Experimenting business models with network effects: a real options perspective

Charlotte Krychowski
TELECOM Ecole de Management
charlotte.krychowski@telecom-em.eu

Bertrand Quélin
HEC
quelin@hec.fr

Bulat Sanditov
TELECOM Ecole de Management
bulat.sanditov@telecom-em.eu

Résumé :

Lorsqu'une technologie de rupture apparaît, il est difficile pour les nouveaux entrants, comme pour les entreprises en place, de s'imaginer quel est le modèle d'affaires le plus approprié pour extraire tout le potentiel économique de la nouvelle technologie. La littérature a établi qu'il est peu probable de définir le bon modèle d'affaires dès le départ, et que les firmes doivent plutôt procéder à des expériences pour progressivement mettre au point un modèle d'affaires en suivant un principe d'essai – erreur.
Cependant, la recherche actuelle ne dit pas sur quels critères il faut fonder les décisions d'investissements nécessaires pour réaliser ces expériences. Dans le cas d'une technologie de rupture, le premier investissement à réaliser est le lancement commercial de la nouvelle technologie. Cette décision soulève deux problèmes : (1) un problème d'échelle : est-il préférable de lancer la technologie à grande échelle pour obtenir des résultats représentatifs, ou bien sur un périmètre limité pour réduire les coûts du test ? (2) un problème de durée : faut-il prolonger la durée de l'expérience pour améliorer au mieux le modèle d'affaires, ou au contraire l'écourter pour éviter l'imitation par les concurrents ? Ces deux problèmes sont particulièrement difficiles à résoudre lorsque le modèle d'affaires présente des effets de réseau.
Dans cet article, nous étudions dans quelle mesure les options réelles peuvent être utilisées comme aide à la décision d'investissement lorsqu'une firme souhaite tester le modèle d'affaires d'une nouvelle technologie. Nous comparons l'expérimentation d'un modèle d'affaires à une option d'apprentissage, et analysons les différents facteurs affectant la valeur de cette option, en particulier en présence d'effets de réseau. Nous montrons qu'une analyse optionnelle permet d'estimer la durée optimale de l'expérimentation, mais plus difficilement la taille optimale de l'expérimentation lorsque nous sommes en présence d'effets de réseau. Nous illustrons notre approche avec le cas de la téléphonie mobile en Europe, dont le modèle d'affaires a été profondément changé suite à l'introduction de la technologie 3G.

Mots-clés : Expérimentation ; Business Model ; Technologie émergente; Incertitude; Option d'apprentissage

Experimenting business models with network effects: a real options perspective

INTRODUCTION

When a disruptive technology emerges, it is difficult for the inventor as well as for incumbents to figure out the unique business model that will enable to fully realize the economic potential of the new technology (Chesbrough and Rosenbloom, 2002). The literature has established that it is hardly possible to design the right business model from the outset, as firms do not have data on markets that do not exist. Rather, firms should conduct real experiments, and progressively refine their business model through "trial-and-error" learning (e.g. Chesbrough, 2010; McGrath, 2010). However, the literature hardly tells how firms should conduct experiments in a new business model. This is a serious issue, as designing a new business model is a lengthy and potentially risky process.

In this paper, we review the business model literature, and find that firms seeking to introduce a disruptive technology on the market may face two issues in the design of the business model experimentation:

(1) a *scale* issue: is it preferable to launch the technology and experiment the business model on a large scale to improve the fidelity of the test, or should the technology deployment rather take place on a limited scale in order to reduce the cost of the test and to limit downside risk?

(2) a *timing* issue: is it preferable to leave more time in order to properly interpret the results, or to limit the time length of the test in order to keep first mover advantage, and avoid being caught up by competitors?

These tensions are particularly difficult to resolve when the business model underpinning the disruptive technology displays network effects.

Because business model experimentation implies a real market test of the new technology, it requires a significant investment. The investment decision is particularly difficult to make, given the high level of uncertainty and the scale and timing issues faced by the innovating firms. In this context, firms will need to assess the investment decisions required for business model experimentation with decision tools that make sense in an experimental world, like real options reasoning, and rely less on deterministic approaches such as the net present value (McGrath, 2010).

In this paper, we analogize the decision to experiment the business model as an option to learn. During the experiment, the innovative firm has the possibility to refine its business model. After this exploration phase, the new technology can be either rolled-out to cover the whole market if the business model proves successful, or the firm will have to abandon the technology – or find an alternative business model – if the experiment is a failure. We explore to what extent the valuation of this option to learn helps firms determine the optimal scale and time length of the business model experimentation.

The paper is structured in four parts. In the first section, we review how the literature has addressed the issue of business model experimentation. In section 2, we explain why a business model experiment can be valued as an option to learn, and what factors affect its value. In section 3, we present the framework determining the optimal length of the experiment and provide an illustrative use in the mobile telecommunications industry. In section 4, we analyze to what extent the option to learn may be used to determine the optimal size of the experiment.

1. EXPERIMENTING THE BUSINESS MODEL OF A DISRUPTIVE TECHNOLOGY

1.1. BUSINESS MODEL DESIGN OF A DISRUPTIVE TECHNOLOGY

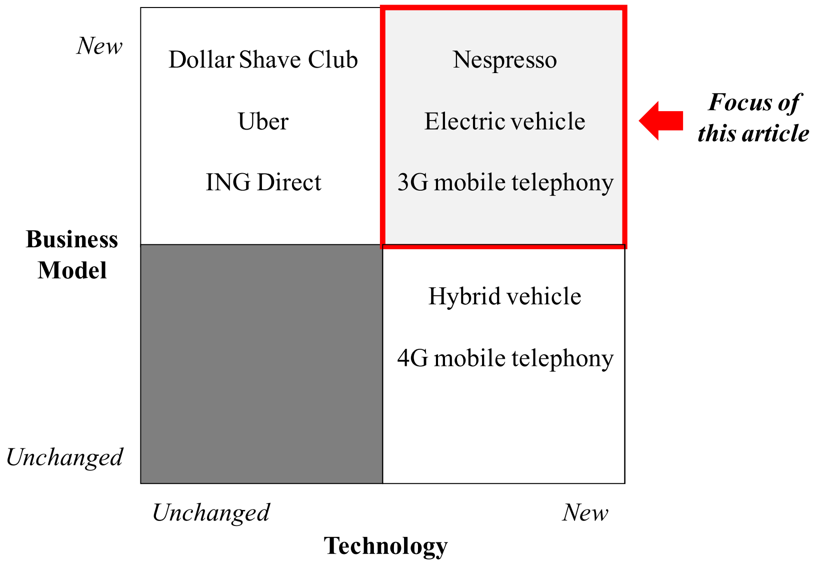
The literature on innovation has traditionally distinguished between incremental technological innovations, which marginally improve the performance of a product, and radical technological innovations, which significantly improve the performance of a product. In contrast, Christensen (1997) analyzes technological innovation from a different perspective: he establishes a distinction between *sustaining* technologies, which improve the performance of established products for mainstream customers, and *disruptive* technologies, which "*bring to a market a very different value proposition than had been available previously.*" Sustaining technologies may be quite radical from a technological perspective. For example, in the disk drive industry studied by Christensen, the thin film technology introduced a major improvement in the disk performance, but was a sustainable technology because it addressed the mainstream customers and used the same value network as the previous technologies. Conversely, a disruptive technology may not necessarily introduce a radical improvement in the performance of the product. In fact, it may even be a less capable technology, as was the case with hydraulics-actuated excavators which disrupted the mechanical excavator industry (Christensen, 1997).

New products based on a disruptive technology have different attribute sets than existing products (McMillan and McGrath, 2000). They attract different customer groups (i.e. market segments) than those served by the mainstream technology. These maybe either less well-off customers, who cannot afford the mainstream technology, or customers whose needs are not served by the mainstream technology. As a consequence, a disruptive technology can be defined as "*a technology that changes the bases of competition by changing the performance metrics along which firms compete*" (Danneells, 2004:249).

