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Catch me if you can: A simulation model of the internationalization of digital platforms

Esteban García-Canal [a,*], Mauro F. Guillén [b], Borja Ponte [a]

[a] University of Oviedo, Department of Business Administration, Campus del Cristo, Avda. Cristo s/n, 33071 Oviedo, Spain
[b] The Wharton School of the University of Pennsylvania, 255 S. 38th St., Suite 108, Philadelphia, PA 19104, United States

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ABSTRACT

Digital platforms have grown rapidly by facilitating connections among users to exchange products, services, or information. However, very few platforms have a truly global footprint given that factors such as competition, imitation, innovation, and cultural and political barriers hamper a digital platform's international growth path. The geographical scope of network effects plays a crucial role in this process, impacting users at various levels from the local to the global. We model the dynamics of international platform competition and predict its outcomes in terms of global potential market percentage through a simulation of the international growth of a two-sided platform in competition with two follower platforms in different locations (home/abroad) and different internationalization strategies (gradual/accelerated), and operating under different network effects (local/global). The model contemplates different delays in the launching of the rival platforms and different degrees of innovation (improvement) in comparison with the original platform.

Our findings highlight the crucial role of network effects, with global effects benefiting first movers and local effects favoring followers, especially if they start in a market different from the first mover's. Moreover, domestic followers must innovate, while followers in less competitive markets with local network effects have more options to increase potential market percentage, including launching a clone. These insights offer valuable suggestions for strategy development and regulatory considerations related to market share, market power, and international expansion.

1. Introduction

Digital platforms are online technological devices aimed at connecting users who would otherwise face difficulties reaching each other for the purpose of engaging in the exchange of products, services, and/or information (Cusumano et al., 2019; Guillén, 2021). They have grown exponentially in recent years, both in for-profit and nonprofit contexts (Leong et al., 2020; Logue & Grimes, 2022; UNCTAD, 2019). They can be one-sided or multisided (Cennamo, 2021; Cusumano et al., 2019; Guillén, 2021; Hagiu & Wright, 2015b), depending on whether all users are the same, as in a telephone network, or if different categories of users can be identified, such as buyers and sellers of products and services. Acting as market makers and integrators, either in the role of resellers or

* Corresponding author at: Esteban García-Canal. University of Oviedo, Department of Business Administration, Campus del Cristo, Avda. Cristo s/n, 33071 Oviedo, Spain.

E-mail addresses: egarcia@uniovi.es (E. García-Canal), guillen@wharton.upenn.edu (M.F. Guillén), ponteborja@uniovi.es (B. Ponte).

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marketplaces (Hagiu & Wright, 2015a), multisided digital platforms serve as orchestrators in networks or ecosystems, creating an internal market within user communities that wouldn't otherwise exist (e.g., Banalieva & Dhanaraj, 2019), unleashing significant growth opportunities in many industries.

The growth of digital platforms is fueled by the scalability of their digital assets (Giustiziero et al., 2023; Reuber et al., 2021). Growth is not merely an opportunity for digital platforms; it is an imperative. The "network effect," as described by Katz and Shapiro (1994), means that with each additional user, a platform becomes more appealing and valuable to both existing and potential users, whether on the same side —resulting in a direct effect— or on other sides —yielding an indirect effect. Consequently, platforms need to expand and grow quickly on all sides of the platform to reach a critical mass of users before another platform does (Eisenmann, 2006). Although this growth can be global in scope (Birkinshaw, 2022), platforms with a truly global presence are the exception rather than the rule (Guillén, 2021; Knee, 2018).

In the world of traditional platforms such as videotape standards, heavily reliant on platform-specific physical assets and infrastructure, domestic and international growth often follows a winner-takes-all dynamic. This dynamic leads to one dominant platform eventually securing a monopoly for itself (Rietveld & Schilling, 2020; Rysman, 2009). However, the growth dynamics for digital platforms take on a different complexion due to lower switching costs (Cullen & Farronato, 2021). Research suggests that the success of a specific expansion path adopted by a digital platform is driven by both competition and imitation (Karhu et al., 2018; Karhu & Ritala, 2021), as well as country barriers (Banalieva & Dhanaraj, 2019; Curchod et al., 2020; Jean & Tan, 2019; Nambisan, 2020).

Competing platforms may adopt a variety of international growth strategies. Regardless of their chosen approach, first-moving digital platforms always confront the risk of imitation. If the first mover opts for a gradual internationalization strategy (Johanson & Vahlne, 1977), foreign imitators could have sufficient time to replicate its business model in their respective home markets. Conversely, embracing an accelerated internationalization path (Guillén & García-Canal, 2009; Weerawardena et al., 2007) may expose the first mover to the possibility that other competitors introduce alternative platforms in its domestic market. In this context, country barriers and the geographical scope of network effects introduce additional variability to the process. The crucial aspect of the geographical scope of network effects lies in its impact, which is sometimes limited not to all users but exclusively to those in specific locations. This impact can take place at different levels, including city, country, region, and global (Guillén, 2021; Knee, 2018; Stallkamp & Schotter, 2021). Consequently, followers encounter several trade-offs as they navigate choices related to their internationalization strategy, degree of innovation, and even the selection of the first country in which to launch their platform. Notably, some companies launch platforms in countries different than their own. Given the uncertainty surrounding the final outcome of platform competition and the numerous trade-offs involved, the identification of an appropriate international strategy for digital platforms would be beneficial for effective management.

Unfortunately, previous research has not yet been able to clearly identify the boundary conditions under which network effects play in favor of the first mover or the followers, who might be in a position to hinder the growth of the first mover or even become leaders themselves. Although the impact of network effects on a platform's growth is more complex than just the direct impact of the size of the network (Afuah, 2013; Chen et al., 2019; Eisenmann, 2006), there are only a handful of conceptual studies on platform internationalization that consider the impact of network effects (Brouthers et al., 2016; Guillén, 2021; Knee, 2018; Stallkamp & Schotter, 2021). These studies have not fully assessed the interplay between the strategic choices of the first mover and followers in the presence of different types of network effects, degrees of innovation, and imitation as platforms strive to reach a critical mass of users worldwide. This is an important research gap because the outcomes of international competition among digital platforms have substantial implications for all participants in the ecosystem, including users, entrepreneurs, venture capitalists, advertisers, regulators, and incumbent companies whose traditional business models may be disrupted by digital platforms.

To address this research gap, we develop a simulation model. The model captures the endogenous competitive dynamics arising from the launch of a two-sided digital platform which faces competition from both domestic and foreign followers. In our model, platforms can operate under two types of network effects in terms of geographical scope: local (only users in a country count) or global (all users count the same wherever they are). In addition, platforms can adopt either a gradual or an accelerated international strategy, along with different degrees of innovation. Our model accounts for positive direct and indirect network effects under all scenarios. The novelty of the digital platform phenomenon, the lack of sufficient empirical evidence, the multitude of scenarios that exist, and the subsequent trade-offs involved justify the adoption of a simulation methodology (Papachristos, 2020). While other studies have applied simulation techniques to the field of digital platforms (for a review, see Haurand & Stummer, 2023), they have focused on the determinants of platform adoption by users. Our model is the first in the literature to concentrate on the international growth of digital platforms. We analyze the two-sided case because most multi-sided platforms have only two types of users (Eisenmann et al., 2006; Hagiu & Wright, 2015b). Our unit of analysis is the platform, rather than the firm, as there are cases where the same firm has launched multiple platforms for different purposes, sometimes even in different countries, as the case of the Match Group in digital dating services illustrates. In contrast to apps that can be instantly downloaded globally (e.g., Chen et al., 2019), our model focuses on digital platforms that require complementary country-specific investments for successful entry and growth. Examples include online food delivery, accommodation services, and ride-hailing, among others. Our study also highlights the critical role of the geographical scope of network effects in shaping the dynamics of business platform internationalization. Furthermore, we explore the boundary conditions, encompassing factors such as time to market, the degree of innovation, and the followers' location choice, which influence whether and when a follower can achieve a leadership position in the market. Our model contributes to the existing literature on the initial growth of digital platforms, as originally addressed by Eisenmann (2006). It underscores the significance of strategic choices, including the trade-offs between domestic and international expansion, imitation versus innovation, and considerations regarding the platform's location. While previous research has emphasized the importance of initial growth in launching digital platforms, these trade-offs significantly broaden the strategic possibilities available to firms introducing a digital platform. This expansion of strategic options justifies the application of simulation techniques in our analysis.

2. Trade-offs in the global expansion of digital platforms

The literature on the internationalization of digital platforms has seen significant growth in the past decade. Despite being far from exhaustive, it presents intriguing findings that challenge conventional assumptions regarding the expansion of digital platforms. From this extensive body of literature, two primary conclusions emerge. First, digital platform's global availability does not automatically translate into global scale or a global footprint (Chen et al., 2019). Digital platforms confront dilemmas and trade-offs similar to those faced by traditional firms when expanding globally. Second, in addition to highlighting that network effects do not consistently lead to a winner-takes-all outcome for digital platforms (Cullen & Farronato, 2021), existing research emphasizes significant variations linked to the geographical scope of network effects (Cusumano et al., 2019; Knee, 2018; Stallkamp & Schotter, 2021).

Contrary to the belief that digital businesses are immune to the localization vs. globalization dilemma, existing research emphasizes its significance for digital platforms (Nambisan, 2020; Parente et al., 2018). Certainly, the global reach of the internet favors platform expansion, allowing for the virtual exploitation of digital assets across markets (Nambisan, 2020). In addition, internet technologies facilitate global brand recognition (Steenkamp, 2020), and digital platforms leverage digital infrastructure to cater to user communities, scalable for foreign markets (Monaghan et al., 2020). Nevertheless, three critical localization forces—government policies and regulations, infrastructure, and culture—apply to digital platforms. Some specific factors, such as those related to national security or citizen privacy, require platforms to employ non-market strategies to navigate local regulations (Curchod et al., 2020). As with conventional international expansion projects, political and non-market strategies prove essential for digital platforms (Boddewyn & Brewer, 1994). Furthermore, differences in customer needs and values between countries reduce the appeal of foreign platforms to local customers (Chen et al., 2019; Dahabiyeh & Constantinides, 2022). In the initial phases of platform expansion into a new country, a failure to address local needs and demands may diminish the significance of the global network size for local customers (Afuah, 2013; Chen et al., 2019). Moreover, cross-industry differences in the host market make it difficult to integrate the ecosystem needed to operate in foreign countries (Rong et al., 2022), especially when non-digital resources are involved (Stallkamp et al., 2022).

Given these cross-country barriers, prior research suggests that digital platforms must carefully consider their foreign entry choices. Chen et al. (2019) found that the influence of the markets in which digital platforms establish a presence affects their global expansion into other markets, because prospective users of digital platforms often examine the trends in platform adoption in more sophisticated markets. Shaheer et al. (2020) discovered that digital platforms need to pay attention to the type of users they will attract in foreign countries. Brouthers et al. (2016) and Punt et al. (2023) suggest that platforms can leverage their existing network of users to enter into other foreign countries. Whereas digital platforms can exploit new ways of entering into foreign markets, Ojala et al. (2018, 2020) show how different technical and strategic bottlenecks in the form of complementary technologies and resources can limit the internationalization of these platforms. To overcome potential obstacles, Rasmussen and Petersen (2017) emphasize the importance of a pivoting strategy, akin to the lean startup methodology, by making necessary adjustments to adapt the platform to new products and customers during the platform's international expansion process. Cross country differences, however, also create opportunities for some companies that operate as startup factories, like Rocket internet (Baumann et al., 2018), that launch digital platforms that clone already existing business models in underserved or untapped markets in emerging countries. Overall, the literature underscores that digital platforms need to plan the sequence of international expansion by considering not only each country in isolation but also how each new country paves the way for future expansions.

