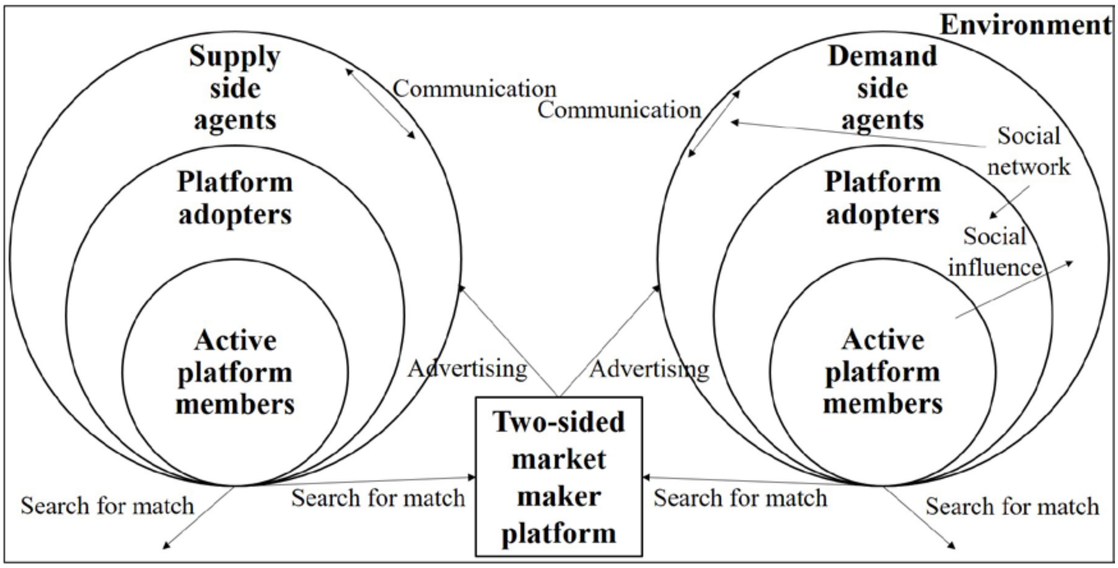

Figure 1. The agent-based simulation model.

3.1 Model entities

The model considers agents for each of the two sides of the platform. Upon initialisation, populations of potential suppliers and agents who might potentially join the platform on the demand side are created. If they are searching for a match, these supply-side and demand-side agents might become aware of the platform and join it, that is, they become active platform members and thus join the rank of platform adopters. Potential members become aware of the platform through advertising or communication with another agent who has already adopted the platform. At the beginning of a simulation run, some agents are randomly chosen to be the first active platform members; in reality, these are typically personal or professional contacts of the operators/founders. These initial platform members become the first adopters and may act as multipliers with regard to platform awareness. When analysing platform development, we further distinguish among *adopters*, who have signed up for the platform and been active on it at least once, *members* of the platform, who currently have an account, and *active members*, who not only have an account but are also currently looking for a match. The presence of account fees may cause some groups of agents to always be active if they have an account and to leave the platform immediately after achieving the desired matches. The same behaviour does not necessarily apply to platform members who do not pay fees, as they may remain members even if they are (at least temporarily) not actively searching for a match. Thus, while all platform adopters have been active on the platform at least once (when adopting it), they can be either active platform members or ex-members of the platform or, in the case of demand-side agents, inactive platform members. To avoid overcrowding in Figure 1, the set of platform adopters on the demand side who are not active platform members were not further divided into subsets of ex-members and inactive members, and the platform adopters on the supply side who are not currently active platform members are not additionally labelled as ex-members of the platform.