In other words, disruptive technologies are technologies that require a new business model to deliver value. The term "business model" was introduced in the academic literature by Chesbrough and Rosenbloom (2002). A business model can be defined as a unique combination of assets, competences, internal activities and value network in order to create and deliver value (e.g. Demil and Lecocq, 2010; Teece, 2010; Zott and Amit, 2010; Zott et al, 2011). The value proposition defines what is offered to which groups of customers and how it is delivered. By analyzing several technological innovations at Xerox Park, Chesbrough and Rosenbloom (2002) show that in some instances a technological innovation can successfully employ the business model already familiar to the innovative firm, while in other instances it is necessary to come up with a new business model in order to unlock latent value from early stage technology.

In this paper, we focus on technological innovations that require a new business model (Figure 1). For example, in the automotive industry, manufacturers developed two different technologies for Low Emitting Vehicles (LEV): hybrid vehicle and electric vehicle. Hybrid vehicle addressed the mainstream of the market and could be exploited through the dominant business model of the automotive industry (Bohnsack et al, 2015). In contrast, Electric vehicle needed a completely renewed business model, which OEMs refined over time (Bohnsack et al., 2014).

Figure 1: Business Model and Technological innovation



At the same time, not all business model innovations involve the use of a new technology. There are numerous forms of business model innovations (e.g. sponsor-based monetization, servitization, low-cost, usage-based business models) that are not primarily based on a technological innovation. For example, Dollar Shave Club (which innovated by developing a monthly subscription to receive razor blades by post each month) or Uber in the transportation industry, introduced new business models without using a new technology. While some of the findings of this article may apply to business model experimentation when there is no new technology involved, the analysis concentrates on the case of business model experimentation involving a disruptive technology. Indeed, the business model experimentation of a disruptive technology presents specific constraints (manufacturing investments; technological obsolescence) which do not arise in other categories of business model innovations.

1.2. THE NECESSITY OF BUSINESS MODEL EXPERIMENTATION FOR DISRUPTIVE TECHNOLOGIES

The main difficulty for a firm pioneering a disruptive technology is that it does not know from the outset what the appropriate business model will be. Christensen’s (1997) case studies show that incumbent firms display remarkable capabilities in forecasting the evolution of established markets, and may therefore invest large amounts of money in sustaining technologies. By contrast, it is particularly difficult to deal with disruptive technologies, for which no reliable financial projections can be made.

Generally speaking, many scholars in the business model literature (e.g. Hayashi, 2009; Chesbrough, 2010; McGrath, 2010) argue that firms simply lack data to support any strategic decision on the implementation of a new business model. To generate new data, firms need to make some experiments around new business models. Firms should not strive to analytically identify the right solution from the outset. Instead, they may better refine their business model through "trial-and-error" learning. For example, when 3Com was spinned-off from Xerox, its business model did not emerge fully formed. Generally speaking, spin-offs from Xerox that were successful had gone through an extensive exploration phase before discovering an economically attractive business model. In contrast, those ventures which conducted a limited search for an effective business model failed (Chesbrough and Rosenbloom, 2002).
At an industry level, firms may test different business models for an early stage technology. Managers know that a new business model will emerge, but it is not at all clear what the eventual "new" business model will turn out to be (Chesbrough 2010). McGrath (2010) compares this phenomenon to the "era of ferment" that can be observed in the history of technology. There are periods during which several technologies compete at the same time, until a "dominant design" is eventually victorious. Similarly, when a disruptive technology appears, incumbents and new entrants simultaneously test various business models. For example, Bourreau *et al.* (2012) describe seven business models that are explored simultaneously by record labels following the introduction of digital music. Similarly, Benghozi and Luybareva (2014) describe numerous business models explored by French press websites.

Ideally, firms should test a business model on a very limited scale, and then scale it up only when the concept has been proven. Chesbrough (2010) advises managers to engage in "*high fidelity, low cost, quick performing and usefully informative experiments*" (p.362). In some cases, it is indeed possible to conduct the business model exploration phase on a limited scale, and leverage the business model through large scale replication once it is stabilized, e.g. through the operation of a large number of similar outlets (Winter and Szulanski, 2001).

But overall, little is said in the literature on how firms conduct business model experimentation. Empirical research tends to concentrate on industries, in which the business model can be created and refined on a small sample of the population, before being rolled-out to the larger market. Empirical studies describing this approach can be found in the banking (Winter and Szulanski, 2001; Dunford et al., 2010), the fast food (examples of McDonalds and Starbucks provided by Winter and Szulanski), the retail (Sosna et al., 2010) and the insurance (DeSyllas and Sako, 2013) industries. While these examples describe the testing of a new business model on a restricted geographical area, it is also possible to test it only on specific segments of customers. For example, Netflix elaborated its business model on the movie aficionados segment, even if it had in sight the mass market since the beginning (Chartterjee, 2003).

Unfortunately, this incremental approach is not always feasible, especially when the business model underpinning the disruptive innovation displays some network effects. We explore below the dilemmas that firms may face when determining the optimal size and time length of their business model experiments.

1.3. THE SCALE ISSUE RAISED BY BUSINESS MODEL EXPERIMENTATION

On the one hand, testing a business model in real market conditions is costly, and for this reason, the innovative firm will seek to keep the size of the test as limited as possible.

First, compared to a full strike roll-out of the new business model, the phased roll-out of the business model generates extra-cost, because the innovative firm needs to compensate for the heterogeneity between the roll-out and the non roll-out areas. For example, Pennings and Lint (2000) explain that this discrepancy between the two areas generate significant marketing costs, which quickly go up with the size and duration of the test. From a manufacturing point of view, it is of course more expensive to maintain the production of different "generations" of technologies, and it is more expensive to build a pilot plant and later expand it, rather than build the full-scale plant from the outset.

Second, a "real life" test of the business model underpinning a new technology entails significant and, to a large extent, irreversible capital expenditures. For example, the construction of a pilot plant would typically cost \$3M, which is much higher than the cost of a market study (\$3K), of focus group studies (\$14K) or of an advertising study (\$25K)

(McGrath, 2010). A firm undertaking the partial roll-out of a new technology in order to test its business model is therefore exposed to high sunk costs if the test is a failure.
For example, Hewlett-Packard could not recover the cost of building significant manufacturing capacities for the "Kittyhawk" disk-drive, which was targeting the Personal Digital Assistants (PDA) market. Very few units of Kittyhawk were sold, as the PDA market failed to materialize substantially in spite of very optimistic predictions from the main industry stakeholders. Later, it appeared that companies producing mass-market video games systems would buy very large volumes of Kittyhawk if Hewlett-Packard could make available a much less sophisticated and lower priced version. Unfortunately, Hewlett-Packard had already invested aggressively in Kittyhawk with PDAs as the original target, and no more money was left to adapt the product to other markets (Christensen 1997).

In all, there is therefore a strong incentive to keep the business model experimentation as limited as possible. On the other hand, experiments should take place on a representative scale. Building on Thomke's (2002) works on testing new products, Chesbrough (2010) argues that a good experimentation relies on high fidelity, i.e. it should take place in "real conditions" that are representative of the larger market.

In some industries, a business model experiment can be performed on a very limited scale, yet obtain very reliable results. For example, ING Direct elaborated its business model of an online bank in only one country (Canada), before progressively replicating it eight other countries (Dunford et al., 2010). In the dietary retail industry, the Naturhouse crafted its business model with only four outlets (Sosna et al., 2010). The auto insurer industry Progressive tested its "pay-as-you-drive" business model first in the city of Houston, Texas, and later deployed it across the whole state of Texas. It was then progressively rolled-out across the U.S. territory, with 19 states covered in 2009, 30 in 2011 and finally 50 in 2012.