In the context of digital platform growth, the study of network effects draws on the broader literature concerning the establishment of industry standards. Research on "standard wars," as in cases like VCR formats, computer hardware and software systems, and video games and consoles—has highlighted winner-takes-all dynamics (Rietveld & Schilling, 2020; Rysman, 2009). However, for digital platforms that rely on information and network effects, achieving a winner-takes-all outcome, even within a single country, is far from assured (Cullen & Farronato, 2021; Farronato et al., 2023; Li & Netessine, 2020; Zhu et al., 2019), especially considering that multi-homing (i.e., the simultaneous use of alternative platforms) is more feasible in digital platforms, as they typically do not require platform-specific physical devices (Eisenmann et al., 2006). Irrespective of cross-country barriers, previous research has shown that the geographic scope of network effects is vital in platform internationalization (Cusumano et al., 2019; Knee, 2018; Stallkamp & Schotter, 2021). This geographical scope varies significantly depending on the circumstances. In some cases, the co-location of users is integral to the business model, as seen in ride-hailing platforms like Uber (Garud et al., 2022). In other cases, location holds little importance, and users count equally regardless of their location, as exemplified by WhatsApp. Most platforms fall between these two extremes, with a complex interplay between geography and network effects. Some conceptual papers have discussed the geographical scope of network effects in the context of digital platform internationalization, highlighting that when network effects are confined to one country or region, expanding into new areas often means starting from scratch, irrespective of the platform's user base in other countries (Brouthers et al., 2016; Guillén, 2021; Knee, 2018; Stallkamp & Schotter, 2021). Nevertheless, the final impact of network effects on international competition between platforms is also influenced by other factors such as time to market and degree of innovation, the interaction of which with these effects has not been explored yet.

Prior research also suggests that the competitive advantage of digital platforms within international networks is rooted in their ability to meet users' diverse needs, innovate, adapt, and scan for new opportunities as they expand globally and always remain more attractive to users (e.g., Banalieva & Dhanaraj, 2019; Helfat & Raubitschek, 2018; Ojala et al., 2020; Rasmussen & Petersen, 2017). These intuitive ideas underscore the importance of innovation but have not yet been rigorously modeled or empirically assessed. Digital platform business models are easily replicable (Karhu et al., 2018; Karhu & Ritala, 2021). Competitors can attract users that the original platform fails to entice by simply mimicking its business model, a strategy known as cloning (Epstein, 2011). This allows followers to introduce clones of the original platform, adapted to different contexts or with enhanced features. Tinder is perhaps the best example of an innovating platform. Launched in an industry with established incumbents such as eHarmony or Match.com, Tinder disrupted the industry by focusing on an underserved segment: young adults. It introduced features that improved the customer experience, like swiping, allowing users to accept or decline potential matches based on physical appearance. This case illustrates one of the drivers of platform growth: targeting a niche that isn't perfectly served by incumbents and developing an innovative platform that delivers a better consumer experience (Abolfathi & Santamaria, 2020). Successful platform growth, therefore, does not solely involve stealing current customers from incumbents but also attracting new segments of users to the industry and/or adapting an existing business model to the specifics of one region.

Given the relevance of imitation, location choice, geographical scope of network effects, and innovation, we argue that the impact of each of these variables on international competitive dynamics will be driven by the timing of market entry and the international strategies adopted by each platform. Both the first mover and the followers face important trade-offs related to the timing of their choices, their degree of innovation and the speed of international expansion. While the initial growth of the first mover allows it to capitalize on network effects (Eisenmann, 2006), it must decide whether to expand abroad earlier or later, potentially leaving parts of the domestic or foreign markets unattended. Followers, on the other hand, grapple with the dilemma of a quick response by introducing a clone or taking the time to develop an improved version of the platform. They also have to make choices regarding a gradual or accelerated international strategy, as well as the country where the platform is first launched.

In the following section, we delve deeper into these trade-offs by introducing a simulation model. The model aims to illuminate the endogenous competitive dynamics that can be anticipated when launching a two-sided digital platform. The model assumes that digital platforms necessitate substantial country-specific investments for successful entry and growth. Platforms can operate under either local or global network effects and must navigate a competitive landscape comprising a first mover and domestic and foreign followers. These followers can become either mere clones of the original platform or innovators. In addition, when expanding abroad, all platforms have the option to adopt either a gradual or an accelerated international strategy and will encounter liabilities due to cross-country differences. By simulating these scenarios, our goal is to provide valuable insights into the complex and evolving landscape of digital platform competition in a globalized world.

3. Simulation model

Our methodological approach is based on modeling and simulation techniques (Davis et al., 2007). This approach has recently gained popularity in the study of strategic issues (see, e.g., Chandra & Wilkinson, 2017; Haurand & Stummer, 2023; Wu et al., 2019), as it allows scholars to glimpse into the long-term consequences of different managerial behaviors and investigate the inherent complex dynamics of organizations and their environments. We develop a formal simulation model to explore how platform internationalization strategies, strategic innovation decisions, network effects, and competition play out across geographies. Our goal is to develop theoretical propositions about the when, where, and how of international expansion that facilitate the understanding of the competitive dynamics of digital platforms and can serve for future empirical research on digital platforms.

The model considers the competition between three two-sided digital platforms that act as mere brokers.[1] Airbnb in the accommodation business would be an example of this type of business. We consider three geographic areas as potential markets to model the impact of different kinds of network effects. Platform 1 (*the first mover*) starts operating at time $t = 0$ from geographic area 1, which is situated at an increasing distance from geographic areas 2 and 3, respectively. Platform 2 (*the foreign follower*) starts operating from the most distant geographic area (3), establishing there in $t = T_{L2}$. Platform 3 (*the domestic follower*) starts operating from the same geographic area as the first mover (1), but it establishes in this area at $t = T_{L3}$. We note that T_{L2} and T_{L3} represent time lags that provide the first mover with a specific, time-based competitive advantage.

We assume that the followers can take their time to innovate and offer a better version of the platform, which provides them with a product-based competitive advantage, as opposed to launching a mere clone with little time delay. The quality of the new platforms, defined by the parameters q_2 and q_3 (for Platforms 2 and 3, respectively), is measured with respect to the benchmark $q_1 = 1$, which identifies the first mover. We assume that the potential of the platform to attract new users increases as q_p grows. Although different scenarios will be explored later in the simulation analysis, it is reasonable to assume that higher levels of innovation imply longer time lags (i.e., increased q_p leads to increased T_{Lp}), i.e. it takes more time to develop a better product. In this sense, each follower needs to face a strategic innovation decision: either clone ($q_p = 1$, $T_{Lp} = t^*$, representing a small time lag) or innovate ($q_p > 1$, $T_{Lp} > t^*$).

Our analysis also concerns the internationalization strategies of digital platforms. While each platform starts operating in one geographic market, we assume that it will move to other markets as its presence in its local market consolidates. Specifically, platforms will first enter the adjacent geographic market (2, for all platforms), and will later move to the farthest area (3 for the first mover and the local follower; 1 for the foreign follower). In this fashion, different strategies can be defined based on the potential market percentage limit, a decision parameter we denote by ML_p. In particular, we contemplate international expansion as a process of increasing commitments, establishing a difference between gradual and accelerated internationalization strategies (see Guillén & García-Canal,

[1] Digital platforms can be grouped in two big blocks: brokers and providers (Hagiu and Wright 2015a; Hennart, 2019). Broker platforms such as marketplaces or social networks connect individuals and/or firms among themselves just for the sake of making transactions and/or interacting. They do not fix prices, just acting as facilitators (Curchod et al., 2020; Hagiu and Wright, 2015a; Hennart, 2019). Providers, on the other hand, deliver physical or digital goods or services to their clients. As a result, they are forced to build some distribution infrastructure and secure the sourcing of products and contents. These categories are not necessarily exclusive, as some providers also operate as brokers for some purposes.

2009). In the former, a platform advances to a new area when it has achieved a higher potential market percentage than in the latter (i.e., gradual international strategies are characterized by higher ML_p).

The model also considers that network effects have a geographical dimension, depending on the geographical scope at which the aggregation of users adds value to the platform. Whereas in the case of food delivery or ride-hailing platforms network effects are basically defined at the surrounding area level (buyers only care about the complementary sellers already collocated with them and vice versa), in other platforms, like accommodation ones, network effects have a wider reach, as potential guests value the availability of accommodations in any potential destination of their interest and hosts value the availability of potential guests irrespective of their origin. In this context, two distinct geographical scopes for network effects can be identified at opposite ends of the spectrum: global and local network effects. When network effects are global, all users count the same irrespective of their location; when they are local, new users only have an influence in the geographic market in which they participate. Even though our model can also contemplate intermediate cases, our analysis in this paper centers on contrasting global and local network effects to elucidate the distinctions between both.

3.1. Definition of variables

We build a discrete-time simulation model of a system with $P = 3$ platforms ($p = \{1,2,3\}$) and $N = 3$ geographic areas ($n = \{1,2,3\}$) during $T = 180$ periods ($t = \{1,2, \ldots,180\}$). We use the following variables, which we categorize into three types, to define the dynamics of the network. To enhance the model's general applicability, we align the terminology with that typically used in two-sided platforms, designating sellers and buyers as the two distinct user types.

- o *State variables* - describe the state of the network at the end of period t:
- ■ $g^p_{n,t}$ denotes the **number of buyers** of platform p in geographic market n at the end of period t;
- ■ $h^p_{n,t}$ denotes the **number of sellers** of platform p in geographic market n at the end of period t.
- o *Flow variables* - describe the users entering the network during period t:
- ■ $\Delta g^p_{n,t}$ denotes the **number of new buyers** of platform p in geographic area n during period t;
- ■ $\Delta h^p_{n,t}$ denotes the **number of new sellers** of platform p in geographic area n during period t.
- o *Process variables* - determine the generation of new buyers and sellers that take place in period t:
- ■ $r^p_{n,t}$ denotes the **area resource investments** of platform p in geographic market n for period t. We note that $r^p_{n,t}$ is normalized, such that $\sum_n r^p_{n,t} = 1 \forall p,t$; e.g., $r^p_{n_1,t} > r^p_{n_2,t}$ indicates that platform p allocates more resources to area n_1 than to area n_2 for period t.
- ■ $m^p_{n,t}$ denotes the **area market impact** of platform p in geographic market n in period t. In this case, $m^p_{n,t} > 1$ implies that the platform is amplifying the network effects, mainly due to their area investments, while $m^p_{n,t} < 1$ means that those effects are attenuated.
- ■ $s^u_{n,t}$ denotes the **saturation effects** in geographic market n for period t for either buyers ($u = g$) or sellers ($u = h$). This models the loss of strength of the network effects as the number of buyers and sellers approach the size of the market; in this sense, $s^u_{n,t} \leq 1, \forall u,n,t$.

3.2. Sequence of events

We consider that the following three-stage sequence of events occurs each period t. This defines the dynamic behavior of the system over time.

1. First, the three platforms decide the area resource investments for period t in each geographic market n. This is represented by $\{r^1_{1,t}, r^1_{2,t}, r^1_{3,t}\}$, $\{r^2_{1,t}, r^2_{2,t}, r^2_{3,t}\}$, and $\{r^3_{1,t}, r^3_{2,t}, r^3_{3,t}\}$ for Platforms 1, 2, and 3, respectively. This determines the area market impact of each platform p during period t in each area n, along with the area market impact in the previous period, t-1. That is, both $r^p_{n,t}$ and $m^p_{n,t-1}$ influence $m^p_{n,t}$.
2. Then, the number of new buyers and sellers in each market for period t is calculated for the platforms. This is based on the quantification of network effects. For a specific platform p and area n, $\Delta g^p_{n,t}$ and $\Delta h^p_{n,t}$ depend on:
   i. The baseline network effects, which in turn depend on the number of buyers and sellers in the previous period, t-1, in this and the other markets: $g^p_{1,t-1}$, $g^p_{2,t-1}$, $g^p_{3,t-1}$, $h^p_{1,t-1}$, $h^p_{2,t-1}$, $h^p_{3,t-1}$;
   ii. The quality of the platform, compared to the first mover, identified by the parameter $q_p \geq 1 \forall p$;
   iii. The platform's area market impact in the market under consideration, i.e., $m^p_{n,t}$;
   iv. The saturation effects of the market under consideration, i.e., $s^g_{n,t}$ and $s^h_{n,t}$;
   v. Regulatory barriers and cultural differences that affect the platform p in the market n, represented by the distance parameter $d_{p,n}$, $\forall p,n$.