3.2 Environment and social network

All agents are distributed (usually geographically) within the environment (i.e., the modelled market). This distribution may follow a real-world distribution, for instance, based on population density (or some other meaningful distribution). Agents from each side of the platform might be linked with other agents from the same side through (social) networks. Usually, demand-side agents representing customers are interconnected through such a social network (for an overview, see Kiesling et al., 2012), whereas supply-side agents do not need to be linked with each other. Such networks affect the communication between agents and the social influence amongst agents (given that these effects have been modelled). Again, we refrain from modelling supply-side agents as social individuals, because they represent businesses that are not interlinked in a social network and are not subject to social influence, but communicate based on business reasons alone.

3.3 Searching for a match

Upon the start of a simulation run, agents begin (inter-)acting. According to their needs (e.g. when searching for employees or for employment, as in the application example described in the following section), agents may enter the platform (if they are aware of its existence). Their decision to adopt the platform is determined by the particular conditions (e.g. fees), their perceptions of the platform's success (driven by the number of agents on the other side of the platform, presuming that this information is available), their prior experiences and individual preferences, etc. Once agents have adopted the platform and are willing to actively use it, the platform strives to find matches between agents from opposite sides. After a successful match, the agents involved may stay on the platform but become inactive or leave the platform, perhaps coming back when they need another match. If no match is established, agents will eventually leave the platform (and probably be somewhat disappointed, which may have a negative effect on word-of-mouth recommendation). It is noteworthy that agents who are not aware of the platform or who have decided not to adopt or use it will search for a match that satisfies their needs by means of alternative (traditional) instruments (e.g. job notices in newspapers when searching for an employee). However, given a sufficient number of members on both sides of the platform, it can be expected that searching for a match is more efficient and convenient when using the digital platform.

3.4 Communication, social influence, and advertising

Agents from the same side may meet from time to time and exchange information about the novel platform and/or their experiences with it. Our model allows agents to interact following a given communication scheme (e.g., once a month with a given probability of both agents actually meeting at a congress or regularly occurring event). Obviously, only agents who are directly interconnected in the social network have opportunities to exchange information with each other. While in principle, it is feasible to implement a dynamic social network, in which edges appear or disappear, we have not yet done so.

If social influence plays a role (for one or both sides), its strength depends on the number of peers who are already active members of the platform. In our model, (next to gaining awareness through observation of other agents using the platform), agents may be prompted to use the platform by observing that some peers are using it. This is a prime example of same-side network effects, that is, as more agents on one side join as active members, (group) pressure increases for non-adopting agents from that side to also join the platform.

Advertising, in the current version of the model, only makes agents aware of the platform. It can be directed towards a pre-defined group of agents and will inform some random members of this group about the existence of the platform and the services it provides.

4 The Sample Application

The agent-based model described above has been tested with data from an actual two-sided platform in operation. We do not use the name of the platform to avoid influencing the platform or its potential competitors and we have distorted some of the data (particularly with respect to the scale of the number of members on the two sides as well as the number of successful matches). This platform matches dentists looking for a job (the demand side) with hiring dental offices (the supply side). Data was obtained directly from one of the platform's founders, who is still involved full-time in managing the start-up company operating the platform. Thus, model assumptions regarding the behaviour of agents are typically supported either by actual market data or the experience of the platform operator. In the few case in which data for parameterisation was missing (e.g., for the social network), we derived values from the literature and thoroughly discussed these assumptions with the platform operator. Given the specificity of our application case, simulation results are not generalizable for platform behaviour. Still, the research aim of demonstrating the applicability of agent-based simulation to the early-stage development of a two-sided platform is accomplished.

4.1 Model entities

As mentioned above, the supply side consists of dental offices offering jobs and the demand side is composed of dentists looking for a job (typically, demand-side agents are still employed and thus not under particular pressure to find a job; rather, they are curious about their market value and in principle are willing to move to another job, perhaps in a different city). In the simulation runs for this application case, we consider 3000 dental offices and 3500 dentists (which is a scaled down and slightly distorted compared to the actual market for this platform). Of these, one random dental office is chosen as the first active supplier on the platform and around 200 dentists are selected to become the first members on the demand side. This initialisation routine reflects the real situation when the platform was launched: the dental office contacted the founder of the platform indicating its need for the platform's service and the founders initially personally contacted dentists, inviting them to the platform.