However, when the tested business model displays network effects, critical mass has to be reached so that the business model experiment can be meaningful. In the case of network effects generated by a two-sided business model, the literature (e.g. Sun and Tse 2009) shows that the initial size of each group of agent is critical in the expansion of the platform. If one group of agents is too small, the network will not develop even if the other group of agents is large. Similarly, in the case of indirect network effects caused by complementary offers, the literature describes a "chicken-and-egg" problem: potential customers usually delay adoption of a really new product until the complementary technologies become available. Conversely, complementors tend not to develop complementary products or service until sales of the focal product has reached critical mass (Gupta et al, 1999; Min et al, 2006). Below this threshold, it will not be possible to test the business model, because the value creation does not take place (Adner and Kapoor, 2010).

1.4. THE TIMING ISSUE RAISED BY BUSINESS MODEL EXPERIMENTATION

Experimenting a new business model is a lengthy process. According to Chesbrough (2007), it takes much more time than the typical two-year to three-year rotation time of top managers to formulate and conduct business model experiments, collect data, interpret them and derive the appropriate conclusions on how to reframe the business model. Similarly, Sosna and colleagues (2010) describe a five-year phase of experiments and exploration as part of a business model innovation conducted by a Spanish dietary products business.

Several reasons contribute to explain this long maturation process. First, a business model is a complex combination of elements that interact with each other. For example, in Demil and Lecocq's (2010) RCOV model, a business model is made up of three interelated components: Resources and Competences (RC), internal and external Organization (O) and Value Proposition (V). A change in one component will entail (voluntary or unintended) changes in other elements of this component, as well as with the other components. Therefore, one can expect that it will take time until the whole business model "stabilizes". These dynamics are further complicated by two properties of the causal relationships between the elements of a business model (Casadesus-Masanell and Ricart, 2010). First, there may be some feedback loops that strengthen the model at every iteration. Second, some changes may have *flexible* – i.e. rapid – consequences on other elements of the business model, while other have *rigid* consequences on other elements, i.e. consequences that appear only progressively over time. In the later case, the impact of an experiment on the profitability of the business model will be particularly difficult to assess within a short time frame.

When business model experimentation is dealing with a disruptive technology, there is an additional layer of complexity stemming from the dynamics of customer needs. The literature on new product development has established that identifying customer needs for a new technology is difficult, and all the more so as their preferences change in the process of discovering and experiencing a new product technology (Carpenter and Nakamoto 1989). Therefore, it is necessary to establish links between the dynamics of customer needs on the one hand, and the dynamics of product innovation technology on the other hand (Bohlmann, Spanjol et al. 2013). If we apply this reasoning to business model characteristics instead of new product features, we can expect that changes in the business model (e.g. distribution network, price structure, product offering – which can be enriched thanks to strategic partnerships with complementors) will affect customers preferences. The evolution of customer preferences should in turn be taken into account for later business model changes. This interplay between customers' needs dynamics and business model dynamics entails that experimenting a new business model in the case of a disruptive technology is a lengthy process.

If it takes a long time to craft a business model, it may make sense for firms to undertake quite lengthy business model experiments. On the other hand, if the experimentation phase lasts for too long, there is the risk of being overtaken by competitors.

Christensen's (1997) case studies, in particular in the disk-drive and in the mechanical excavator industry, seem to confirm the importance of first-mover advantage in the case of a disruptive technology. Incumbents who had not invested early enough in disruptive technologies failed; at best, they could expect to have a stake in the new market by selling the disruptive technology to their traditional customer base. In contrast, the timing of investment in sustaining innovations, even if those were radical, did not seem to be critical. Christensen provides examples of incumbents who invested quite late in radical innovations (e.g. thin film head in the disk drive industry), yet managed to catch-up.

Initially, the innovative firm may be protected by isolating mechanisms such as exclusive partnerships with key complementors, or patents. To seek protection from imitation, the pioneer can patent the technology itself. The innovative firm can also patent key processes underpinning its business model with business method patents (Wagner and Cockburn, 2010). For example, the protection offered by its business methods patents allowed the auto insurer Progressive to "save time" from competition imitation, and to elaborate an advanced underwriting system that became the cornerstone of its usage-based business model (Desyllas and Sako, 2013). In addition, rivals' willingness to imitate may be initially limited due to the lack of visibility of the innovation, or to the high degree of uncertainty regarding the success of the new technology.

However, these protections will inevitably be eroded with time. Exclusive partnerships will end with the contract. Patents have a limited lifetime and can be "invented around". The uncertainty will decrease, as the success of the innovator's experiment can be observed, and would-be rival develop their own experiments. In short, the longer the experimentation lasts, the higher the probability of imitation.

To sum up, investment decisions related to business model experiments have to be made by resolving two issues. The first issue concerns the scale of the experiment, and involves resolving a trade-off between on the one hand, the cost of a partial market introduction and the need to limit sunk costs, and on the other hand the fidelity of the experiment. The second issue is dealing with the time length of the experiment. It involves making a trade-off between (1) the necessity to make experimentation lengthy enough to interpret results properly, and (2) the risk of being overtaken by rivals if the firm waits for too long before deploying the technology on the entire market.

To support these decisions, managers will need appropriate financial tools. A disciplined decision process will be all the more necessary, as managers may face strong institutional pressures, given the amounts of money at stake, the complexity of the decision and the high level of uncertainty. In the following section, we present the real options approach. We explore how this framework may produce optimal recommendations regarding the length and scale of deployment of a new technology in a context of a high level of business model uncertainty.

2. BUSINESS MODEL TESTING AS AN OPTION TO LEARN

2.1. THE REAL OPTION LITERATURE ON MARKET ENTRY

The real option literature has devoted considerable attention to the optimal date of market entry. Research has highlighted that when market entry entails irreversible investments, and when there is a high level of market uncertainty, postponing the decision to enter the market until uncertainty is resolved has value. This value corresponds to the deferral option (*a.k.a.* option to wait), which is killed once the firm decides to enter the market. On the other hand, if the firm enters the market successfully, it will be able to take advantage of its position to expand its business in this market when new growth opportunities appear. This growth potential is captured by the "option to grow". However, this option to grow is shared with competitors, and will accrue mainly to those firms benefiting from first mover advantages (Kulatilaka and Perotti, 1998). As a consequence, there is a tension between the deferral option, which creates an incentive to delay market entry, and the growth option, which creates an incentive to accelerate market entry. Whether the deferral option has a greater impact on the optimal date of market entry than the growth option (or vice-versa) depends on numerous factors, such as the level of uncertainty (Folta and O'Brien, 2004). Some researchers (Lin and Kulatilaka, 2007; Chintakananda and McIntyre, 2014) have explored the dueling effects of the deferral and the growth options on market entry in the case of markets with network effects. In particular, Lin and Kulatilaka (2007) show that network effects increase both the value of the option to wait and of the option to grow.

Rather than concentrating on the optimal date of market entry, this paper focuses the attention on the dynamics of investment in the post-entry phase. Indeed, as suggested by the study conducted by Staykova and Damsgaard (2015) in the digital payment market, the timing of expansion may be of equal importance as the timing of entry. In market with network effects, the competitive advantages gained from early market entry can be annulled if the expansion is not executed within the optimal time. Therefore, when a firm has decided to launch a disruptive technology on the market and test its business model "in the real world", the key questions are *at what scale* and *for how long* the experiment should take place. Because the experiment will enable the firm to progressively refine its business model and reduce the uncertainty regarding its economic potential, we believe that the investment decisions related to the experiment can be analyzed as an option to learn.