3. Finally, the number of buyers and sellers can be updated in each geographic market n for each platform p, that is, $g^p_{n,t}$ and $h^p_{n,t}$. This is the accumulated sum of the number of new buyers and sellers from the start of the simulation, i.e., $\{\Delta g^p_{n,1}, \ldots, \Delta g^p_{n,t}\}$, $\{\Delta h^p_{n,1}, \ldots, \Delta h^p_{n,t}.\}$

3.3. Dynamics of the network

The previous sequence of events can be translated into the set of difference equations that is described below, which mathematically formalize the discrete-time system under study.

First, the area market impact of each platform (p) in each geographic market (n) during each period (t), $m^p_{n,t}$, is expressed as the weighted average of two components, where γ^p_n defines their weight, as shown in Eq. (1).

$$m^p_{n,t} = \left(1-\gamma^p_n\right)m^p_{n,t-1} + \gamma^p_n \frac{\lambda^p_n}{1+\kappa^p_n exp\left(-\alpha^p_n r^p_{n,t}\right)} \quad (1)$$

The first component is the area market impact of the platform for the previous period, $m^p_{n,t-1}$. In this fashion, we assume that area resource investments help the platform create market impact not only in the current but also in future periods (unless γ^p_n=1).[2]

The second component is a logistic function of the area resource investments of the platform during the same period in the market under consideration, $r^p_{n,t}$. We use a S-shaped, logistic curve, as it models a certain degree of inefficiency in the extremes of the interval (i.e., particularly low and high investments). In this logistic curve, λ^p_n is the supremum (i.e., the maximum amplification that the investment can provoke on the network effects), α^p_n is the growth rate (which determines the steepness of the curve), and κ^p_n is the adjustment parameter (determining the value of the curve for $r^p_{n,t} = 0$; setting $\kappa^p_n = 1 - \lambda^p_n$ results in a value of 1, which neither amplifies nor attenuates the network effects).

Now we consider the second stage of the sequence of events. The new buyers and sellers of each platform (p) in each geographic market (n) for each period (t), $\Delta g^p_{n,t}$ and $\Delta h^p_{n,t}$, are calculated by multiplying five factors: the quality of the platform (q_p), the area market impact ($m^p_{n,t}$), the baseline network effects, the saturation effects ($s^u_{n,t}$), and the distance parameter ($d_{p,n}$). This is formalized by Eqs. (2) and (3).

$$\Delta g^p_{n,t} = q_p m^p_{n,t}\left(\varphi^g_n g^p_{n,t-1} + \varphi^{h\to g}_n h^p_{n,t-1} + \sum_{i\neq n}\psi^g_{i\to n} g^p_{i,t-1} + \sum_{i\neq n}\psi^{h\to g}_{i\to n} h^p_{i,t-1}\right)s^g_{n,t} d_{p,n} \quad (2)$$

$$\Delta h^p_{n,t} = q_p m^p_{n,t}\left(\varphi^h_n h^p_{n,t-1} + \varphi^{g\to h}_n g^p_{n,t-1} + \sum_{i\neq n}\psi^h_{i\to n} h^p_{i,t-1} + \sum_{i\neq n}\psi^{g\to h}_{i\to n} g^p_{i,t-1}\right)s^h_{n,t} d_{p,n} \quad (3)$$

The baseline network effects, represented between brackets in Eqs. (2) and (3), model how users of the platform in each geographical area attract more users in this and the other areas. In them, the first two addends model the network effects within the same market (intra-market), while the last two model those among different areas (inter-market). Specifically: φ^g_n (φ^h_n) is the auto-correlation parameter that considers how buyers (sellers) of area n attract more buyers (sellers) to this market; $\varphi^{h\to g}_n$ ($\varphi^{g\to h}_n$) is the cross-correlation parameter that explains how sellers (buyers) of area n attract new buyers (sellers) in this market; $\psi^g_{i\to n}$ ($\psi^h_{i\to n}$) describe the influence of buyers (sellers) of the other markets (i) in the new buyers (sellers) in n; and $\psi^{h\to g}_{i\to n}$ ($\psi^{g\to h}_{i\to n}$) consider how sellers (buyers) of the other markets (i) attract new buyers (sellers) in n. We also note that the first and third addends model the same-side (direct) network effects (buyers attract more buyers; sellers attract more sellers), while the second and fourth addends consider the (indirect) cross-side network effects (sellers attract more buyers, and vice versa). The definition of all these parameters allows usto distinguish between different types of network effects (e.g., global vs. local).

At this point, we recall that the parameter that represents the quality of the platform ($q_p \geq 1$) allows us to consider strategic innovation decisions. Thus, $q_1 = 1$ defines the benchmark for Platform 1; while Platforms 2 and 3 can opt for either cloning ($q_p = 1$) or launching a better platform ($q_p > 1$), taking into account that the latter would amplify the network effects, as illustrated by Eqs. (2) and (3), but it would require more time to launch the platform to the market. In addition, the distance parameter ($d_{p,n} \leq 1$) considers regulatory barriers and cultural differences, which may also play a key role in the internationalization of digital platforms. By setting $d_{p,n} < 1$ in those geographic areas distant from the platform's initial one, this parameter decreases the platform's capacity to create new buyers and sellers in these areas, indicating lower effectiveness of resource investments.

The saturation effects in each geographical market (n) during each period (t), $s^u_{n,t}$ ($u = g$ for buyers, $u = h$ for sellers) depend on the

[2] It is important to underline that the inertia of the area market impact is higher as $\gamma^p_n \in [0,1]$ decreases. That is, the benefits of high area resource investments are achieved sooner for high values of γ^p_n. Indeed, note that the particular case $\gamma^p_n = 1$ results in the area market impact of the platform in each month being independent of that in the previous month.

number of users at the end of the previous period (t-1) of the three platforms, $\sum_p g^p_{n,t-1}$ and $\sum_p h^p_{n,t-1}$. Also, it depends on the size of the market n in terms of buyers, denoted by θ^g_n, and sellers, θ^h_n. We use the exponential relationships shown in Eqs. (4) and (5).[3] At this point, we note that these equations model an important simplifying assumption of our work: users are mutually exclusive, that is, they can only be users of one of the two platforms.

$$s^g_{n,t} = exp\left(1 - \frac{\theta^g_n}{\theta^g_n - \sum_p g^p_{n,t-1}}\right) \tag{4}$$

$$s^h_{n,t} = exp\left(1 - \frac{\theta^h_n}{\theta^h_n - \sum_p h^p_{n,t-1}}\right) \tag{5}$$

Finally, the fundamental relationships shown in Eqs. (6) and (7) apply, shaping the dynamics of the system over time. They model the third stage of the previously defined sequence of events.

$$g^p_{n,t} = g^p_{n,t-1} + \Delta g^p_{n,t} \tag{6}$$

$$h^p_{n,t} = h^p_{n,t-1} + \Delta h^p_{n,t} \tag{7}$$

3.4. Key performance metrics

To evaluate the performance of the different internationalization strategies for exploiting network effects as well as the impact of the strategic innovation decisions, we calculate the overall worldwide potential market percentage of each platform (p) at the end of the 180-period simulation run from both perspectives: buyers, MP^g_p, and sellers, MP^h_p. We define the *potential market percentage* for each platform as the ratio of the total number of buyers ($\sum_n g^p_{n,T}$), or sellers ($\sum_n h^p_{n,T}$), at the end of the simulation to the overall size of the market ($\sum_n \theta^g_n$ for buyers, and $\sum_n \theta^h_n$ for sellers), as expressed in Eqs. (8) and (9).

$$MP^g_p = \sum\nolimits_n g^p_{n,T} \Big/ \sum\nolimits_n \theta^g_n \tag{8}$$

$$MP^h_p = \sum\nolimits_n h^p_{n,T} \Big/ \sum\nolimits_n \theta^h_n \tag{9}$$

3.5. General conditions

In this section, we present information about the general conditions of the experimentation process, which have been applied to all simulations (unless otherwise specified in the sensitivity analysis).

First, we define the same size for the three geographic markets, specifically, $\theta^g_n = 2,000,000$ and $\theta^h_n = 1,000,000$, $\forall n$. Also, in all cases, we assume that the platforms start with 100 buyers and 50 sellers in their initial geographical area (in $t = 0$ for Platform 1; in $t = T_{L2}$ for Platform 2; in $t = T_{L2}$ for Platform 3).

Second, to characterize the area market impact, we always use the following configuration: $\gamma^p_n = 0.5$, $\lambda^p_n = 10$, $\alpha^p_n = 5$, and $\kappa^p_n = 9$, $\forall p,n$. Here, $\gamma^p_n = 0.5$ gives the same weight to both components of Eq. (1), while the other parameters define the S-shaped logistic curve within the interval [0,1]. They make that the logistic curve equals 1 for $r^p_{n,t} = 0$ (the lack of area resource investments does not amplify the network effects), and tends asymptotically to 10 as $r^p_{n,t}$ increases (maximum amplification level).

Third, we use the following setup to define the global and local network effects in Eqs. (2) and (3). For the global scenario, we use $\varphi^g_n = \varphi^{h\to g}_n = \psi^g_{i\to n} = \psi^{h\to g}_{i\to n} = 0.02$ and $\varphi^h_n = \varphi^{g\to h}_n = \psi^h_{i\to n} = \psi^{g\to h}_{i\to n} = 0.01$, $\forall n$. Notice that the strength of the parameters that consider the network effects within the same area is the same as that of the parameters that consider the network effects among different markets. In contrast, for the local scenario, we use $\varphi^g_n = \varphi^{h\to g}_n = 0.02$ and $\varphi^h_n = \varphi^{g\to h}_n = 0.01$, $\forall n$, for the parameters that consider the network effects within the same market, and $\psi^g_{i\to n} = \psi^{h\to g}_{i\to n} = 0$ and $\psi^h_{i\to n} = \psi^{g\to h}_{i\to n} = 0$ for the parameters that consider the network effects between different markets.

Note that, following the above parameters for the network effects, capacity of the markets, and the initial values, we treat the two sides of the platform (buyers and sellers) symmetrically to simplify the presentation of results. That is, when a seller is added, two buyers are added, and vice versa.

Fourth, the distance parameters are set to $d_{p,n} = 1$ for the initial geographic area of each platform, and $d_{p,n} = 0.9$ for the others,

[3] The exponential relationship takes into consideration that the potential to increase the number of buyers and sellers decrease dramatically as the organization approaches the size of the market. Notice that when $g^p_{n,t-1} \ll \theta^g_n$ ($h^p_{n,t-1} \ll \theta^h_n$), we obtain $s^{p,g}_{n,t} \approx 1$ ($s^{p,g}_{n,t} \approx 1$); however, when $g^p_{n,t-1} \approx \theta^g_n$ ($h^p_{n,t-1} \approx \theta^h_n$), we obtain $s^{p,g}_{n,t} \approx 0$ ($s^{p,g}_{n,t} \approx 0$).

resulting in a 10% reduction in the platform's capacity to create new buyers and sellers in these areas due to the regulatory barriers and cultural differences.

