An Economic Theory of Dynamic Capabilities

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"Three types of managerial activities can make a capability dynamic: sensing (which means identifying and assessing opportunities outside your company), seizing (mobilizing your resources to capture value from those opportunities), and transforming (continuous renewal)." Teece, as quoted in Kleiner [2013]

1 Introduction

There is growing evidence in the economics literature of significant and persistent productivity differences between firms. For instance, in U.S. manufacturing a plant in the 90th percentile of productivity can produce twice as much as a plant in the 10th percentile using the same amount of inputs (Syverson [2004]). Hsieh and Klenow [2009] find even higher differences in China and India. These differences have also been noted by strategic management scholars. Firm level effects are larger than industry level effects and are a significant determinant of firm performance.[1]

However, while both areas agree on the empirical evidence, they have different approaches to understanding the underlying mechanism behind the performance differences. Recent work in economics has focused on differences in management practices as a source of these persistent differences (Gibbons et al. [2012], Bloom and Van Reenen [2010, 2007]). Strategic management scholars have identified specific mechanisms, such as dynamic capabilities,

[1]Evidence includes Hansen and Wernerfelt [1989], McGahan and Porter [1997], and McGahan [1999] which find firm effects to be larger than industry level effects. Furthermore McGahan and Porter [1997], and McGahan [1999] quantify firm effects as approximately twice as large as industry level effects.

often knowledge-based, that give rise to these persistent differences (Teece et al. [1997], Grant [1996] and Kogut and Zander [1996]). Although many different definitions of dynamic capabilities exist, in this chapter we focus on those that fit with the organizing quote (above) by Teece. These capabilities are based on differences in three types of managerial activities: identifying new opportunities (sensing), mobilizing current resources to take advantage of new opportunities (seizing); and continually transforming the firm, its products and processes (transforming). In this chapter we begin to bridge the gap between the economics and management literatures by describing these three forms of dynamic capabilities in an economic model. The goal of this agenda is to bring the ideas of dynamic capabilities to the economics literature concerning management practices and sharpen the predictions of the theory from the management literature, in order to influence future empirical work.

Our analysis is based on the idea that dynamic capabilities are related to innovation. We therefore model dynamic capabilities as manifesting themselves in the efficacy of the firm's ability to innovate by allowing firms to choose the probability of successful innovation. We modify a basic model of investing to develop new products to accommodate examples of all three types of managerial activities described above. The formal model helps to clarify the sources and effects of these capabilities.

The first application, "sensing," shows how information can generate competitive advantage in innovation, providing a microfoundation for dynamic capabilities. In order to model sensing, firms differ in how much they know about important characteristics of the new opportunities around them. We show how information about these opportunities generates a dynamic capability described in the model. Whether or not this shows up more in terms of profits or in realized innovation rates depends on details of *what* the firm is sensing and how it responds to the information. The model points to one clear measure, return on investment, that is always linked to the capability.

The next two applications take the source of the capability as a cost advantage in innovative activity. We first consider "seizing" which is ability of a firm to simultaneously exploit current opportunities and explore new ones. This is also known in the management literature as ambidexterity. March's seminal work (March [1991]) noted that because of the difference in time frames between exploration and exploitation, namely that exploitation provides an almost certain, immediate return, while exploration entails an uncertain future return, it is difficult to balance these two activities. Others have noted that the resource requirements and incentives needed for both activities are quite different and further that this dynamic capability requires the use of structural ambidexterity, or the ability to simultaneously exploit and explore O'Reilly and Tushman [2008a].[2]

Our model incorporates this notion that innovative activity comes at the expense of current profits, so that there is a trade-off between exploitation of past innovations and development of new ones. More ambidextrous organizations can do so with less foregone profitability from exploiting past innovations. However, since ambidextrous organizations choose to invest more in innovative activities, they therefore may be less profitable on existing lines of business, because the use of their dynamic capability masks its existence in measured profitability. We also show how this model naturally leads to overtaking, where performance differences may erode precisely because of the form of the dynamic capability, as firms with more to exploit may have more to lose. The effect captured by our model aligns well with observations from certain industries: for instance, in the photo-lithographic alignment equipment industry, Henderson and Clark [1990] argue that employee focus on improving the current generation led incumbent firms to disregard the threat posed by the next generation of products.