2.2. ANALOGY BETWEEN A BUSINESS MODEL EXPERIMENT AND THE OPTION TO LEARN

The option to learn is useful to understand why the value of a project may increase when it is sequenced in several phases. For example, let us consider a firm planning to launch a new product on the market. As the success of the new product is highly uncertain, the firm contemplates the construction of a pilot plant, in order to test the new product on a limited scale during two years. On the one hand, it is more costly to invest in several phases (in our example, build the pilot plant, and later the large plant), compared to all at once. On the other hand, it might be preferable not to launch a large project at once in order to adapt the course of action to economic circumstances: if after two years the results of the pilot plant fail to live up to expectations, the firm will not build the large plant. The value of this managerial flexibility corresponds to the value of the option to learn, acquired by the firm through the construction of the pilot plant. Therefore, it is worth "investing" in learning as long as the value of the project with flexibility (the option value) minus the "cost of flexibility" (the building of the pilot plant) is greater than the value of the project without flexibility (building the large plant from the outset).

In the literature, the option to learn has already been used in the context of a new product market entry. Pennings and Lint (2000) developed a real options model to investigate whether it is preferable to introduce a new product in a phased roll-out, compared to a worldwide launch. Their model also determines the optimal size of the roll-out area. The authors start from the result of a survey conducted by the consultancy Booz Allen and Hamilton (1982) finding that about 35% of all newly introduced products fail, although the NPV was positive at the moment of the market introduction. They also cite the example of Lever's failed pan-European introduction of the new Persil detergent. Under these circumstances, and despite the extra-cost of partially rolling-out the new product instead of a worldwide launch, it may be optimal to "learn from the market" by phasing out the introduction of the new product.

Similarly to Pennings and Lint's reasoning for new product testing, we can analogize the experiment of a new business model as an option to learn. This optional reasoning is well summarized by a quote of an ING Direct executive about the testing of the direct retail banking business model: *"[We thought] try it out in Canada. If it's a success, we'll move on. If it's a failure, [we'd take the view] OK we failed in Canada; it cost a couple of million dollars but still we tried"* (Dunford et al., 2010:660). This quote illustrates the characteristics of a real option, in which a firm commits an initial limited amount of money, and depending on the results obtained, later decides whether to pursue or not.

However, the business model is a different unit of analysis than the product (Zott et al, 2011). First, a business model is a complex construct, as it combines many elements, on the market side, but also on the underlying organizational side. As indicated earlier, the dynamics of business model evolution are complex, and it takes therefore a long time before the conclusions of a business model experiment can be drawn. In contrast, the test of a new product is significantly quicker, and would typically take one year, as suggested by Pennings and Lint's example of Philips testing the CD-I product. Therefore, we need to determine the optimal duration of the experimentation, which is not performed in Pennings and Lint's model. If we adopt a medium term perspective, then it is crucial to take into account the risk of imitation by competition, which is not the case in Pennings and Lint's model.

Second, a business model is boundary spanning construct that goes beyond the limits of the firm as it also includes the value network of the firm (suppliers, complementors, distributors). This creates complex dynamics and potential network effects. As a consequence, the relationship between the size of the test and the value of the option to learn is not necessarily linear, as is assumed in Pennings and Lint's model.

We illustrate below with an example in the mobile telephony industry how it may be crucial to experiment the business model of a disruptive industry, and how the learning in the appropriate business model takes place over time and across the boundaries of the firm.

2.3. ILLUSTRATION IN THE MOBILE TELEPHONY INDUSTRY

We illustrate our framework with the case of the introduction of the 3G (third generation) technology in Western Europe. Contrary to 4G, which only led to an increased speed of data transmission, the 3G technology led to a deep transformation of the business model of Mobile Network Operators (MNOs), as summarized in Figure 2. But the business model of 3G described in Figure 3 did not arrive fully formed. Rather, it was subject to intensive experimentation following partial deployment of the technology by various European MNOs. In this paper, we briefly present some of the main experiments conducted by two MNOs: (1) a new entrant, the 3 Group, who deployed from scratch a 3G network in three European markets (Italy, UK and Sweden), about one year earlier than other European MNOs and (2) an incumbent, the French operator Orange, who deployed 3G in 2004 / early 2005 on a portion of the territory in the French, UK and Spanish markets[1].

2.3.1. 3G: A DISRUPTIVE TECHNOLOGY IN THE MOBILE TELECOMMUNICATIONS INDUSTRY

Figure 2: Changes entailed by 3G on MNOs' business model

Value proposition	2G	3G
Services offered	Voice; Data: SMS, MMS	Voice; Data: SMS, MMS, internet; quadruple play; personalized services
Complementary goods and services	Feature phones	Smartphones Applications and content
Pricing structure and level	Subsidized phones Average voice ARPU: 25.8 c€/mn	Subsidized phone **or** SIM-only Average voice ARPU: 18.2 c€/mn Data: fair use / time-based / unlimited
Organization		
External (ecosystem)	MNOs, Landline operators, network and phone vendors	Operators: fixed/ mobile convergence; network and phone vendors; application developers; OTT
Internal	Own distribution network	Web-based contracts
Resources and competencies		
Key assets	Own telecommunication network	Network sharing
Key competencies	Marketing; network coverage	Provision of content; QoS

Due to the major changes in the MNOs' business model, 3G can be considered as a disruptive technology. It is also a good case to illustrate this paper, because mobile telephony displays significant network effects. Direct network effects are of course created by the very nature of the offering. But there are also strong indirect network effects, due to the high impact of two categories of complementors on the diffusion of the technology: (1) handset manufacturers and (2) content and application providers. One of the main reasons explaining the very low initial take off of 3G subscribers was that complementors had not initially developed an

[1] *Source : "Mostly Mobile – Ofcom's mobile sector assessment", Ofcom, July 2009, p.74*

adequate offering for 3G subscribers. In the early 2000s, existing 3G handsets did not offer the necessary features for a user-friendly utilization of mobile Internet services (remember that iPhone was launched only in 2007!). The devices were heavy and had very limited battery autonomy. The screens were fragile and their size was small. On the content side, no application provider had come up with a "killer application" that would convince the customers of the necessity to switch to 3G. Multi-media services such as video conferencing or the mobile consultation of e-mails or weather forecasts were considered of a marginal interest.

It is interesting to note how difficult it is to design a business model without conducting a real market experiment. For example, before launching its offer in the UK, the 3 Group surveyed over 15,000 consumers from 150 focus groups between July 2001 and November 2002. This market research revealed that a subscription fee of €105/month was the most promising tariff. In fact, once the commercial offer was launched, it turned out that this price was much too high, and the 3 Group had to lower several times its subscription fees (Dunnewijk and Hultén, 2007).
Below are a few examples of the changes in the business model that the 3Group and Orange tested as part of the deployment of their 3G network.

2.3.2. Learning in the value proposition component

3G considerably enriched the value proposition of MNOs, who could offer not only voice but also data transmission. The challenge was to determine the appropriate pricing structure and pricing level for the data transmission service that did not exist before. MNOs thus experimented different pricing structures for data, ranging from unlimited data transmission to a usage base pricing through a flat rate until a certain threshold was reached.
Another difficulty came from the fact that smartphones were much more expensive than feature phones. The 3 Group initially sold handsets at a price between €600 and €680 in the UK. But due to disappointing sales it halved the price to €300 (Dunnewijk and Hultén 2007). The very high price of handsets also entailed that the subsidization of handsets, that was traditionally part of the mobile subscription, became much too costly for MNOs. As a consequence, Orange started offering "SIM only" subscription plans.