4.2 Environment and social network

All agents are allocated in one of the ten federal states of pre-1989 (pre-unification) Germany (the examined platform only operates in the former Western Germany). Agents are randomly distributed within their state–a rough approximation, as the density of dental offices (and dentists) is higher in towns than in more rural areas. The dentists as individual humans are connected in a small-world network with (Watts and Strogatz, 1998), for which, however, number of connections per agent is difficult to estimate. Based on an empirical study in the context of innovation diffusion of repeat purchase products, Stummer et al. (2015) considered three direct contacts for each consumer on average. In our applications case, we are concerned with professional contacts, suggesting that the social network is less dense. We therefore set the respective parameter to just two contacts, which has been approved by the network operator. As noted above, the supply side is not interlinked via a social network, as dental offices are not considered social human beings, but rather businesses, interacting with their peers only at special business events, and not otherwise interacting on a regular basis.

4.3 Searching for a match

Dental offices (dentists) usually start looking for a match every thirty months on average. Naturally, a dentist is only looking for a single (full-time) job, while a dental office might have more than one free position at a time (i.e., about 30% of offices search for two applicants simultaneously). These assumptions are in accordance with the data provided by the platform operator.

If the respective agents looking for a match are aware of the platform, they join it to increase their chances of finding a match. For the dentists, this is free of charge, while the dental offices pay for the platform's services; this is a common pricing strategy for market maker platforms. The differences in pricing also manifest themselves in the differing behaviour of agents who quit searching on the platform: while approximately 90% of dentists remain (inactively) on the platform after finding a match, dental offices always leave the platform. This behaviour is modelled to depict real-life switching behaviour described by the platform operator.

Once a dental office joins the platform, their job offer is available on the platform for up to one year. During this time, the probability of matching an offered job is 45%, on average, unless the dental office finds a match outside of the platform. If no match is achieved, offers are withdrawn. If a dentist does not find a match within two or three years, they will also become inactive on the platform. Just like the dental offices, the dentists might also leave the platform because they found a match outside of it. This is again modelled to fit the situation for our sample platform. Figure 2 gives a visual overview of the procedure of adopting the platform.

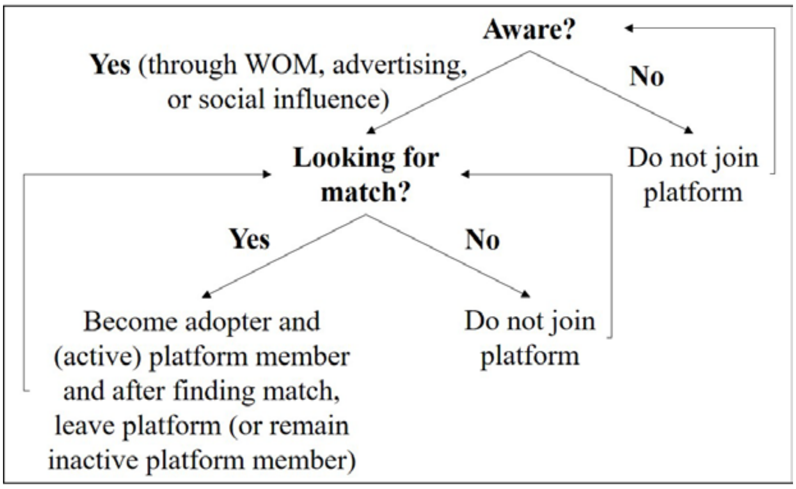

Figure 2. Visualization of the adoption procedure.