In addition, we establish market saturation thresholds of $ML_p = 50\%$ and $ML_p = 15\%$ for the gradual and accelerated internationalization strategies, respectively. Thus, we assume that a platform that follows a gradual internationalization strategy advances to a new area when it has achieved 50% of potential market percentage. Meanwhile, in the case of the accelerated internationalization strategy, the platform expands to a new area upon achieving 15% potential market percentage. Once the threshold is reached in a geographical area, the platform reallocates resources to the following area, with a comparatively small portion, characterized by $r^p_{n,t} = 10\%$, retained to facilitate future growth in that region. In the event that the relocation threshold (50%/15%) is reached in the three areas at any point, resources are evenly spread across the three areas for the remainder of the simulation. Last, we highlight that an important assumption in our study is that financial investment is fixed over the time horizon of the simulation (due to $\sum_n r^p_{n,t} = 1, \forall p,t$).

4. Results

We present the results from the simulation in four steps: (1) we identify the strategies that lead to the most likely outcomes under each scenario; (2) we examine the trade-offs between innovation and time lags for the two follower platforms, given that innovation can lead to better results but usually takes more time to develop, a lag that benefits platforms that do not innovate; (3) we examine the viability of cloning strategies by analyzing the worst-case scenarios for cloning platforms; and (4) we perform a sensitivity analysis to examine the outcomes when both followers initiate from a more remote country and when there are disparities in market size.

4.1. Nash equilibrium analysis

Our model predicts the expected outcome in terms of potential market percentage depending on the internationalization strategy decision (accelerated or gradual) made by three platforms: the first mover and two followers, one starting from an untapped geographical area (the foreign follower) and the other starting from the same competitive geographical area as the first mover (domestic follower). Each iteration in our simulation model has therefore eight possible outcomes, as three platforms have to choose between two internationalization strategies. However, not all of these possible outcomes are equally likely or stable. To identify the optimal choices for a platform, we need to take into account the choices of the other players. For this reason, a combination of strategies is only feasible if each player cannot be better off by changing its strategy, provided that the other players hold their decisions. Accordingly, we used the insights of game theory (Kreps, 1990) to identify the existence of Nash equilibria in each iteration. Under a Nash equilibrium no player has incentives to change its strategy given the choices of the other players in a specific game (Maskin, 1985).[4] They constitute the most likely outcomes for the competitive dynamics of the three platforms in each scenario (Brickley et al., 2000).

Table 1 presents the results of the simulation over 180 periods for 64 different scenarios: 8 combinations of two internationalization strategies (accelerated or gradual) by three platforms, 2 network effect settings (global or local), and 4 combinations of innovation (clone or innovation) by two follower platforms (the foreign follower and the domestic follower). In this analysis, we contemplate two levels of innovation. First, $q_p = 1$, which corresponds to a clone version of the first mover's platform, launched with a time lag of $T_{Lp} = 3$ periods. Second, $q_p = 1.25$, which corresponds to a moderately improved platform that amplifies the impact of network effects by 25%, and that is launched with a time lag of $T_{Lp} = 9$ periods (this provides the leader, and potentially the other follower, with a considerably time-based competitive advantage). As mentioned, country barriers reduce the impact of market investments.

We found only one Nash equilibrium in each of the eight iterations. In the four iterations with global network effects, the three platforms reach a Nash equilibrium when all three platforms choose an accelerated strategy. This result makes sense because waiting to start operations in a new geographical area enables competing platforms to enjoy a head start. There are, however, winners and losers, as the outcomes in terms of potential market percentage are sharply different. When the followers launch mere clones of the first mover's platform, the first mover gets almost half (48.8%) of the total market, whereas the distant follower obtains 22.8% and the domestic follower 16.9%. Quite interestingly, the trade-off between innovation and time lag plays in this initial simulation in favor of the first mover, especially when the innovation effort is made by the domestic follower. The final potential market percentage of the first mover rises to 51.8% when only the domestic follower innovates and to 53.8% when both followers do. In this context, innovation, at the level we are presently considering, does not yield returns for either the foreign or domestic followers due to the additional time required to launch the platform. However, for higher levels of innovation and/or shorter time lags, the outcome would be different, as we shall see later.

By contrast, in the four iterations with local network effects, the Nash equilibrium is found when only the domestic follower chooses an accelerated internationalization while both the first mover and the foreign follower choose a gradual internationalization strategy.

[4] We understand each setting in Table 1 as formed by two different non-cooperative games: one for global network effects and the other for local network effects. In each of these games, we have investigated the existence of Nash equilibria through the definition of this concept. Specifically, we have created three variables, one for each platform, named 'switching propensity', sp_i (i refers to the number that identifies each platform). For each strategy profile (i.e., a set of internationalization strategies), $sp_i = 1$ if Platform 1 does better by unilaterally changing their strategy (assuming the strategies of the other players do not change), and $sp_i = 0$, otherwise. Therefore, a strategy profile becomes a Nash equilibrium in a specific non-cooperative game if and only if $\sum_i sp_i = 0$. This ensures that no platform benefit by switching their internationalization strategy.

Table 1
Results of the simulation. It shows the potential market percentage of each platform depending on the type of network effects, the platform's international strategy and a moderate level of innovation of the followers that amplifies the impact of network effects a 25% ($q_p = 1.25$). The highlighted strategic profiles in each case constitute a Nash equilibrium.

Strategy profiles and internationalization strategies								
Strategy profile	1	2	3	4	5	6	7	8
1st mover	Gradual	Gradual	Gradual	Gradual	Acceler.	Acceler.	Acceler.	Acceler.
For/Follow.	Gradual	Gradual	Acceler.	Acceler.	Gradual	Gradual	Acceler.	Acceler.
Dom/Follow.	Gradual	Acceler.	Gradual	Acceler.	Gradual	Acceler.	Gradual	Acceler.
***Setting I* – Both followers are clones**								
Strategy profile	1	2	3	4	5	6	7	8
Potential market percentage – *Global network effects*								
1st mover	41.94%	36.19%	42.73%	35.24%	50.48%	50.10%	50.88%	48.81%
For/Follow.	32.81%	28.70%	31.50%	27.14%	20.90%	20.18%	21.84%	22.77%
Dom/Follow.	13.72%	23.13%	13.68%	25.89%	17.05%	18.04%	15.57%	16.88%
Potential market percentage – *Local network effects*								
1st mover	29.34%	29.94%	34.68%	31.67%	20.87%	24.37%	22.08%	24.49%
For/Follow.	44.48%	38.10%	38.34%	35.56%	42.73%	37.78%	37.22%	35.38%
Dom/Follow.	10.95%	15.78%	10.95%	15.52%	20.17%	20.63%	22.57%	20.79%
***Setting II* – The foreign follower is a clone, but the domestic follower innovates**								
Strategy profile	1	2	3	4	5	6	7	8
Potential market percentage – *Global network effects*								
1st mover	48.41%	48.85%	47.69%	45.50%	52.70%	52.03%	53.22%	51.78%
For/Follow.	29.71%	28.89%	30.59%	31.67%	21.72%	21.03%	22.24%	23.33%
Dom/Follow.	10.38%	10.48%	10.15%	10.76%	14.16%	15.35%	12.90%	13.42%
Potential market percentage – *Local network effects*								
1st mover	29.12%	28.20%	34.47%	28.69%	19.84%	22.52%	19.49%	22.06%
For/Follow.	44.48%	36.26%	38.34%	35.02%	37.72%	34.62%	35.17%	33.86%
Dom/Follow.	11.33%	19.34%	11.34%	19.00%	26.58%	25.69%	28.46%	25.31%
***Setting III* – The domestic follower is a clone, but the foreign follower innovates**								
Strategy profile	1	2	3	4	5	6	7	8
Potential market percentage – *Global network effects*								
1st mover	43.72%	38.30%	43.23%	36.57%	52.52%	52.03%	52.16%	50.70%
For/Follow.	31.20%	26.58%	31.26%	25.70%	19.14%	18.33%	20.18%	19.93%
Dom/Follow.	13.71%	23.25%	13.75%	26.14%	16.86%	18.04%	16.05%	17.91%
Potential market percentage – *Local network effects*								
1st mover	22.85%	24.06%	30.88%	27.42%	17.93%	21.78%	19.29%	22.84%
For/Follow.	50.78%	45.92%	42.79%	41.34%	46.28%	43.44%	42.75%	39.33%
Dom/Follow.	10.95%	13.52%	10.95%	14.29%	19.07%	18.61%	20.27%	19.46%
***Setting IV* – Both followers innovate**								
Strategy profile	1	2	3	4	5	6	7	8
Potential market percentage – *Global network effects*								
1st mover	49.89%	50.40%	50.60%	48.78%	55.13%	54.31%	54.66%	53.81%
For/Follow.	28.01%	27.11%	27.78%	28.90%	19.17%	18.70%	20.37%	20.93%
Dom/Follow.	10.74%	10.83%	10.02%	10.99%	14.30%	15.49%	13.44%	13.85%
Potential market percentage – *Local network effects*								
1st mover	22.64%	23.01%	30.67%	25.87%	17.43%	20.41%	17.94%	20.84%
For/Follow.	50.77%	44.65%	42.79%	39.60%	45.38%	40.78%	40.59%	37.77%
Dom/Follow.	11.33%	16.44%	11.34%	17.59%	21.09%	22.76%	24.85%	23.34%

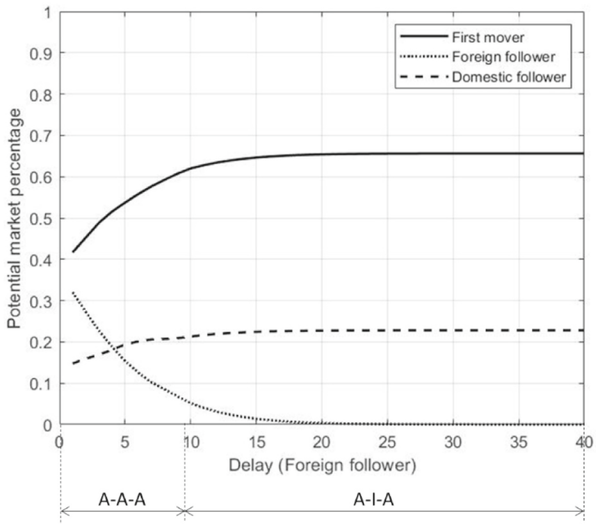
Without local competition at the start, the foreign follower is the winner in terms of potential market percentage, always choosing a gradual strategy. This is also intuitive in that, when network effects apply only within the borders of a geographical area, platforms willing to become market leaders are encouraged to consolidate their current position in one area before expanding to another. However, this does not apply to platforms being at a disadvantage either for having a lower-quality platform and/or a minority position in the domestic geographical area. Let's take a look, for instance, at the simplest scenario in which all of the players compete with a similar platform (followers as cloners of the first mover). The Nash equilibrium is reached when the first mover and the domestic follower follow a gradual strategy and the domestic follower an accelerated one. Interestingly, the first mover is surpassed by the foreign follower in terms of potential market percentage (38.10% the follower, 29.94% the first mover). The domestic follower, being relegated to a small fraction of the local market adopts an accelerated strategy, but gets a modest 15.78% of the overall potential market percentage.

Despite being surpassed by the foreign follower, this is the best scenario for the first mover when competing under local network effects. Even though local competition by the domestic follower prevents the first mover from attaining the largest market share, any innovation by the followers is going to take an additional toll on the first mover's market share. Local competition is especially harmful in the case of local network effects, and that is why the winner in terms of potential market percentage is always the foreign follower, at least with this innovation-time lag trade-off, because it faces no competition in its area of origin.