Another key challenge in the 3G business model was to use content services in order to stimulate the data component of ARPU (Average Revenue Per User) and to increase customers' fidelity. The 3 Group thus developed a sophisticated offer that included numerous multimedia services. For example in the UK, it offered video mobile services including highlights of the Barclays Premiership, full-length music videos, comedy, games, news and financial information. In Sweden, the 3 Group created the most successful service for downloading music in the country (Dunnewijk and Hultén, 2007). In this way, and although it had to considerably lower their voice subscription plans to attract new subscribers, the 3 Group managed to generate a higher ARPU than the average of the market[2]. As for Orange, it reached a deal with the music streaming provider Deezer to include Deezer's premium offer (at €4.99 per month) into the price of their premium subscription plans in France and in the UK. MNOs also tested content as a source of additional revenues. For example, with "Orange TV mobile", Orange offered for €9 per month the access to 68 TV channels as well as to its two own channels Orange Sports and Orange Movies (also available separately for €6 per month each).

2.3.3. Learning in the organizational component

In France, the apparition of SIM-only subscriptions, which are sold directly over the Internet, led to a significant change of Orange's distribution channels, considerably reducing the importance of its retail network and of independent retailers.

The provision of content services also led to a much more complex ecosystem than the traditional mobile telephony ecosystem. New players entering the mobile telephony value network included: application providers, application aggregators, content providers (TV channels, video games producers), content aggregators, social networks, middleware / platform vendors (e.g. Apple, Android-Google) and Voice Over IP providers (Google Voice, Skype). The main challenge was (and still is) to find out how to share value with these new players, in particular with so called "Over The Top" (OTT) players (like YouTube), which derive value from telecommunication networks, yet do not invest in them. Orange also innovated by taking a majority stake in content providers such as Deezer (music) and Dailymotion (videos).

---

[2] For example in 2003, 3 UK ARPU was €68, against an ARPU of €51 for Vodafone UK (source: 3gnewsroom.com)

2.3.4. LEARNING IN THE RESOURCES AND COMPETENCES COMPONENT

In order to enrich and differentiate its value proposition, Orange decided to develop a capability in the provision of contents. It created two TV channels Orange Sports and Orange Cinema Series (OCS), respectively specialized in sports and movies / TV series. It turned out that the necessary investments to acquire sports and movies diffusion rights were very high, and the two channels accumulated €700m losses between 2008 and 2011. Eventually, Orange decided to close down the sports channel, and to stop the exclusivity of the movie channel (OCS).

In the following section, we show how real options can be used to determine the optimal length of a business model experiment, and provide an illustration of the model with the 3G example.

3. REAL OPTION ANALYSIS TO DETERMINE THE OPTIMAL LENGTH OF A BUSINESS MODEL EXPERIMENT

3.1. VALUE OF THE BUSINESS MODEL WITH THE LEARNING OPTION

We consider here the "real market" experiment of the business model underpinning a disruptive technology. This implies that the offering using the new technology is deployed only to a portion of the total targeted population, either because the deployment takes place on a limited geographical area, or because it is limited to specific segments of potential customers.

Let us note S_t the expected value at time t of the cash-flows generated by the tested business model once the new offering is rolled-out to the total population, and I the corresponding investment cost. If the business model is tested with a partial roll-out covering χ % of the total targeted population during a period of T years, then the value of the business model with the experiment (V) can be estimated as follows: $V = \chi\,(S_0 - I) + (1 - \chi)\,V_c - X$.

In other words, the value of the experiment has two main components. The first component $\chi\,(S_0 - I)$ corresponds to the net cash-flows generated by the launch of the new offering on the tested part of the population. The second component corresponds to the value of the learning option that the pioneering firm can capture on the remaining part of the population. To obtain the net value of the experiment, we need to subtract the cost of the experiment X. X corresponds to the extra-cost generated by the partial roll-out, compared to a scenario where the new offering would have been deployed at once across the total targeted population.

V_c is a *call* option, whose underlying asset is S_t and exercise price I. The exercise of V_c means that the offering using the disruptive technology will be deployed to the rest of the population if the test of the business model on the partial roll-out is a success, i.e. if the test reveals that $S_t - I > 0$, with $t < T$.

Options that can be exercised only when the option expires are called "European options", whereas options that can be exercised at any date before expiration are called "American options". In the case of business model experiment, V_c can be considered as an American option, i.e. it can be exercised at any time during the length of the experimentation T. The option model solves simultaneously the option value and the optimal exercise date.

3.2. Impact of the length of the test on the total project value

If the total value of the business model with the experiment is calculated as

$V = \chi\ (S_0 - I) + (1 - \chi)\ V_c - X$, then there are several ways through which this value V is impacted by the length of the test (Table 1).

Table 1: Impact of the test length on the value of the business model experimentation

Benefits of a quick test	Benefits of a lengthy test
The cost of the experiment (X) is lower	There is a higher probability that the tested business model benefits from positive "external" events
The risk of being overtaken by competitors is lower (δ)	The focal firm has more time to refine its business model, and therefore to increase its profitability
The number of years of cash-flows is lower	External stakeholders (suppliers, complementors, distributors, regulator) will be given more time to adapt to the new technology, and therefore potentially increase the profitability of the tested business model.

On the one hand, several phenomena favor a quick test. First, the quicker the technology is rolled-out to the whole population with the new business model, the shorter the period during which the firm exploits two different technologies and two different business models will be. Therefore, the esxtra operating cost generated by the experiment X is lower in case of a quick test.
Second, the quicker the technology is rolled-out to the whole population with the new business model, the lower is the risk that the new business model is imitated by competition. If the firm waits for too long before rolling out the new technology to the whole population, then the cash-flows generated by the new business model will be lower because of competitive pressure. Technically, this is accounted for by introducing a dividend rate δ that decreases the value of the underlying asset S_t as time passes (e.g. Lander, 2000).
Lastly, a quick test will enable the firm to benefit from cash-flows generated by the new technology for a longer period of time. Indeed, any technology has a limited lifetime, and will have to be replaced by a more performing technology when it becomes obsolete. If the test lasts for too long, then this reduces the number of years of cash-flows during which the new technology can be exploited on the whole population. This is accounted for in the option calculation by reducing the value of S_t as time passes.

On the other hand, several phenomena favor a longer experiment. Indeed, the value of an option is *cet. par.* increasing with time, since the option's holder can take advantage of positive events, without being exposed to the risk of negative events. In the case of business model experiment, the innovative firm may benefit during the experiment of favorable external events (e.g. higher fuel prices in the case of the electric vehicle). Second, the longer the experiment, the more the innovative firm will have time to refine its business model, and therefore increase its profitability. The crafting of the business model includes the collaboration with external stakeholders, such as the regulator. A longer experiment will leave the focal firm more time to convince the regulator of the potential benefits of the new business model. Lastly, indirect network effects create a positive correlation between the value of the learning option and the length of the business model experiment, since a longer experiment will leave more time for the development of complementary offering, and therefore enhance the attractiveness of the tested business model.

Technically, the fact that the probability of generating a more profitable business model is increasing with time is captured in the option calculation with the volatility parameter σ.

The model enables to resolve the tensions between the respective benefits of a long and of a short experiment. We provide below an illustration with fictive, yet realistic, figures (expressed in Monetary Units, or MU) in the mobile telephony industry.

3.3. Calculation of the optimal size of the 3G business model experiment

We calculate below the optimal length of a real experiment for the 3G business model, with the assumption that it is tested on $\chi = 25\%$ of the targeted population.

The expected cash-flows generated by 3G at the beginning of the test are $S_0 = 1152$ MU, whereas the cost of deploying the 3G network in the whole territory is estimated at $I = 1120$ MU. The maximum duration of the 3G experiment is $T = 4$ years. After four years, the option disappears because 3G will be replaced by another technology (e.g. LTE or 4G).

The value of the option to learn V_c is estimated with the "Black and Scholes' approximation". The Black and Scholes formula enables the evaluation of a European option. However, it is possible to use it to approximate the value of an American option – as it is the case here – by calculating the maximum value of different European options with different maturity dates.