4.4 Word of mouth and advertising for dental offices

Agents other than the initial agents on the platform are not aware of the platform at the beginning of the simulation. Dental offices become aware of the platform through two possible scenarios: word of mouth of platform success from others at regular get-togethers (congresses) or advertising. Get-togethers happen every month, either at countrywide congresses twice a year or local meetings, which take place the other ten months. If a dental office has successfully found a match through the platform in their last attempt, they tell a random other person at the congress about their success. However, if they are currently seeking a match through the platform, they remain silent to reduce competition for potential matches. Because their interlocutor might be a total stranger, the conversation results only 25% of the time in the second person becoming aware of the platform and adopting it if they have a vacancy at their dental office. Moreover, dental offices are exposed to a special form of advertising, namely, cold calling by the platform operators. In most cases, the cold caller succeeds in talking to a decision maker at the dental offices and makes them aware of the existence of the platform; typically, they can convince the decision maker to adopt the platform. However, directly contacting dental offices is time-consuming, and thus, only ~5% of dental offices currently searching for a match but not yet aware of the platform can be enrolled each year through this advertising measure. These assumptions are again all based on the actual situation for our specific application case.

4.5 Word of mouth, social influence, and advertising for dentists

While dentists also attend congresses and are subject to advertising, they might additionally observe that colleagues with whom they are connected through their social network are currently looking for a job through the platform, that is, they might experience social influence. Dentists are modelled to meet random colleagues from their immediate social network (i.e., colleagues to whom they are directly linked) on average once a year at a congress. If they are a member of the platform, they talk to them about the platform, thus making them aware. If the newly aware agents are looking for a job, they will join the platform with a probability of 25%. Social influence also comes into play approximately twice a year, when some dentists observe colleagues in their immediate social network looking for a job through the platform. If the observer is seeking a job, they also become an active member of the platform (additionally, if they were not yet aware of the platform, they become aware of it) with a probability of 50%. Thus, as the share of dentists being active on the platform increases, the probability of dentists joining the platform increases, i.e., the more agents become adopters through social influence. Advertising affects the dentists once a year on average with a probability of 5%, as it consists of (local) newspaper notices, which are read only by agents being interested in finding a new job.

It should again be noted that parameterisation of the social network and the probability of word-of-mouth occurrences as well as success rates of making an interlocutor aware of the platform is not straightforward, particularly as we did not interview dentists or managers of dental offices ourselves. Still, our interviewee from the platform company is very experienced in this field (speaking frequently with both managers and dentists) and the parameters of our model are based on this real-world experience. As this sample application is meant only to illustrate the applicability of agent-based modelling to analyse platform development, we believe the available data is sufficient to meet this objective. If the simulation tool is to be used for strategic decision-making in the course of initiating a new platform, we suggest more extensive research, performing necessary interviews to collect all the data necessary to appropriately parameterise the model as accurately as possible. In addition, extensive sensitivity analyses should be run to learn which parameters really affect the model and then double-check these parameters.

5 Simulation Results and Discussion

Simulations based on the above model were run 100 times with different seeds for drawing random variables for the diverse stochastic events (e.g. determining communication events or which agents are affected by advertisement campaigns, etc.). Results for each run are provided on a per-month basis and overall results are calculated by averaging over all runs. All simulation runs start with the foundation of the platform in 2012 and span the six years through the end of 2017 as well as projecting another six years into the future to the simulation horizon at the end of 2023. The simulation results were compared to the expert's description of the platform's current situation and its expected future development; the simulation outcome was found to be in close agreement with the expert's statements.

Before continuing with results, recall that the aim of this paper is to demonstrate the applicability of ABM rather, and thus, these results must be carefully interpreted in terms of the assumptions made for this specific application case. Internal influences (e.g., increase or decrease in personnel, changes in management team, pivots, etc.) and external influences (e.g., competition or governmental regulations) might also affect real-world outcomes for this specific platform. Competition, for instance, might be beneficial to early platform growth if the service offered is particularly novel and radical, as knowledge of another platform offering a similar service might raise awareness and acceptance of the type of service. However, competition might limit the highest possible market share each individual platform might reach as the market may be limited and they must divide it amongst themselves. Thus, the effect of competition cannot clearly be gauged or generalised; rather, it must be evaluated for each specific scenario. Other factors might include whether the competition existed at platform foundation or entered the market later, or whether the service offered by the platform is a radical or incremental innovation. Such an examination of further scenarios and variations of internal and external influences, however, is beyond the scope of this paper.