The final application we model, "transformation," captures the idea that existing experiences of the firm, to the extent that they can be transformed, are a source of cost advantages for innovative activities. In other words, incumbents in current leading designs may get an extra return: the potential to transform their current abilities into new ones, making them more able to become leaders in new, often related products. This raises the return from incumbency and unambiguously increases the amount of effort expended by non-incumbents who do not yet have the ability to transform, but seek to attain it. As we show in a simple two-period model, this can lead to interesting patterns of innovation: even though the incumbents have a comparative advantage (thanks to the dynamic capability) in innovation, it can be that new entrants actually invest *more* because they have the additional incentive to do so. Which effect dominates, depends on the expected future returns from obtaining the dynamic capability, but also on whether it creates cost advantage in terms of marginal or fixed costs. Therefore, lack of investment in innovativeness on the incumbents' part does not mean that the dynamic

[2]This occurs by the internal alignment of values, incentives and cultures in O'Reilly and Tushman [2008a]

capabilities are not based on the ability to continually transform. Extending this logic to other forms of dynamic capabilities suggests that in a dynamic industry it may be hard to measure the strength of dynamic capabilities by comparing investment in innovation of different firms (for example, incumbents vs. new entrants). The reason is that even though firms without dynamic capabilities may have lower immediate returns from innovation, they are additionally motivated by the hope to acquire dynamic capabilities and that incents them to invest more.

Our modeling approach focuses on the external-to-the-firm effects of dynamic capabilities and not specifically how internal organization facilitates them. Internal organizational design is an important aspect of dynamic capabilities[3] that would also benefit from development of economics models. Using organization economics to further understand dynamic capabilities would further dialog between the two fields, but is beyond the scope of this paper. The organization economics literature provides a variety of ways in which organizational differences might lead to cost advantages, including Alchian and Demsetz [1972].

Each of these applications stems from the same economic model of costs and benefits of innovation. We describe that general setup in section 2. Then, in section 3, we introduce the three applications that use the general setup to derive results about the manifestation of dynamic capabilities implied by the model. The model highlights that dynamic capabilities may manifest themselves in different ways in terms of profits, return on investment, and innovation levels in different cases, and shows how the model can help to understand how different capabilities might have different measurable impacts. At the conclusion of that section we describe how heterogeneity in dynamic capabilities among incumbents might be modeled, so that some incumbents have the dynamic capability, and others do not.

2 The Innovation Technology and Dynamic Capabilities

Dynamic capabilities have been defined as "the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments"(Teece et al. [1997]). Central to our framework,

[3] For instance see Eisenhardt and Martin [2000].

therefore, is a changing environment, which is modeled as new product areas. These product areas may be either new markets or submarkets. This allows us to consider the firm's dynamic capability as impacting the firm's likelihood of profitably engaging in new areas. We start by describing a benchmark model of stochastic innovation. In the model firms can differ for ex ante and ex post reasons. First, the ex ante capabilities of firms may differ. For instance, some firms may be able to invest less and obtain the same probability of successful innovation. Second, firms may differ ex post even when they have the same capabilities. This is due to stochastic outcomes. We then modify the basic model to illustrate sensing, seizing, and transforming dynamic capabilities.

2.1 Model of Stochastic Innovation

In our model firms invest in order to achieve an innovation that allows production of a new product. The results of investment are stochastic; two firms which make the same investments may have different outcomes. A key element of the model is the cost function for attempting to innovate: the more resources a firm commits to innovation, the more likely it is to succeed. We assume that the cost of having a probability of success in innovation, q, is

$$c(q) = F + \frac{\theta}{1-q}.$$

This form includes several important features. Innovation is never assured, as $lim_{q\to 1} c(q)$ is infinite. Innovation has a fixed cost component F. Firms can differ both in terms of the fixed cost component F and the variable cost shifting θ.[4] One interpretation of success, since success will be associated with an opportunity to earn profits, is as speed of success: if only the first (few) firms to develop a new product will be able to profitably sell it, then here a successful innovation means one that is generated fast enough to be able to generate profits. Throughout the paper we use the word innovation synonymously with q for simplicity.

While the model does presume that higher spending is associated with greater success at a *given* firm, it does not require that higher spending is associated with greater success *across* firms. Steve Jobs is reported to have

[4]Many results can be generalized to the case where $c(q) = F + \theta v(q)$, where $v(q)$ is a convex, increasing variable cost component on $[0, 1]$.

said “Innovation has nothing to do with how many R&D dollars you have. When Apple came up with the Mac, IBM was spending at least one hundred times more on R&D. It's about... how much you get it.” (Kirkpatrick [1998]). If a firm (like IBM) has relatively higher θ than another firm (like Apple), higher spending for the same success rate q is consistent with the model. The model does, however, assume that it isn't low spending per se that makes a firm successful. At the margin at least, firms have something productive to do with R&D dollars, although at possibly very different rates across firms.