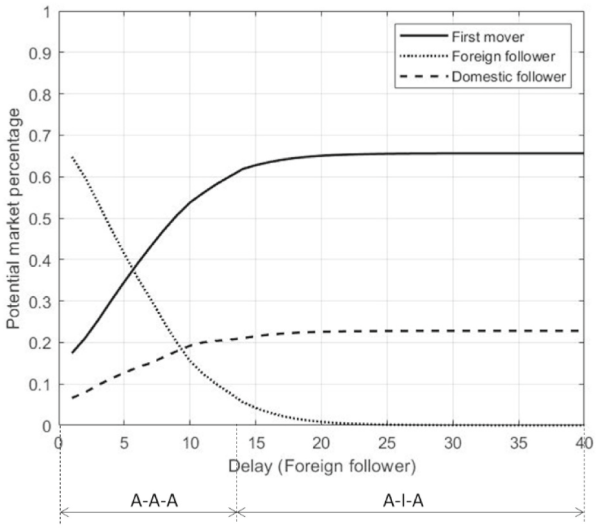
Far from being an aggressive strategy, accelerated internationalization when operating under local network effects is a reflection of weakness under the conditions of our simulations. This is a counterintuitive result of our simulation because the rewards of an accelerated strategy are quite small in terms of catching up with the first mover. Accelerated strategies are, thus, either a must in the case of global network effects, or a second-best choice for underperforming platforms operating under local network effects.

A second counterintuitive result is that the first mover never reaches a leadership position in any of the scenarios of local network effects. As mentioned above, even in the most benign one (where the followers are clones) the first mover is surpassed by the foreign follower due to the lower degree of competition in its home market, where there is no competition, and the fact that the first mover has to compete with a domestic platform.

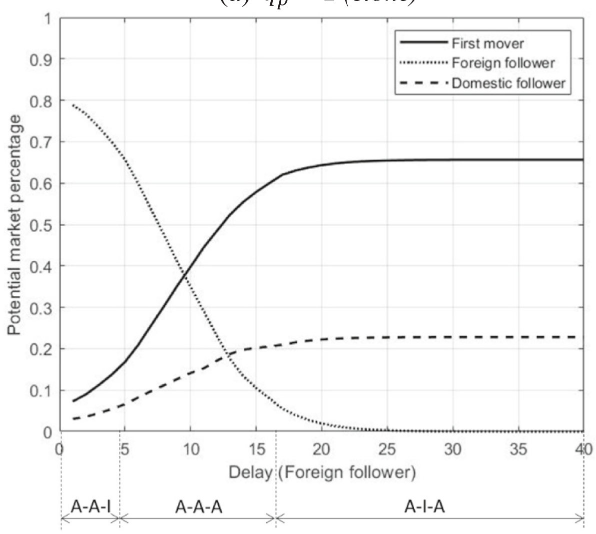
We have established so far that the individual choices that lead to the most likely outcomes (Nash equilibria) are different depending on the nature of the network effects (local or global). A Nash equilibrium is reached when all three platforms adopt an accelerated international strategy when competing under global network effects. Under local network effects, however, reaching a Nash equilibrium requires the first mover and the foreign follower to adopt a gradual international strategy, whereas the domestic follower should adopt an accelerated international strategy.



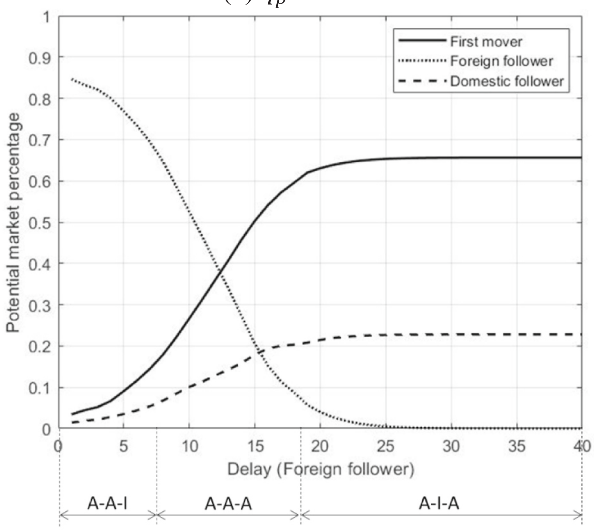
(a) $q_p = 1$ *(clone)*



(b) $q_p = 1.25$



(c) $q_p = 1.5$



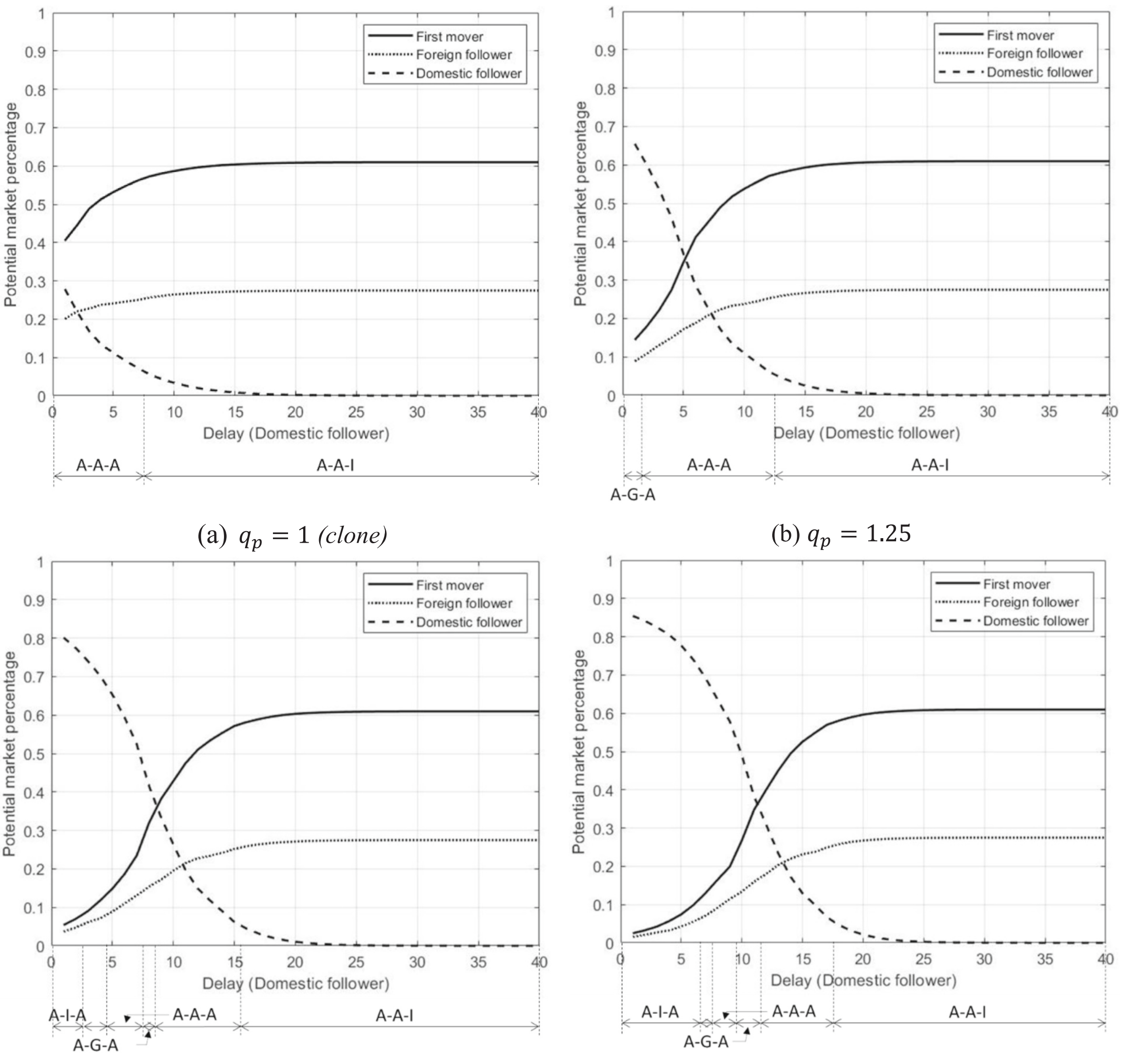
(d) $q_p = 1.75$

Fig. 1. Relationship between the potential market percentage of each platform and the delay of the foreign follower in the presence of global network effects for the Nash equilibrium strategy profile in each case under four different levels of innovation ($q_p = \{1, 1.25, 1.5, 1.75\}$).
Note: We assume that the domestic follower is characterized by $q_p = 1$ and $T_{Lp} = 3$ periods. These figures also show, at the bottom of the chart, the international strategies that lead to the Nash equilibrium for each level of delay. The order in which they are listed is first mover/foreign follower/domestic follower. G denotes Gradual; A, accelerated; and I, indifferent.

4.2. *Trade-offs between innovation and time to market*

In a second stage, we adopted the perspective of the laggards to model the decision to clone or innovate, without assuming fixed time lags as done in the previous section. Additionally, we assumed that the first mover would pursue an accelerated strategy in the case of global network effects and a gradual strategy in the case of local network effects. In this sense, we contemplate a wider spectrum of levels of innovation by the followers as well as a wider range of potential time lags.

As we have two followers, we let the parameters of innovation and time to market to vary for one of them while considering that the other follows a cloning strategy with a three-period delay. We run estimations considering global and local network effects involving four levels of innovation q_p, namely $q_p = \{1, 1.25, 1.5, 1.75\}$, with multiple delays from $T_{Lp} = 1$ period to $T_{Lp} = 40$ periods. Thus, this stage results in a total of 640 simulation runs (4 levels of $q_p \times 40$ levels of $T_{Lp} \times 2$ platforms $\times$ 2 network effect settings). For each simulation, we identified the Nash equilibrium following the procedure described in the previous section in order to calculate the



(a) $q_p = 1$ *(clone)*

(b) $q_p = 1.25$

(c) $q_p = 1.5$

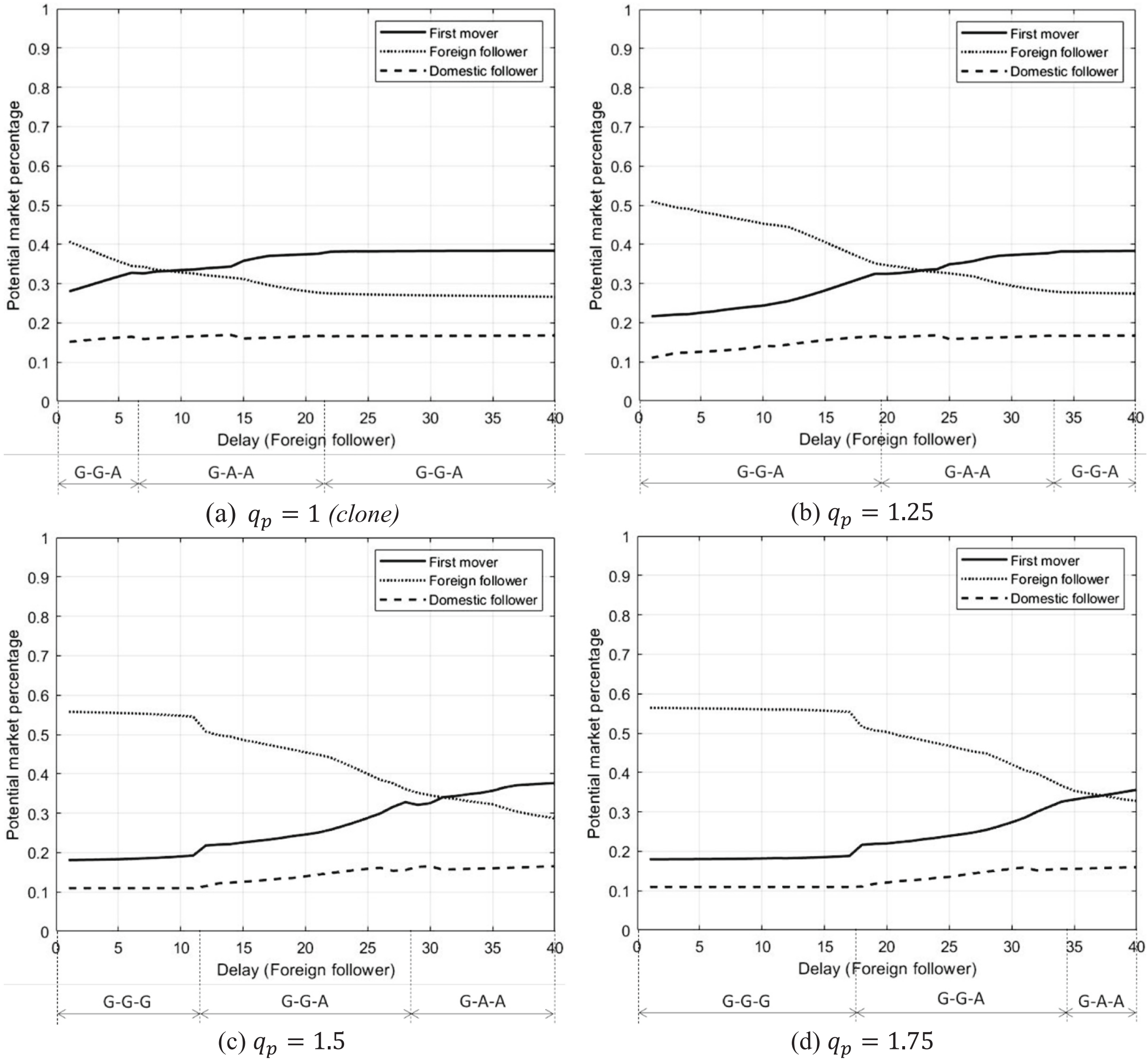
(d) $q_p = 1.75$

Fig. 2. Relationship between the potential market percentage of each platform and the delay of the domestic follower in the presence of global network effects for the Nash equilibrium strategy profile in each case under four different levels of innovation ($q_p = \{1, 1.25, 1.5, 1.75\}$).