As Figure 3 shows, adoption by supply-side agents (dental offices) is slow at first, as they are more difficult to recruit than demand-side agents (dentists). Especially for the dental offices, adoption follows a prototypical S-curve, which at the end of 2023 is not far away from (hypothetical) full adoption (i.e., all dental offices have been active on the platform at least once). As of today (end of 2017), however, the turning point of this S-curve has not yet been reached: it will take about another two years until this happens. There are more possible platform adopters on the demand side, as there are 3500 dentists and only 3000 dental offices inhabiting the platform’s recruitment zone. Right after the foundation of the platform, dentists are also easier to recruit as they do not pay for platform membership and are open to changing jobs even if they are currently still employed, as can be seen in the steepness of the line showing the number of dentists who have already adopted the platform. Thus, six years after platform foundation (end of 2017), more dentists than dental offices have adopted the platform; however, this trend reverses slightly (the graphs intersect in 2021), and by the end of 2023, slightly more dental offices than dentists will have adopted the platform. The reason for the accelerated growth of the number of adopters from the supply side can be explained by an increase in word-of-mouth communication leading to greater awareness of the platform among dental offices, which is discussed in more detail below.

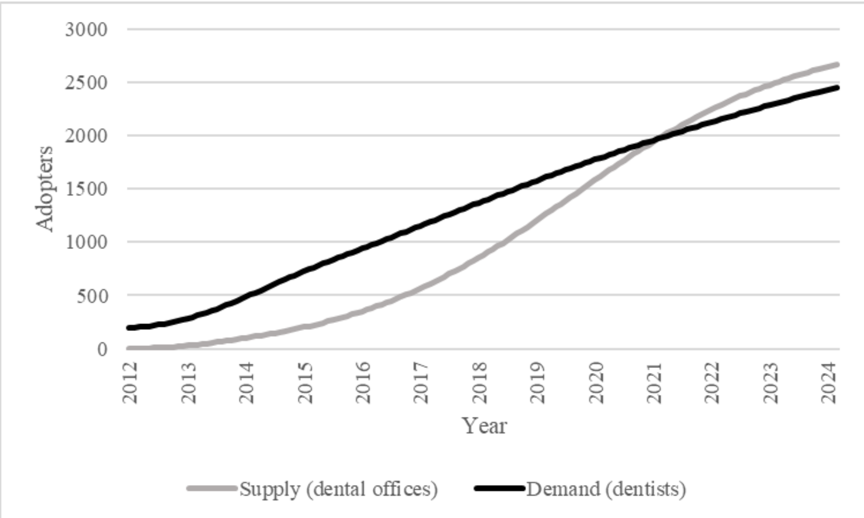

Figure 3. Number of dental offices and dentists having adopted the platform.

Even though supply-side agents (dental offices) who have become adopters leave the platform after finding a match, the number of suppliers who are currently active on the platform also shows a steady S-shaped upward trend, reaching a maximum at about 450 dental offices being active members.

Interestingly, if more dentists than dental offices adopt the platform over time, the number of successful matches also rises (discussed below), leading to larger numbers of dental offices leaving the platform over time (as it becomes easier and quicker for them to find suitable dentists). If the platform were to perfectly match all supply and demand instantaneously, and given that the 3000 dental offices, on average, need to fill a vacancy about every 2.5 years (30 months), around 3000/30 = 100 dental offices can be expected to be active in each month, each of them remaining on the platform for only a short time, then leaving after being matched and returning again only when the next job vacancies occur. Thus, declines in active membership that do not drop below 100 active members actually signify the effectiveness of the platform in matching dental offices with dentists.