We use the following parameters values for the Black and Scholes formula: risk-free rate: $r_f = 5\%$p.a.; volatility $\sigma = 20\%$. We assume that the risk of imitation and the reduced cash-flows due to technical obsolescence, captured by the dividend parameter δ, increase strongly with time (Table 2). The costs of the experimentation correspond to the extra-costs generated by the increased complexity of network operating costs (due to the simultaneous use of the 2G and 3G technologies) and increased marketing and communication costs (due to differentiated offerings in the rolled-out and non-rolled out areas). These costs also increase with the duration of the experiment (Table 2).

Table 2: Variation through time of the dividend rate and of the cost of experimentation

	Duration of the business model experiment (years)			
	1	2	3	4
Dividend rate δ (%)	0%	3%	10%	20%
Cost of the experiment (MU)	15	20	25	30

Depending on the duration, the value of the 3G business model experiment varies between 66MU and 122MU (Figure 3).

Figure 3: Illustrative calculation of the value of the 3G business model experiment

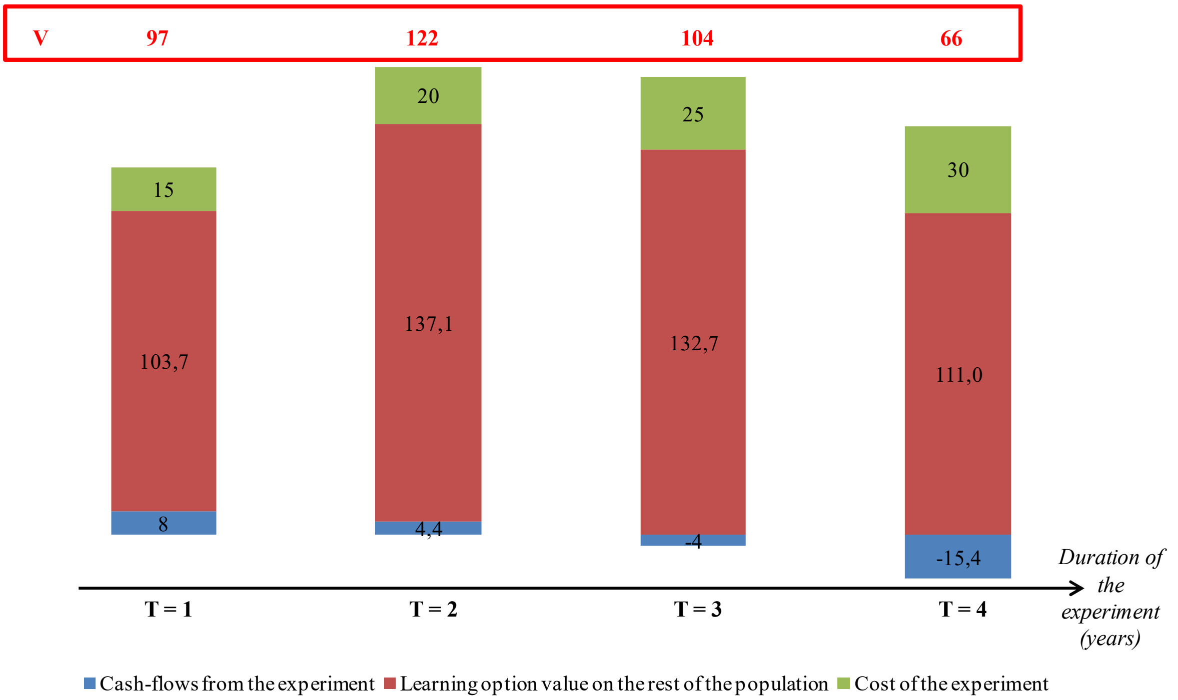


Figure 3 shows that in the case of 3G, the optimal duration of the business model experiment is two years. After three years, the value of the experiment decreases sharply because of the risk of imitation.

4. REAL OPTION ANALYSIS TO DETERMINE THE OPTIMAL SIZE OF A BUSINESS MODEL EXPERIMENT

4.1. IMPACT OF NETWORK EFFECTS ON BUSINESS MODEL EXPERIMENTATION

Table 3 summarizes the respective benefits of a “small” and of a “large” business model experimentation.

Table 3: Impact of the test size on the value of the business model experimentation

<table>
<tr><th>Benefits of a limited test</th><th>Benefits of a large test</th></tr>
<tr><td>The cost of the test c is lower</td><td>Higher test fidelity, i.e. the value of the option to learn can be better evaluated</td></tr>
<tr><td>The downside risks are lower, and the upside potential is larger</td><td rowspan="2">Larger probability of “convincing” the other stakeholders of the business model: complementors; other group(s) of “users” in the case of a multi-sided BM; regulator</td></tr>
<tr><td>The experiment is less visible, entailing a lower risk of being copied by competitors</td></tr>
</table>

Key:

	Factor affecting only business models with network effects

It appears that in all cases, there are benefits associated with a reduced test size: the extra-operating costs generated by the test are lower, the sunk costs in case of failure of the experiment are lower, and the visibility of the test is lower, thus reducing the risk of competitive imitation.
This is the reason why we can find in the literature examples of business models experiments conducted on reduced sample sizes (e.g. Sosna et al., 2010; Dunford et al., 2010).

However, when the tested business model displays network effects, it may be more beneficial to conduct a large test. This can be explained by two phenomena. First, as will be demonstrated in the next section, it is difficult to assess the profitability of a business model on a reduced sample if the business model displays network effects. Second, if the test is too limited, the focal firm will not be able to experiment the different facets of its business model because the sales will not have reached the critical mass to attract the other stakeholders of the business model: complementor, other groups of users in the case of a multi-sided business model, regulator in the case of a highly regulated industry.

Network effects arise when the value that users derive from a product increases with the number of users. *Direct* network effects are generated when users of a given product interact frequently. This is for example the case for the telephone or for multi-players video games. Second, network effects are created when product adoption requires some degree of learning investment. In that case, customers will tend to prefer products already displaying a large installed base of users, which signals a long term viability of the product (compared to competing product with a lower installed base). Third, network effects appear when the new offering is based on a multi-sided business model, i.e. when two (or more) independent groups of agents are linked through a common platform, e.g. merchants and users in the case of payment cards, or travelers looking for an accommodation and property owners in the case of the AirBnB platform. Finally, *indirect* network effects arise when the value to users of the focal product is increased by complementary products, services or infrastructures.

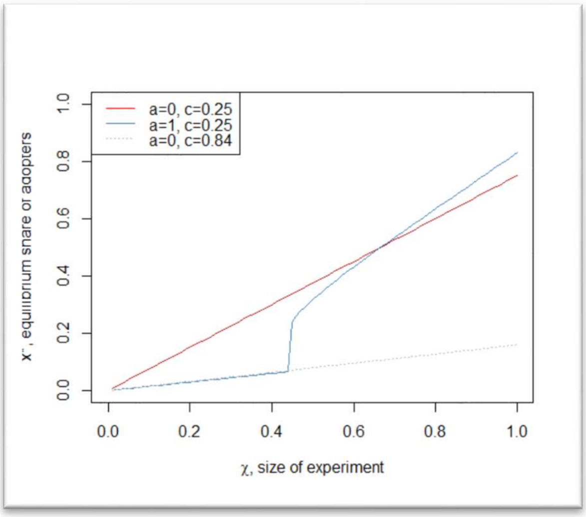
As outlined Chintakananda and McIntyre (2014), the literature usually focuses on two extreme market configurations: either the market is supposed to be "incremental", i.e. there are no network effects, or the network effects are supposed to be so strong that we are in a situation of "winner-takes-all" (WTA) market. In fact, some of the value of an offering may depend on stand-alone aspects, while another component of the value of the offering may be positively correlated with the number of users. Therefore, network effects should better be viewed as a continuum. Thus, Lin and Kulatilaka (2007) developed a real options model in which the value of the deferral and growth options depend on the degree of the network effect intensity. Network intensity can be defined as *"the extent to which the value of a product to a consumer is dependent on the total size of its installed base"* (Chintakananda and McIntyre, 2014:1541). As outlined by these researchers, network intensity can also be manipulated by firms through the way the value proposition is defined, e.g. by proposing "friends and familyplans" in mobile telephony.