The present discounted value of profits from successfully innovating and producing a new product is π. To maximize expected profits from investment in innovation, the firm solves

$$max_q\{\pi q - c(q)\}.$$

Therefore optimal investment q solves

$$\begin{aligned} \pi &= c'(q) \\ &= \frac{\theta}{(1-q)^2}. \end{aligned}$$

So

$$q = 1 - \sqrt{\frac{\theta}{\pi}}. \tag{1}$$

Expected profits are

$$\pi q - c(q) = \pi\left(1 - \sqrt{\frac{\theta}{\pi}}\right) - F - \frac{\theta}{1-\left(1-\sqrt{\frac{\theta}{\pi}}\right)} = \pi - F - 2\sqrt{\pi\theta}.$$

Notice that in this static model, both F and θ, affect firm profits, whereas only θ, affects the firm's level of innovation, while F determines only whether the firm invests at all.

3 Three applications: Dynamic Capabilities as Sensing, Seizing, and Transforming

In this section we build on the general framework to interpret the organizing quote from Teece. In the first subsection, firms differ in their ability to determine the profitability of different new products. We show how this ability to sense opportunities leads to dynamic capabilities of the sort described by the general framework. Then we study firm ambidexterity explicitly in order to incorporate the idea that firms have different abilities to profit from new opportunities due to cannibalization. In the final subsection we consider the effect of dynamic capabilities that allow the firm to transform current resources in order to create and produce new products. When studying the effect of transformation, we extend the model to consider the impact of differences in these capabilities on dynamic industry evolution. Finally, it is important to note, that each case is a very narrow view of the three types of dynamic capabilities that Teece discusses.

3.1 Sensing: Dynamic Capabilities and Information

We define sensing as a firm ability to identify better when an opportunity is a good one. While both economists and strategic management scholars have emphasized the importance of human capital in providing the firm with competitive advantage (Huff [1990], Burt [2009], and Becker [2009]), the literature in strategic management has focused on the underlying mechanism. As noted in the strategic management literature, this requires that the firm has the ability to recognize both the market and the technological opportunities, as well as be able to mobilize the necessary resources (Teece [2007], Helfat et al. [2007], and Maritan [2001]).

We model the sensing dynamic capability in a case where each firm has several independent opportunities to innovate, each opportunity with different values of π, θ and F, reflecting the quality of the opportunity through differences in the return to innovation and the cost of innovating. Firms may differ in their information about π, θ and F. For simplicity, in this section we discuss explicitly the case where either the firm knows each opportunity's characteristics perfectly, and therefore has dynamic capability of sensing opportunities, or must decide based on expectations $E(\pi)$, $E(\theta)$ and $E(F)$ because it lacks the sensing dynamic capability. Moreover, we assume that π and θ are independent. The results extend directly if the distribution of θ and F for the firm without the dynamic capability is any mean preserving spread of the distribution for the firm with the dynamic capability. This implies that any informative signal generates dynamic capabilities of the sort described here. The results are not, by contrast, about firms that differ with regard to the mean of the distribution itself: the firms view the opportunities as equally likely to be good, on average, but simply have more or less precise signals about the quality of any given project.

For the firm without the dynamic capability, the choice of q is just based on the expected values. If the firm chooses to invest, it selects innovation level

$$q = 1 - \sqrt{\frac{E(\theta)}{E(\pi)}}.$$

It invests so long as the expected return is positive:

$$E(\pi) - E(F) - 2\sqrt{E(\pi)E(\theta)} \geq 0.$$

The firm with specific knowledge of π, θ and F chooses (as in the benchmark model) $q = 1 - \sqrt{\frac{\theta}{\pi}}$, and earns expected profits in any opportunity it enters given by $\pi - F - 2\sqrt{\pi\theta}$.

3.1.1 Profits and Return on Investment

First, suppose that the firm with the sensing dynamic capability (i.e., superior information) invests a positive amount for every possible information it possesses. Then the sensing dynamic capability results in strictly higher profits on average since:

$$E(\pi) - E(F) - 2E(\sqrt{\pi\theta}) > E(\pi) - E(F) - 2\sqrt{E(\pi)E(\theta)}.$$

The former is the average profits for the firm that chooses $q = 1 - \sqrt{\frac{\theta}{\pi}}$ given the knowledge of θ and π, while the latter is the profits for the firm without the dynamic capability of sensing, which chooses $q = 1 - \sqrt{\frac{E(\theta)}{E(\pi)}}$. The source of the higher profits can be seen by separating the total profits into the costs of innovation, $F - \sqrt{\pi\theta}$, and the expected profits from the innovations, $q\pi = \pi - \sqrt{\pi\theta}$. Information about θ and π lowers costs by allowing the firm to tailor their investment efforts to, in the case of sensing θ, the lowest cost opportunities, and in the case of sensing π, the ones with the highest reward.