Demand-side agents (dentists) leave the platform infrequently even after finding a match because they pay no fees; thus, the number of members on the demand side is much higher than the number of members on the supply side. However, not all demand-side members are active, as seen in Figure 4.

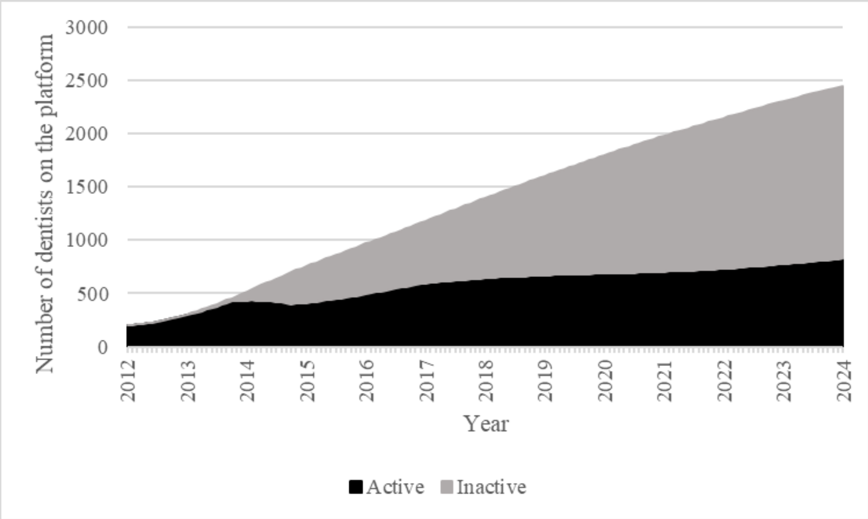

Figure 4. Number of active and inactive dentists on the platform.

As more demand-side agents are successfully matched with an increasing supply, more dentists will find a match on the platform more quickly and consequently stop actively searching for a job. This explains the slight dent in active demand-side members at the end of 2014, when more dentists have been matched with dental offices (and, as a result, have become inactive) than additional dentists joined the platform and only few of the inactive dentists became active again as this group was rather small in 2014 and consisted mostly of dentists who had accepted a new job very recently and therefore were not interested in actively searching for a different job. Analogously to the reasoning above, in a perfect market, there would be about 3500/30 = 117 active dentists per month finding a job through the platform and thus leaving at once.

The more dental offices and dentists adopt the platform, the more matches there are between them, as can be observed in Figure 5.

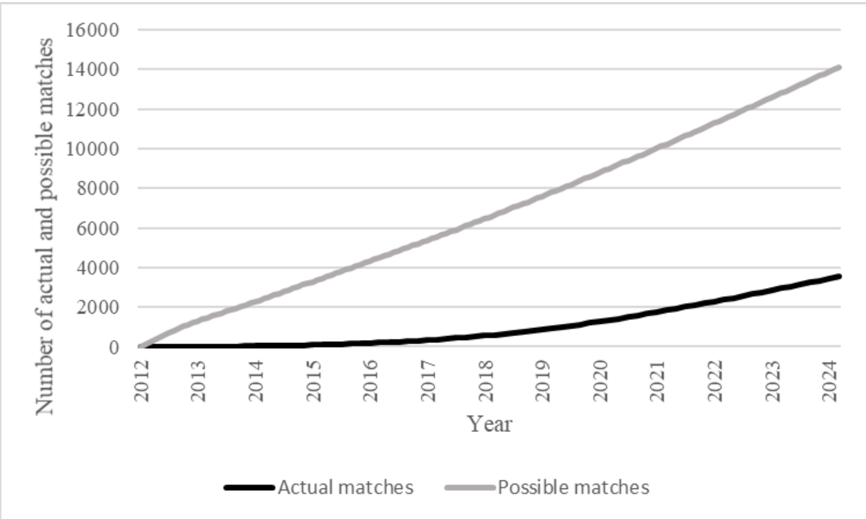

Figure 5. Number of matches that have already been made and number of possible matches.