Note: We assume that the foreign follower is characterized by $q_p = 1$ and $T_{Lp} = 3$ periods. These figures also show, at the bottom of the chart, the international strategies that lead to the Nash equilibrium for each level of delay. The order in which they are listed is first mover/foreign follower/domestic follower. G denotes Gradual; A, accelerated; and I, indifferent.

expected potential market percentage. In some cases, there are two Nash equilibria, but this only happens when one of the followers is unable to reach a critical mass in its market of origin so as to consider moving abroad (15% of the country of origin market, a 5% of the total market share). In these cases, the international strategy is indifferent for this follower, as gradual or accelerated have not been already implemented, so any strategy for this platform leads to the same results in terms of potential market percentage.

The outcomes of these simulations are shown in Figs. 1 to 4. Each figure includes four panels corresponding to the four levels of innovation described above. Figs. 1 and 2 deal with the scenarios of global network effects and Figs. 3 and 4 deal with the scenarios of local network effects. As for the strategic choices of laggards, Figs. 1 and 3 show the outcomes for the foreign laggard, and Figs. 2 and 4 show the outcomes for the domestic laggard. For instance, Fig. 1 shows the potential market percentage distribution depending on the choices of innovation and time lag by the foreign follower under global network effects. Panel A is for the choice of a clone platform, panel B for an improved platform that amplifies the impact of network effects a 25%, panel C for a platform improved a 50% and finally panel D for an improved platform at the 75% level. The potential market percentage for each time lag is calculated for the combination of international strategy choices that lead to a Nash equilibrium in each specific simulation. These figures also show, at the bottom of the chart, the international strategies that lead to the Nash equilibrium for each level of delay. The order in which they are listed is first

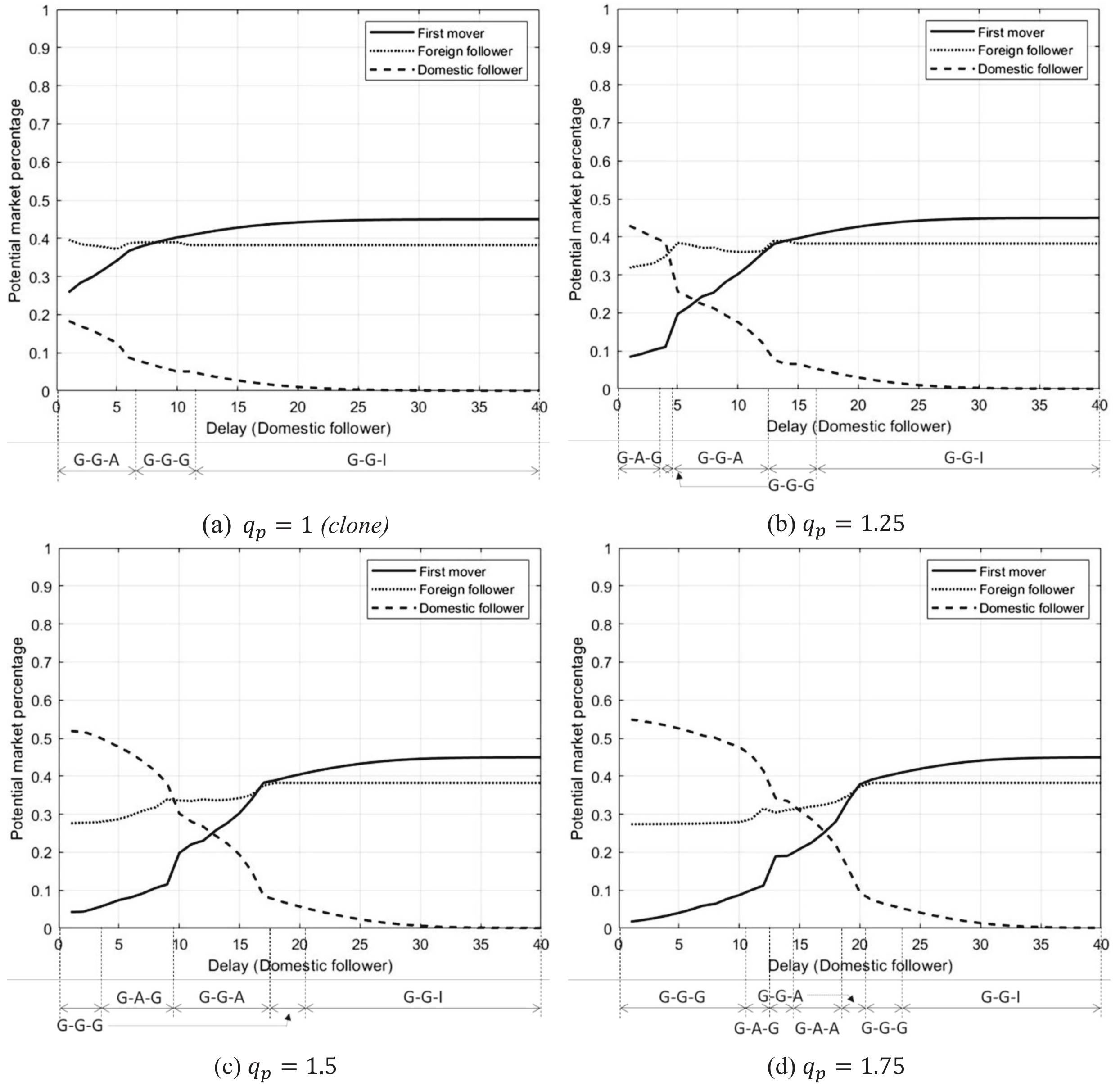


(a) $q_p = 1$ *(clone)* (b) $q_p = 1.25$

(c) $q_p = 1.5$ (d) $q_p = 1.75$

Fig. 3. Relationship between the potential market percentage of each platform and the delay of the foreign follower in the presence of local network effects for the Nash equilibrium strategy profile in each case under four different levels of innovation ($q_p = \{1, 1.25, 1.5, 1.75\}$).

Note: We assume that the domestic follower is characterized by $q_p = 1$ and $T_{Lp} = 3$ periods. These figures also show, at the bottom of the chart, the international strategies that lead to the Nash equilibrium for each level of delay. The order in which they are listed is first mover/foreign follower/domestic follower. G denotes Gradual; A, accelerated; and I, indifferent.



(a) $q_p = 1$ *(clone)* (b) $q_p = 1.25$

(c) $q_p = 1.5$ (d) $q_p = 1.75$

Fig. 4. Relationship between the potential market percentage of each platform and the delay of the domestic follower in the presence of local network effects for the Nash equilibrium strategy profile in each case under for different levels of innovation ($q_p = \{1, 1.25, 1.5, 1.75\}$).
Note: We assume that the foreign follower is characterized by $q_p = 1$ and $T_{Lp} = 3$ periods. These figures also show, at the bottom of the chart, the international strategies that lead to the Nash equilibrium for each level of delay. The order in which they are listed is first mover/foreign follower/domestic follower. G denotes Gradual; A, accelerated; and I, indifferent.

mover/foreign follower/domestic follower. G denotes Gradual; A, accelerated and I, indifferent. When operating under global network effects, all of the platforms, generally speaking, are better off by following an accelerated international strategy, although too much waiting proves disastrous for a follower, no matter whether it is the domestic or the foreign one. When operating under local network effects, gradual strategies are usually the best choice, although there are some exceptions. One is the case of the domestic follower when being a clone, and another one is the foreign follower when being a clone or moderate innovator and/or launching late the platform. In these cases, accelerated strategies are a better choice for followers, despite operating under local network effects.

Generally speaking, these figures show that, as expected, improving the platform and/or reducing the time to market of the follower's platforms increases the chances of reaching leadership positions. However, the length of the time window available for the followers varies in each context. Based on the simulations presented in Figs. 1 to 4, Fig. 5 shows the maximum time lags that result in a follower platform becoming the market leader according to its level of innovation, conditional on the other follower being a clone of the first mover. Local network effects constitute the most benign scenario for this purpose. As innovation increases, local network

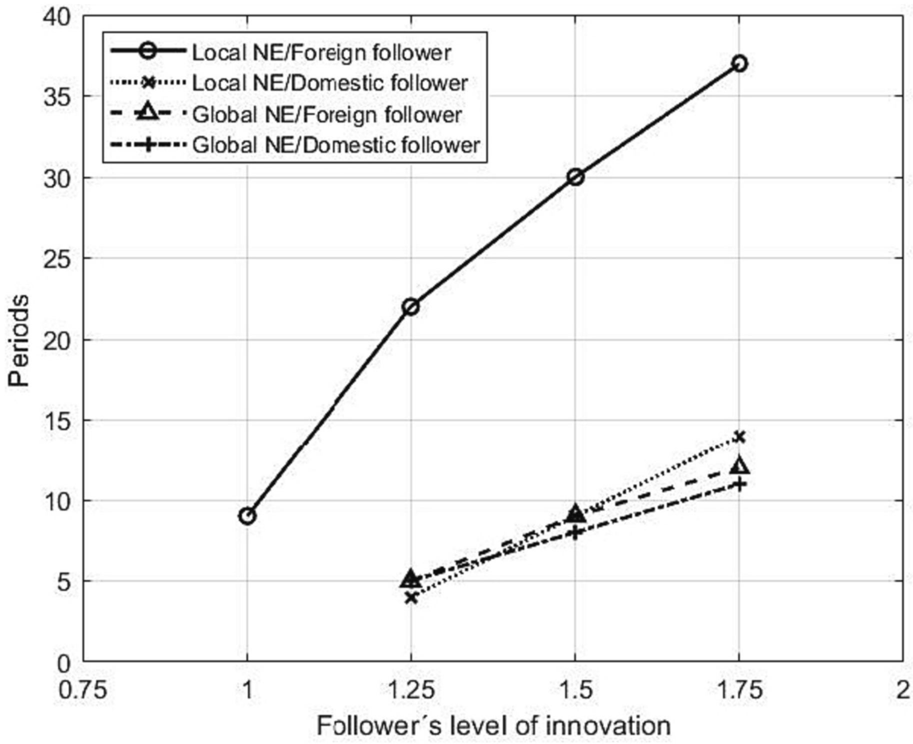


Fig. 5. Maximum lags resulting in market leadership.
Note: Figure shows the maximum time lags that result in a follower platform becoming the market leader as a function of its level innovation, conditional on the other follower being a clone of the first mover with a time lag of three periods. Local NE: Local network effects. Global NE: Global network effects.

effects tend to have longer maximum time lags compared to global network effects. However, it is the foreign follower the one that enjoys more leeway in terms of time to market, not only to become a global leader, but also to build a solid position against the first mover, as Figs. 3 and 4 also show. Cabify and Gaana constitute good examples of these situations. Launched in Spain in May 2011, about a year after Uber started to operate in the United States, Cabify started out by offering a differentiated, luxury service which was an innovation at the time and that helped it to build a strong position not only in Spain but also across Latin America. Gaana, the Indian music streaming platform, was launched in April 2010, four years after Spotify was founded in April 2006, and nearly ten years before Spotify entered India in February 2019. Gaana focused on offering the Indian music listener a local experience, which required building a local music catalog, which helped it to build a leadership position there.