4.2. Impact of network effects on the optimal size of the experiment

We present here a model establishing a relationship between the number of users and the size of the experiment χ. The details of the model are presented in Appendix 1.

Figure 4 illustrates the model at two extreme intensities of the network effects (for cut-off value of $c = 0.25$). The red line represents the case of no network intensity ($a = 0$), while the blue line represents the case of maximum network intensity ($a = 1$).

Figure 4: Equilibrium share of adopters as the function of the size of the experiment

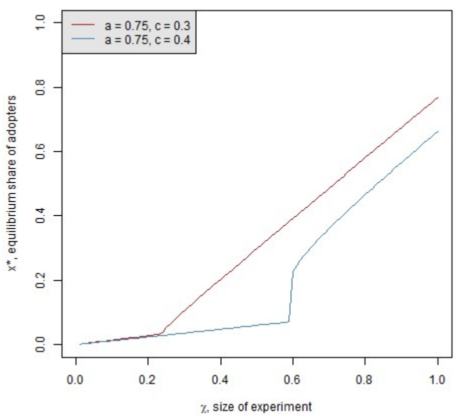


Without network effect the relationship is simple: the share of adopters increases linearly with the size of the experiment χ.

With network effect the system behaves differently. If the size of the experiment is too small, then the installed base of user is very low, and the network effects are too low to attract new users. It drastically changes around $\chi = 45\%$ because at this value the network effects take off and adoption level jumps from below 7% to almost 25%.

This simple model emphasizes the fact that in presence of network effects there might be a minimum size of the experiment below which the experiment will not yield a reliable result, as illustrated by Figure 5.

Figure 5: Comparison of the diffusion rate of two business models with a different market potential



In the example on Figure 5, we compare the diffusion of two business models with the same network intensity (a = 0,75) but with different market potentials, respectively c = 0,3 (i.e. 70% of the total targeted population may adopt) for the red line, and c = 0,4 (i.e. 60% of the total targeted population may adopt) for the blue line.
Because in the case of network effects the number of users takes-off very slowly, Figure 5 shows that if the size of the experiment is below the tipping point (approximately 20% on Figure 5), the firm will not be able to distinguish between a business model with a strong and with a weak market potential.

As highlighted by Adner and Levinthal (2004), not any sequential stream of investment may be analyzed as a real option. In the case of a business model displaying network effect, our model shows that the business model experiment cannot be considered as a simple learning option if the size of the experiment is below the tipping point until the number of users takes-off. Indeed, below this tipping point, there is no information revelation performed by the experiment. Therefore, we are not in a situation in which a limited investment enables a firm to make subsequent informed decisions.
To determine the optimal size of a business experiment in the case of network effects, we therefore need to develop a more sophisticated model solving simultaneously the optimal size and duration of the experiment, and in which the firm has the opportunity at the end of each period to extend the size of the experiment, to continue with the existing size or to abandon the experiment.

CONCLUSION

For firms contemplating the launch of a disruptive technology, the uncertainty regarding the characteristics of the "right" business model is very high. At the same time, real market experimentation is costly – and to a large extent irreversible – because it entails a partial deployment of the new technology. Therefore, the investment decision associated with the business model experiment of a disruptive technology is difficult to make.
Unfortunately, the current literature does not provide clear indication on how to make these decisions. The business model literature encourages real market experiments of new business

models, but tells little on how to make investment decisions related to these experiments. Rather, it focuses on the analysis of organizational processes that enable an effective replication of a business model experiment.

In this paper, we analyze the main factors affecting the optimal size and duration of a business model experiment. We show that a business model experiment can be analogized with an "option to learn", and that the valuation of this option enables a firm to determine the optimal length of a business model experiment. The example of the "3G" technology in the mobile telephony industry illustrates the benefit of conducting a real business model experiment, and shows how the real option model may be used to determine the optimal length of the experiment.

However, we show that the determination of the optimal size of the experiment is more complex when a business model displays network effects. We develop a simple model establishing the relationship between the number of users and the size of the experiment. This model shows that in the case of network effects we do not have all the necessary conditions to analyze a business model experiment as a simple option to learn.

This article presents several limitations. First, the framework would be closer to reality if it allowed the business model pioneer to extend the size of the business model experiment at each period. This could be done by simultaneously solving the optimal size and duration of the test.

Second, network effects are considered here as a whole, whereas in reality there are different categories of network effects. A refined model could take into account the fact that these various categories of network effects have different impacts on the optimal size and length of a business model experiment. For example, the research of Sun and Tse (2009) suggests that when network effects are due to a multi-sided business model, the initial scale of the business model is critical, while its length plays a marginal role. In contrast, in the case of indirect network effects due to the presence of complementors, the work of Adner and Kapoor (2010) suggests that the most critical parameter on the option value is the length of the test. Indeed, the business model experiment will be meaningful only if the focal firm allows complementors sufficient time to develop an offering compatible with the new technology.

Lastly, an interesting research avenue would be to empirically study markets with network effects, and investigate how the number of users increases, depending on the proportion of the population covered by the roll-out. This would enable to more firmly establish the impact of network intensity on the optimal size of the business model experiment.

APPENDIX 1: model

We assume two types of consumers: type I and type II.

Type I consumers value only intrinsic quality of the product and their utility is simply

$$u_i = \varepsilon_i \sim \mathrm{U}(0,1)$$

where ε_i is distributed uniformly at random between 0 and 1. The intrinsic quality of the product and its price determine the cut-off value c so that only consumers with u_i above c adopt the product:

$$u_i > c$$

Thus if the share of such consumers in the population is ϕ, then the demand from this group is

$$x_I = \phi(1 - c).$$

Type II consumers derive their utility from the combination of product intrinsic quality and its popularity reflected by the share of adopters x:

$$u_i = \varepsilon_i\, g(x)$$

where ε_i, distributed uniformly at random between 0 and 1, is the "intrinsic" part of the utility while $g(x)$ is the "social" part of the utility (network effects) that is monotonically increasing in x, consumer i's expectation concerning the number of adopters. In what follows we will consider linear

$$g(x) = 1 - a + 2ax$$

where $a \in [0,1]$ is the strength of network effects. Notice that at $a = 0$ there are no network effects and consumers of type II are indistinguishable from consumers of type I.

For a given cut-off value c, a consumer adopts the product only if $u_i > c$. We can find the marginal consumer with $\varepsilon^*(x, c)$ such that

$$\varepsilon^* g(x) = c$$

and only the consumers with $\varepsilon_i \geq \varepsilon^*$adopt the product. The demand from consumers of type II is

$$x_{II} = (1 - \phi)(1 - \varepsilon^*)$$

The innovative firm decides to test the product on χ fraction of its consumers to observe the demand $x(\chi)$, which it uses to forecast the full-scale adoption level. We focus on the equilibrium, where the expected demand in $g(x)$ of the consumers of type II is equal to the realized demand from the two groups of consumers. Thus the equation for the marginal consumer can be re-written as

$$\varepsilon^* g(x_I + x_{II}) = \varepsilon^* g(\chi\phi(1-c) + \chi(1-\phi)(1-\varepsilon^*)) = c$$

It is well known that such systems may have multiple equilibria and exhibit tipping behaviour (e.g. Shapiro and Varian, 1998).