The cumulative number of matches rises, as does the number of yearly matches (which manifests itself in the increasing steepness of the graph). However, this trend is still small compared to the potential upward mobility of the platform: the number of possible matches that hypothetically could be achieved (through the platform) if all supply-side agents (dental offices) adopted the platform to find a match and were quickly matched is far larger than the number of actual matches made through the platform, as depicted in Figure 5. The relative gap between the number of actual matches and the number of possible matches decreases substantially over time, although in absolute numbers, it becomes wider until it reaches the simulation horizon. At the end of 2017, less than one tenth (about 600 of about 6500 potential matches, an absolute gap of 5900 matches) of all possible matches are realized through the platform, while this increases to a quarter (about 3500 of about 14000, an absolute gap of 10500 matches) of all possible matches by the end of 2023.

It is interesting to see not only the platform growth, in number of both members and successful matches, but also to see where this growth comes from. To adopt the platform, agents must first become aware of it. The sources of awareness for supply-side agents (dentists) over time are shown in Figure 6.

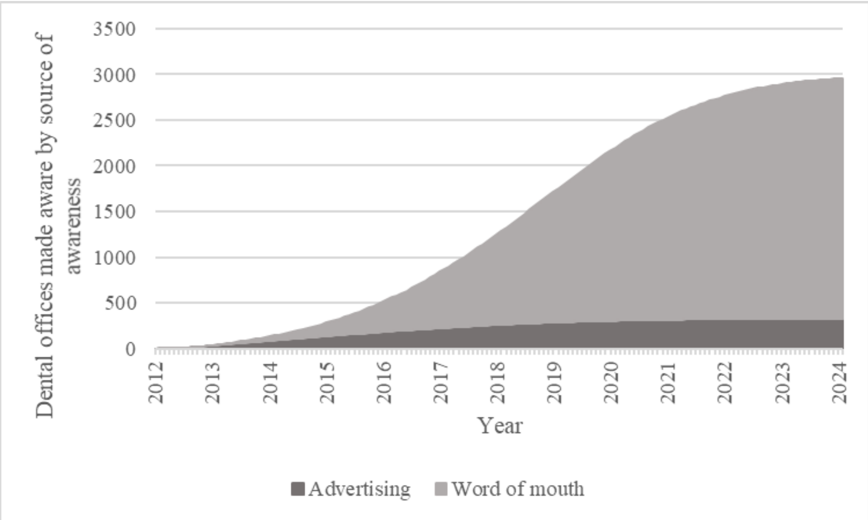

Figure 6. Number of dental offices that have been made aware, by source of awareness.

While there is only one supply-side agent (i.e., one dental office) aware of the platform at the beginning (which was omitted from the graph as it is too small to be visible), this figure increases, following an S-shaped curve, most dramatically through the increase in word-of-mouth notification at congresses. For demand-side agents (dentists), congresses also play an important role in increasing awareness of the platform, but not nearly to the extent as for supply-side agents. Observation has the largest impact among demand-side agents, as can be seen in Figure 7.