Compared to foreign followers, domestic followers face more difficulties in challenging the first mover when operating under local network effects. For starters, in these cases it is impossible to thrive when launching a clone. The case of Lyft illustrates this fact. Launched in the summer of 2012, about 25 months after Uber, largely as a clone, without innovating, Lyft did not capture more market share than Uber anywhere in the world. Effectively challenging the first mover under these circumstances requires quick and/or substantial innovation. Tinder is perhaps the best example of a domestic follower succeeding under local network effects. Tinder followed a different strategy than the incumbents in a market also characterized by local network effects, given that people use the app to meet other people in the vicinity. It was launched in 2012, seven years after first-mover Match. However, it was a much-improved platform than the one of the first mover, thanks in part to the swipe feature, which proved extremely popular. It acquired the largest market share and merged with Match in July 2017. This fact helped the first mover to reach a market leadership position that it would never have reached otherwise.

These examples and our simulation results illustrate how difficult it is for the first mover to become the leader across many markets when network effects are local. Uber is contested almost everywhere: in China by DiDi, in Southeast Asia by Grab, in Africa by Bolt and Jrney, and in Latin America by Cabify. Our results also show that avoiding local competition is a must when launching a platform operating under local network effects. This fact explains why companies funding cloning platforms like the German Rocket Internet locate their startups in foreign countries with little or no competition (Baumann et al., 2018). Being a country or local specialist can also be a valid strategy for these platforms, taking into account that acquisitions are also a frequent means of growth (Gautier & Lamesch, 2021). This strategy was followed by MercadoLibre, the online marketplace, whose focus on Latin America led the platform to become number one in that region, although global leadership in the online auction markets is held by eBay (Hortaçsu et al., 2009).

Global network effects generate a completely different competitive landscape in which the distinction between domestic and foreign followers does not make much of a difference, as our simulation indicates (see Fig. 5). Innovation is the key factor here. The case of Google illustrates this situation. The irruption of Google with a patented algorithm for searching and indexing across the entire global internet disrupted the industry. Yahoo! opted for licensing Google their search engine and relying on their brand name. In the meantime, Google kept developing their capabilities to capitalize on opportunities in related fields such as mobile search, which allowed them to build a solid presence in a greater number of national markets, thus surpassing Yahoo! once and for all (Rindova et al., 2016). Google launched in 1998, about four years after Yahoo! did, having invested time, resources, and effort in innovation. For its part, Baidu started in China in January 2000, six years after Yahoo! and two years after Google. Baidu managed to amass the largest market share in China but only because Google was prevented from operating there on its own terms. Given the global network effects involved in search, Google has dominated every market save for government interventions.

4.3. Worst-case scenario analysis for cloners

Cloning enables a follower platform to avoid delaying entry. Many real-life platforms clone an existing business model to gain market share as quickly as possible in a different geographical area. Based on the simulations presented in Figs. 1 to 4, Fig. 6 shows the worst results in terms of potential market percentage that the cloning follower platform can achieve depending on what the other follower decides to do, i.e. the previously discussed four levels of innovation q_p, namely $q_p = \{1, 1.25, 1.5, 1.75\}$, with $q_p = 1$ denoting cloning.

Our analysis shows that the best context for a cloning strategy is launching the platform in a new geographical area under local network effects, with the other platform (the domestic follower) also cloning. Most importantly, this scenario provides the best protection for the cloning platform if the domestic follower steps up its innovation. Launching a clone in the domestic market of the first mover under local network effects generates a much lower potential market percentage (as illustrated by the previously mentioned case of Lyft), although this percentage remains somewhat stable if the other follower (the foreign follower) innovates. However, under global network effects, the cloning platform loses potential market percentage quite quickly as the other follower platform increases its level of innovation, regardless of which geographical area it enters.

Under global network effects, the potential market percentage of the clone deteriorates very quickly if the other follower innovates. This dynamic is illustrated by the long list of early search engines (WebCrawler, Yahoo!, Lycos, Excite, AltaVista, etc.), which were wiped out by Google's innovative approach to search. Moreover, the fortunes of the domestic follower and the foreign follower converge as the level of innovation increases, an effect that only occurs under global network effects. Once again, this result is driven by the fact that local network effects privilege the incumbent and encourage entering untapped geographical areas, whereas global network effects level the playing field.

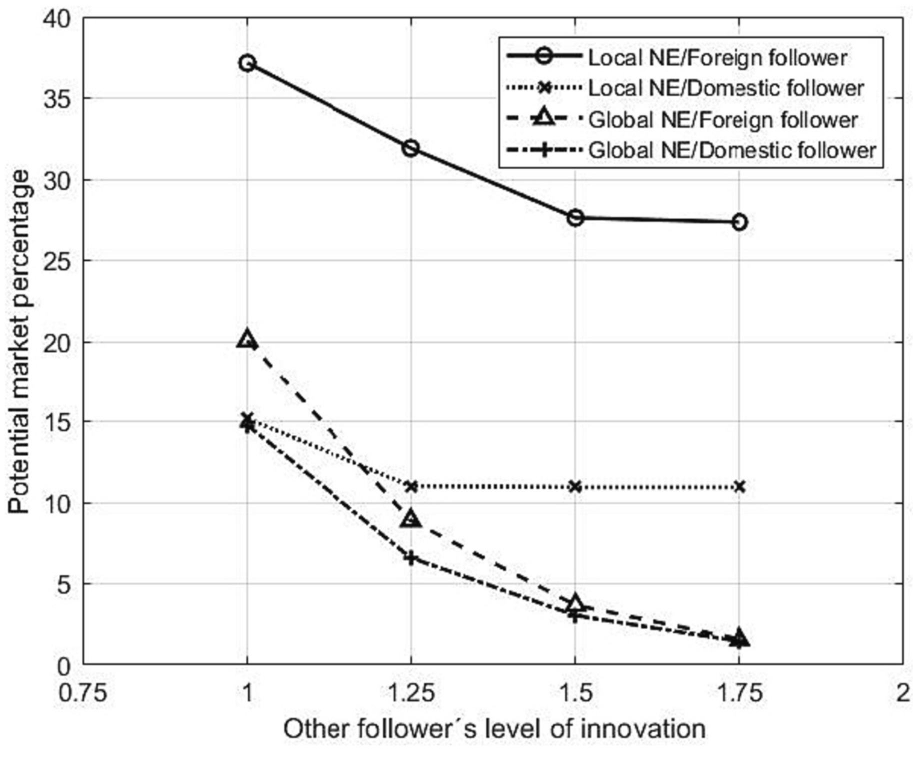


Fig. 6. Minimum potential market percentage for cloning strategy.
Note: Figure shows the worst result in terms of the potential market percentage that a cloning follower platform launched with a three-period time lag can get, depending on the level of innovation of the other follower. Local NE: Local network effects. Global NE: Global network effects.

4.4. Sensitivity analysis

We implemented two main modifications to the simulation model to investigate the impact of variations in the initial parameters on model outcomes. The first modification involved mandating both followers to launch their platform in the geographically farthest country. The second modification introduced variability in the size of the first mover's domestic market. To maintain the paper's concise length, we present only the primary results here, omitting the associated tables and charts. These additional materials are available from the authors upon request.

As might be expected, when both followers initiate their platforms in the most distant country, the primary beneficiary is the first mover. Even when operating under local network effects, the first mover maintains its market leadership when both followers are clones or even for innovations at the level of q_p=1.25, except for small delays in introducing innovations. In the most challenging scenario, involving significant innovation and reduced time to market, the first mover still achieves a potential market percentage of over 25%. Once more, innovation continues to be the exclusive avenue for followers to secure a leadership position in terms of potential market percentage, even though this achievement presents challenges, particularly as the time required to bring an improved platform to market diminishes. In terms of international strategies, accelerated internationalization is still the preferred strategy for all players when operating under global network effects. However, in the case of local network effects, the situation becomes more intricate, leading to the emergence of different Nash equilibria. Here, the first mover consistently adopts a gradual international strategy. In contrast, followers may find advantages in choosing accelerated international strategies to swiftly enter intermediate, potentially untapped, geographic areas.

In cases where there are disparities in the size of the first mover's domestic market, it results in a shift in the players' preferences. In general, larger domestic markets tend to benefit the first mover, particularly when the followers exhibit significant time lags. For instance, when the size of the domestic market is five times larger than other markets, and the followers have time lags of three periods for cloning and nine periods for innovating (the same conditions of Table 1 for the case of equal market sizes), both the first mover and the domestic follower consistently opt for a gradual strategy in all scenarios. Interestingly, the first mover maintains its leadership in terms of potential market percentage, even when faced with follower innovations at the level of q_p=1.25.

Conversely, when the size of the first mover's domestic market diminishes, the foreign follower tends to gain a more significant advantage. This leads to the foreign follower consistently holding the leadership position under local network effects and adopting varying internationalization strategies. In such cases, the first mover may, in certain instances, adopt an accelerated strategy under local network effects, indicating the competitive disadvantage faced by the platform in these circumstances.

5. An emerging theory of international platform growth

Our simulation model offers several key propositions regarding the internationalization of digital platforms. When platforms internationalize, they must make decisions about when, where, and how to approach foreign markets. Our analysis shows that the answer to these questions depends on the nature of the network effects and the strategic choices made by competitors.

The "when" question refers to the moment in which platforms decide to move beyond their market of origin. Under global network effects, all three platforms are better off with an accelerated strategy of growing as quickly as possible, in as many markets as possible, so as to acquire global scale (Reuber et al., 2021). Under local network effects, by contrast, there is no universally superior international strategy, although, in most cases, the winner in terms of potential market percentage follows a gradual strategy. Under local network effects, accelerated strategies tend to be conservative moves for the followers, especially when facing competition in their domestic market. These followers must accelerate their internationalization to find greener pastures where neither the first mover nor the other follower has a consolidated presence. As mentioned in the previous section, variations in the size of the domestic market can alter these preferences, shifting towards a gradual strategy with increased size and an accelerated one with reduced size. Consequently,

Proposition 1a. *When dealing with markets of the same size, platforms choose an accelerated strategy of internationalization when network effects are global.*

Proposition 1b. *Platforms choose a gradual strategy of internationalization when network effects are local, unless they are compelled to accelerate their strategy due to a small domestic market size, heightened competition in their home market, or a delayed introduction of the platform.*

In the context of digital platform competition, the question of "where" pertains to the optimal market for followers to launch. While resource constraints may compel some entrepreneurs or firms to introduce their platforms in their country of origin, in cases where the platform promoter possesses superior infrastructure and global funding capabilities, they have the flexibility to select the destination country. In such scenarios, our simulation model can provide valuable insights. Our analysis reveals that commencing operations in an untapped market doesn't always guarantee superior outcomes for followers. Certainly, under local network effects, it is much better to be a foreign follower than a domestic follower, meaning that one should look for an untapped market to take full advantage of the local network effects without anyone else doing so, at least initially. When network effects are local, every platform starting in a new location faces important set-up costs due to the lack of a base of users (Brouthers et al., 2016). Therefore, there are certain first-mover advantages to being the first platform in a territory. However, under global network effects the benefit of looking for an untapped market to enter with a cloning platform is not initially large, and it disappears as the other follower innovates (Fig. 6). Moreover, in these cases all platforms tend to adopt an accelerated strategy of internationalization, making the choice of location less relevant. Thus,