For the linear network effects function $g(x)$ specified earlier, the equation above, is a quadratic equation. If

$$D = [1 - a + 2a\chi(1 - c\phi)]^2 \geq 8ac\chi(1-\phi)$$

the discriminant is non-negative the two roots of the equation $\varepsilon_1 \leq \varepsilon_2$ define the long-term equilibria, otherwise $D < 0$ and consumers of type II do not adopt. When $0 \leq \varepsilon_1 \leq \varepsilon_2 \leq 1$, two equilibria are possible: one where no consumer of type II adopts, and the one where $(1 - \varepsilon_1)$ fraction of consumer of type II adopts. The larger root ε_2 sets the tipping point/critical mass: if the initial share of adopters is less than $(1-\varepsilon_2)$ that share disappears with the time, if the product crosses $(1-\varepsilon_2)$ it reaches equilibrium with $(1-\varepsilon_1)$ adopters. Several corner situations are also possible: when $\varepsilon_1 < 0$ or the share of adopters among type II is at its maximum $(1-c)$, when $\varepsilon_1 > 1$ the product does not diffuse, when $\varepsilon_2 < 0$ or the share of adopters among type II shrinks to 0, when $\varepsilon_2 > 1$ the 'no diffuse' equilibrium disappears.

REFERENCES

Adner, R. and R. Kapoor (2010). "Value creation in innovation ecosystems: how the structure of technological interdependence affects firm performance in new technology generations." Strategic Management Journal **31**(3): 306-333.

Adner, R. and D. A. Levinthal (2004). "What is not a real option: considering boundaries for the application of real options to business strategy." Academy of Management Review **29**(1): 74-85.

Benghozi, P.-J. and I. Lyubareva (2014). "When Organizations in the Cultural Industries Seek New Business Models: A Case Study of the French Online Press." International Journal of Arts Management **16**(3): 6-19.

Bohlmann, J. D., J. Spanjol, et al. (2013). "The Interplay of Customer and Product Innovation Dynamics: An Exploratory Study." *Journal of Product Innovation Management* **30**(2): 228-244.

Bohnsack, R., J. Pinkse, et al. (2014). "Business models for sustainable technologies: Exploring business model evolution in the case of electric vehicles." Research Policy **43**(2): 284-300.

Bohnsack, R., A. Kolk, et al. (2015). "Catching recurring waves: Low-emission vehicles, international policy developments and firm innovation strategies." Technological Forecasting and Social Change **98**: 71-87.

Booz Allen Hamilton (1982). *New Product Development for the 1980s*. New York, Booz Allen and Hamilton.

Bourreau, M., M. Gensollen, and F. Moreau (2012). The Impact of a Radical Innovation on Business Models: Incremental Adjustments or Big Bang? *Industry & Innovation* **19**(5): 415-435.

Carpenter, G. S. and K. Nakamoto (1989). "Consumer Preference Formation and Pioneering Advantage." *Journal of Marketing Research (JMR)* **26**(3): 285-298.

Casadesus-Masanell, R. and J. E. Ricart (2010). "From Strategy to Business Models and onto Tactics." *Long Range Planning* **43**(2/3): 195-215.

Chesbrough, H. (2007). Business model innovation: it's not just about technology anymore. *Strategy & Leadership* **35**(6): 12-17.

Chesbrough, H. (2010). Business Model Innovation: Opportunities and Barriers. *Long Range Planning* **43**(2–3): 354-363.

Chesbrough, H. and R.S. Rosenbloom (2002). The role of the business model in capturing value from innovation: evidence from Xerox Corporation's technology spin-off companies. *Industrial & Corporate and Change* **11**(3): 529-555.

Chintakananda, A. and D. P. McIntyre (2014). "Market Entry in the Presence of Network Effects: A Real Options Perspective." Journal of Management **40**(6): 1535-1557.

Christensen, C.M. (1997). *The Innovator's Dilemma*. Cambridge, MA, Harvard Business School Press.

Danneels, E. (2004). "Disruptive Technology Reconsidered: A Critique and Research Agenda." Journal of Product Innovation Management **21**(4): 246-258.

Demil, B. and X. Lecocq (2010). Business Model Evolution: In Search of Dynamic Consistency. *Long Range Planning* **43**(2/3): 227-246.

Desyllas, P. and M. Sako (2013). "Profiting from business model innovation: Evidence from Pay-As-You-Drive auto insurance." Research Policy **42**(1): 101-116.

Dunford, R., I. Palmer, et al. (2010). "Business Model Replication for Early and Rapid Internationalisation: The ING Direct Experience." Long Range Planning **43**(5/6): 655-674.

Dunnewijk, T. and S. Hultén (2007). A brief history of mobile communication in Europe. *Telematics and Informatics* **24**(3): 164-179.

Folta, T. B. and J. P. O'Brien (2004). "Entry in the presence of dueling options." Strategic Management Journal **25**(2): 121-138.

Gupta, S., D. C. Jain, et al. (1999). "Modeling the Evolution of Markets with Indirect Network Externalities: An Application to Digital Television." Marketing Science **18**(3): 396.

Hayashi, A. M. (2009). "Do You Have a "Plan B"?" MIT Sloan Management Review **51**(1): 10-11.

Kulatilaka, N. and E. C. Perotti (1998). "Strategic growth options." Management Science **44**(8): 1021.

Lander, D. M. (2000). Do Foregone Earnings Matter When Modeling and Valuing Real Options?: A Black-Scholes Teaching Exercise. *Financial Practice & Education* **10**(2): 121-127.

Lin, L. and N. Kulatilaka (2007). Strategic Growth Options in Network Industries. Advances in Strategic Management. **24:** 177-198.

McGrath, R.G. (2010). Business Models: A Discovery Driven Approach. *Long Range Planning* **43**(2-3): 247-261.

McMillan, I. C. and R. G. McGrath (2000). Technology Strategy in Lumpy Market Landscapes. *In:* Wharton on Managing Emerging Technologies. G.S. Day, P. J. H. Schoemaker, and R.E. Gunther (eds.). New-York, Wiley**:** 150-171.

Min, S., M. U. Kalwani, et al. (2006). "Market Pioneer and Early Follower Survival Risks: A Contingency Analysis of Really New Versus Incrementally New Product-Markets." Journal of Marketing **70**(1): 15-33.

Myers, S.C. (1984). Finance theory and financial strategy. *Interfaces* **14**(1): 126-137.

Pennings, E. and O. Lint (2000). Market entry, phased rollout or abandonment? A real option approach. *European Journal of Operational Research* **124**(1): 125-138.

Shapiro, C. and H. Varian (1998). Information Rules: A Strategic Guide to the Network Economy, Harvard Business School Press.

Sosna, M., R.N. Trevinyo-Rodríguez, and S.R. Velamuri (2010). Business Model Innovation through Trial-and-Error Learning: The Naturhouse Case. *Long Range Planning* **43**(2–3): 383-407.

Staykova, K. S. and J. Damsgaard (2015). "The race to dominate the mobile payments platform: Entry and expansion strategies." Electronic Commerce Research & Applications **14**(5): 319-330.

Sun, M. and E. Tse (2009). "The Resource-Based View of Competitive Advantage in Two-Sided Markets." Journal of Management Studies **46**(1): 45-64.

Teece, D.J. (2010). Business Models, Business Strategy and Innovation. *Long Range Planning* **43**(2–3): 172-194.

Thomke, S. (2002). *Experimentation Matters*. Cambridge, MA, Harvard Business School Press.

Wagner, S. and I. Cockburn (2010). "Patents and the survival of Internet-related IPOs." Research Policy **39**(2): 214-228.

Winter, S. G. and G. Szulanski (2001). "Replication as Strategy." *Organization Science* **12**(6): 730-743.

Zott, C., R. Amit, L. Massa (2011). The Business Model: Recent Developments and Future Research. *Journal of Management* **37**(4): 1019-1042.