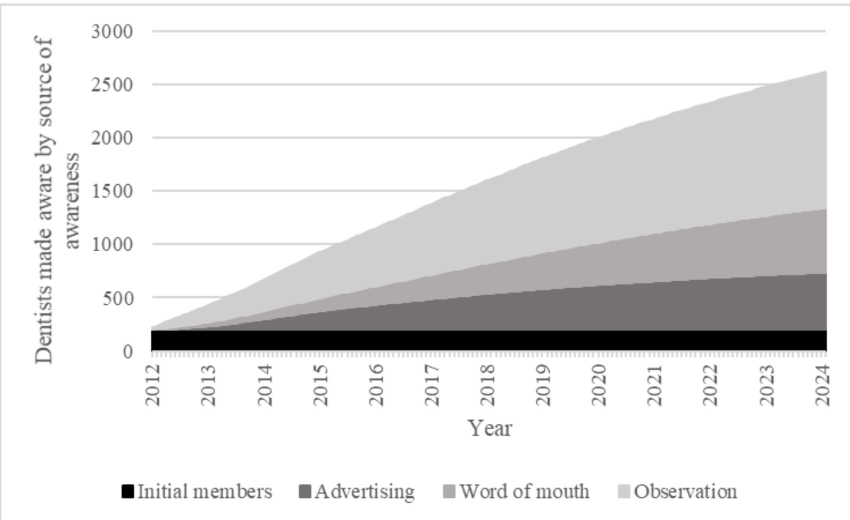

Figure 7. Number of dentists who have been made aware, by source of awareness.

As discussed above, competition might have an influence also on platform awareness, as general awareness of the service offered by a platform could raise awareness of the concept of offering this service on a platform in general, possibly increasing the probability of agents looking for a different provider of the same mediation service.

6 Conclusion

To fulfil the aims of this paper of (i) developing a prototypical agent-based market model that can be used to analyse the platform adoption of heterogeneous agents during early-stage development of two-sided platforms and (ii) testing this model empirically by means of a sample application, we constructed a generic agent-based model of a two-sided market maker platform and parameterised it with the help of the founder of a real-world two-sided platform that matches dental offices offering jobs (the supply side) with dentists looking for vacancies (the demand side). Comparing the model results to the real-world current data on the adoption and success of this platform, as well as taking into consideration the expert's predictions on future developments, we see a good fit. This demonstrates the capabilities of agent-based simulation as an analysis tool for the development of early-stage two-sided platforms.

Such simulations thus have both practical and theoretical relevance. They may be used, for instance, to evaluate various strategies aiming at increasing platform adoption (e.g., different pricing strategies) or to investigate the extent to which explicitly communicating the number of platform adopters on the other side of the platform can affect platform adoption, for instance by enhancing the strength of cross-side network effects. By having the opportunity to analyse the effectivity of alternative strategies, platform operators can reduce the risk of failure accompanying platform foundation and early-stage platform development.

An obvious limitation of the paper is that we can, as of yet, validate only the first half of the simulation results with actual data, while the second half could only be compared to our expert's predictions, as the data concerning the future of the platforms (i.e., the years 2018 through 2023) does not yet exist. Thus, it might be interesting to assess at the end of 2023 whether the sample application has truly developed as predicted by the model. Another limitation of the paper with regard to generalisability of the results lies in the omission of factors such as competition, sudden changes in governmental regulations, and variations in internal business operations (such as an increase in number of employees, different management styles, etc.). However, as was already exemplarily discussed above, analysis of such widely varying scenarios is very complex, both with regard to their scope and timing and to their impact. Thus, we leave this aspect for further research, as our aim was not to depict platform development in a generalizable form but to create a prototypical model that can be adjusted for specific cases. In our application case, for example, direct competition did not play a role as no competing platforms yet exist.

A particularly interesting avenue for further research would be to further develop the model into a decision support tool that offers prospective platform operators an opportunity for simulating, and thus, analysing, the effectiveness of the various strategies for overcoming the chicken-and-egg problem during early-stage platform development (such as those described in Subsection 2.3). These prospective platform operators may also be interested in virtually testing different combinations of measures and learning about the potential impact of alternative environmental conditions (described, e.g., by means of some scenarios). While results from such agent-based market simulations can of course never provide perfect forecasts, and will also always depend to some degree upon the quality of data used for parameterisation (and, thus, on the difficulty of obtaining the required data), such a simulation approach can still contribute to a more substantiated information base when selecting a strategy to apply when entering a (new) market. Furthermore, while the present model includes only one platform, competing platforms could be introduced, enabling managers to test possible responses to competitor strategies.

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