Proposition 2a. *When several locations are feasible for the launch, platforms choose an untapped market when network effects are local.*

Proposition 2b. *When several locations are feasible for the launch, platforms are largely indifferent between an untapped and a competitive market when network effects are global and especially if the other follower platforms innovate.*

The "how" question refers to the extent to which the platform innovates, at the cost of delaying its launching. The trade-off occurs because the longer the time lag, the more time the other platforms enjoy to establish a larger user base. Under local network effects, it is possible to overtake the first mover in potential market percentage with a cloning strategy (no innovation), but only when launching in an untapped market and when dealing with markets of the same size. Otherwise, it is imperative to innovate. Under global network effects, it is impossible to catch up with the first mover without innovating, regardless the market being entered is untapped or competitive. In fact, other factors not explicitly considered in our model may work in favor of the domestic follower, i.e. in launching an innovative platform in the country of the first mover. Usually, first movers in digital platforms come from countries with influential and sophisticated users (Shaheer et al., 2020) and a high clout (Chen et al., 2018), so starting there has some additional advantages in terms of learning and prestige for a follower willing to reach global leadership with a substantially improved platform. This is especially important if we take into account that digital platforms facilitate feedback from users, which is an important source of innovation in digital platforms (Barrett et al., 2016; Henfridsson et al., 2018). Thus, in the case of global network effects, there are no location-based advantages associated with launching an innovative platform in an untapped country. Accordingly,

Proposition 3a. *Platforms can use a cloning strategy to surpass the first mover under local network effects but only if they launch in an untapped market.*

Proposition 3b. *Platforms can surpass the first mover under global network effects but only if they innovate, regardless of their location.*

Our results also speak to the margin of victory of the platform with the largest potential market percentage across all markets. Consistent with the logic of global scale (Reuber et al., 2021), we found that the margin of victory is larger under global network effects compared to local (see Table 1, and Figs. 1 and 2, as compared with Figs. 3 and 4). The reason is in part endogenous, given that global network effects invite all platforms to adopt an accelerated strategy of internationalization. The unexpected result from our simulation is that the margins of victory are larger not only when the first mover wins the overall race but also when a follower wins. Interestingly, it is much harder for the follower to overtake the first mover under global network effects, and only if it innovates (see proposition 3b). Therefore,

Proposition 4a. *Margins of victory are larger under global than under local network effects, regardless of whether the first mover or a follower wins.*

6. Discussion and conclusion

Despite the opportunities associated with the scalability of digital assets in a process known as hyperscaling (Giustiziero et al., 2023), very few digital platforms operate on a truly global scale. Our model elucidates how network effects, international strategies, imitation, and innovation by followers interact to hinder the international growth of a first mover launching a new digital platform. Besides cultural or institutional differences, our model shows that the presence of local network effects becomes a critical factor that promotes imitation and prevents international organic growth by the first mover. When network effects are local, the prospects of the first mover attaining a dominant global market position in terms of potential market percentage are markedly diminished, especially when facing competition in the home market. In such scenarios, foreign markets provide a secure haven for followers, even if they introduce a mere clone of the first mover's platform. Notably, innovation significantly enhances the followers' potential to challenge the first mover's position in all contexts, although our model underscores a trade-off between time-to-market and innovation. Under global network effects, innovation by followers, i.e., launching a much-improved version of the platform, is the main threat faced by first movers. In fact, quick innovation is the only competitive weapon available to domestic followers to challenge the position of the first mover in any scenario.

Our study contributes to the existing research on network effects and digital platform growth by introducing the trade-offs associated with time to market, innovation, and international strategies. In the pioneering work of Eisenmann (2006), it was observed that first movers tend to invest more in marketing to acquire customers compared to laggards. Our model sheds light on this phenomenon, illustrating that the optimal strategy for laggards involves swift innovation and the prompt introduction of an alternative platform. While our model doesn't explicitly consider alternative moves by the laggards, any action that enhances platform functionality can yield similar outcomes as innovation. One such strategy is platform envelopment (Eisenmann et al., 2006), where an existing adjacent platform enters the market by expanding the functionality of its existing platform, aiming to compete in the first mover's market. The uncertainty regarding potential moves by potential laggards underscores the first mover's interest in swiftly capturing a significant potential market percentage. However, our model indicates that this strategy is more advisable under global network effects than in local ones. This is because the first mover can leverage users across multiple markets more effectively. When operating under local network effects, platforms often adhere to multidomestic strategies, as indicated by Stallkamp and Schotter (2021). However, despite following multidomestic strategies, our model demonstrates that platforms competing under local network effects may sometimes need to adopt an accelerated international strategy, especially when dealing with cloning platforms and/or when unable to introduce an improved version of the first mover's platform.

An important contribution of our paper is the introduction of network effects in a formal model of internationalization. There is a lack of formal models to explain the process of international expansion, with a few exceptions, such as Buckley and Casson (1976), Kogut and Kulatilaka (1994), and Asmussen (2009). Although the role of networks had been part of the literature on the internationalization process through the concept of the liability of outsidership (Johanson & Vahlne, 2003, 2009), network effects, as defined in this paper, have not been considered yet in this literature within a formal model. Our simulation shows that the presence of local network effects creates opportunities for the followers to consolidate domestic or local positions that prevent the first mover from reaching global supremacy. Although cultural and institutional barriers can be overcome through persistent effort, consolidated network effects can present a formidable and enduring obstacle that protects the market position of players who have achieved critical mass. While the significance of the geographical scope of network effects has been previously emphasized in research (Guillén, 2021; Knee, 2018; Stallkamp & Schotter, 2021), our model provides a practical framework for understanding and predicting their impact on digital platform internationalization. This not only opens new research possibilities but also offers valuable insights for platform managers and antitrust authorities in making informed decisions.

Our model explains the endogenous competitive dynamics that can be expected as a consequence of the launching of a digital platform and the emergence of domestic and/or foreign followers. Throughout the text, we have provided examples from various industries that illustrate some of the dynamics predicted by our model. However, there are certain actions that the first mover can undertake to alter the competitive dynamic presented here, such as acquiring a domestic or foreign follower (Gautier & Lamesch, 2021) or continuously improving the original platform (Piaskowska et al., 2021). Piaskowska et al. (2021) analysis of the Dropbox case shows how this platform's global leadership has been fueled by innovation and acquisitions. Although our model does not include these moves, it can be utilized to forecast whether and when these types of movements can be expected. When driven by network effects, cross-border mergers and acquisitions by digital platforms make more sense when operating under global network effects. In such scenarios, users from the acquired platform can be migrated to the acquiring one to harness the advantages of network effects and economies of scale (Katz, 2021; Piaskowska et al., 2021). This migration is not without costs because, when both platforms are differentiated, some users can be worse off as their preferred choice has been removed (Farronato et al., 2023), but the overall gains play in favor of merging the platforms. For these reasons, this kind of killer acquisitions —those in which the platform of the target is discontinued (Cunningham et al., 2021; Katz, 2021)— are less justifiable when operating under local network effects. In fact, acquisitions can also be driven by the first mover's objective of eliminating a potential competitor that might eventually become the dominant platform. Despite not explicitly considering acquisitions, our model can still be employed to anticipate the circumstances under which such acquisitions are likely to occur. They can be expected when the first mover's leadership position is at risk, a situation that is more probable under the influence of local network effects and/or the introduction of innovations. Therefore, our simulation model can contribute to antitrust policy by forecasting the potential market percentage that industry players might have achieved if such deals had not been made. If the incumbent/bidder were expected to be surpassed by the target in the absence of the deal, this acquisition could be considered anticompetitive. Domestic acquisitions, i.e. acquiring domestic followers, would be another example of anticompetitive acquisitions, especially if they are killer ones. Our models demonstrate that domestic competition can be particularly detrimental to the first mover's prospects for achieving potential market percentage, so there are incentives to remove this competition. These implications make our model especially valuable at a time when the debate over the regulation of 'big-tech' is raging in the US, Europe, and China (Parker et al., 2021). Besides the application of our model to detect anticompetitive deals, an important conclusion stands out. Anti-trust vigilance and action should not overlook platforms operating in environments driven by local network effects. Under local network effects, the impact of international competition is more attenuated and the returns to innovation are lower, so these platforms also need to be analyzed. Although platforms operating in contexts of global network effects are the ones that are more scrutinized by the media and public opinion, our simulation shows that their potential market percentage through organic growth is the result of international competition and the returns to innovation.

Our study also contributes to the emergent literature on scaling and digitalization in international business (Giustiziero et al., 2023; Monaghan et al., 2020; Reuber et al., 2021; Tippmann et al., 2023). According to Tippmann et al.'s recent survey (Tippmann et al., 2023), there is a lack of studies adopting a longitudinal perspective on this topic, for there is a need to fully understand the variation in the outcomes of international scaling processes. By modeling the interplay among network effects, imitation, and innovation at the international level, our study paves the way for a new approach to this research endeavor. Our model can specifically serve as a reference for organizations when scaling, offering a benchmark for planning international expansion. For example, Varga et al. (2023) and Tippmann et al. (2022) show that realizing platform growth potential through scaling entails investments and organizational adjustments that can pose significant challenges. Although our model has a relatively simple structure, it can effectively demonstrate the final outcome in terms of potential market percentage in the context of a successful platform scaling process, contingent on the nature of network effects, provided that the adjustments mentioned earlier have been implemented.

Although this article is a first step, our model can be extended to analyze other scenarios thanks to its versatility. For instance, the model can consider country differences in market size and potential, but it can be inferred from our results that these differences can work in favor of the follower when its home-country market potential exceeds the first mover's, especially in the presence of local network effects, and when cultural and political barriers are steep. Our model can also be adjusted to consider the case of one-sided platforms acting as providers of goods and/or services to the user, a type of platform that differs from the brokerage business model of most two-sided platforms (Hagiu & Wright, 2015a; Hennart, 2019; Liu et al., 2022). Furthermore, our model can be expanded to encompass various forms of establishing a presence in a foreign country. This is particularly relevant when certain non-digital assets must be secured in a foreign country, necessitating additional investments in that foreign territory (Stallkamp et al., 2023).

In sum, our model shows that first movers introducing a new digital platform need to adapt their international strategy depending on the nature of network effects. Followers willing to challenge the leadership of the first mover need to improve the performance of their platform and/or take advantage of the lack of local competition. When they start from the same country as the first mover, delivering a substantially improved version of the platform is a must. Followers starting from other countries can build a solid position either becoming country specialists waiting to be acquired by another rival or simply by growing internationally with a higher-quality platform than the first mover.

Our model has several limitations, including: (1) we model only three countries and only three platforms; (2) the platforms can grow only by attracting new customers and not by capturing customers from other platforms; (3) the level of investment in a foreign country may vary (Stallkamp et al., 2023); and (4) we have not considered the entire ecosystem that can be generated around the platform (de Meyer & Williamson, 2020; Kindermann et al., 2022) or the competitive reaction of incumbents in the disrupted industry (Chang & Sokol, 2022). We have opted for these simplifications in order to make the model more manageable. However, as previously mentioned, our model can be developed to include these and other extensions. Thus, further research tackling these developments is needed to fully understand the dynamics of international scaling of digital platforms.

CRediT authorship contribution statement

Esteban García-Canal: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Supervision, Validation, Writing – original draft, Writing – review & editing. **Mauro F. Guillén:** Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Supervision, Validation, Writing – original draft, Writing – review & editing. **Borja Ponte:** Formal analysis, Investigation, Methodology, Project administration, Software, Validation, Writing – original draft, Writing – review & editing, Supervision.

Declaration of competing interest

None.

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