If the firm with the ability to sense also chooses to not invest in some projects, its profits must be even higher than the payoff if they invest in all projects, and therefore the conclusion that the sensing dynamic capability strictly raises profits is strengthened. These results imply that, for the firm with the sensing dynamic capability, the return on investment is higher than the firm without the dynamic capability. We turn next to innovation levels and see that the capability need *not* be associated with higher levels of innovation.

3.1.2 Sensing and Innovation Levels

Measuring innovation as a result of the sensing capability is more subtle than measuring profits. Again, we begin with the case where the firm with the sensing capability invests in all projects. Because θ and π enter in different ways in the innovation level, q, we consider these two cases separately assuming that the other factor is perfectly observable to all firms.

In case only firms with the sensing dynamic capability can observe θ, while all firms can observe π, the average amount of innovation by the knowledgeable firm is given by

$$E(q) = 1 - E\sqrt{\frac{\theta}{\pi}}.$$

The firm without the sensing dynamic capability chooses the same amount of innovation for all new products given by

$$E(q) = 1 - \sqrt{\frac{E(\theta)}{\pi}}.$$

Thus, the firm that can sense the cost of innovation across different new products will invest in a greater average amount of innovation than the firm without the dynamic capability. This can be seen by the following inequality:

$$1 - E\sqrt{\frac{\theta}{\pi}} > 1 - \sqrt{\frac{E(\theta)}{\pi}}.$$

Therefore, the firm with the dynamic capability of sensing θ is more innovative, on average, then the firm without this dynamic capability. If the firm with the dynamic capability can choose to not invest in some projects, the excluded projects are those with the highest θ (and therefore the lowest q). This implies that *per project* the innovation level of the firm with the dynamic capability to sense θ is higher still. However, if one measures merely the number of innovations, a firm with the dynamic capability might *not* appear more innovative, since they refrain from spending when the level of θ does not justify the investment, while the firm without the capability still invests (and sometimes innovates) in those cases.

Somewhat surprisingly, in case where the sensing dynamic capability is the ability to better observe π, the relationship between the dynamic capability and total innovation is unambiguously *negative*. First consider the case where the firm has the dynamic capability to sense π. In this case, the firm will have an average amount of innovation given by:

$$E(q) = 1 - E\sqrt{\frac{\theta}{\pi}}.$$

The firm without the dynamic capability to sense π sets its innovation level to

$$E(q) = 1 - \sqrt{\frac{\theta}{E(\pi)}}$$

for all projects since it can not observe π. Since q is concave in π, by Jensen's inequality we have:

$$1 - E\sqrt{\frac{\theta}{\pi}} < 1 - \sqrt{\frac{\theta}{E(\pi)}}.$$

If the firm with the ability to sense π also chooses not to invest in some projects, their total innovation levels will be lower still. We summarize our findings as:

Proposition 1. *Suppose all firms have the same costs and benefits of innovation, but differ in their information about them at the time of making decisions about investment in innovation. In particular, firms with sensing capability observe realized (π, θ, F) before investing, while firms without the sensing capability do not observe them and hence invest conditional on the average $E(\pi)$, $E(\theta)$ and $E(F)$. Then under optimal investment policies:*

a) The firms with sensing dynamic capabilities have strictly higher profits than the firms without.

b) If the firms differ only in their sensing of θ, then when both types of firms invest a positive amount to innovate a product, the expected innovation level of the firms with the sensing capability is higher. Yet, the firms with the sensing capability may invest in a smaller set of products

c) If the firms differ only in their sensing of π, then a firm with the sensing capability invests on average less in innovation. The difference is even higher when firms without the sensing capability invest in all projects while the firms with the sensing capability do not invest in low-profit-potential products.

The dynamic capabilities to sense θ and π result in fundamentally different behavior. While both show up in total expected profits and return on investment, a firm with the ability to sense π will not be more innovative overall, and a firm able to sense θ will only be certain to be more innovative per project undertaken, and not in terms of overall innovation. The robust prediction of the sensing example is that the dynamic capability shows up in return on investment even when it does not show up in innovation rates directly. This simple model suggests that there is a more nuanced view about how expenditure on innovation can help researchers to back out both the type of sensing dynamic capability managers have as well as to identify firms with the dynamic capability.

3.2 Seizing: Dynamic Capabilities and Ambidexterity

In this section we consider explicitly how a new project might impact the profits from existing businesses. This might be a trade-off between mobilizing assets for a new project, and using them to exploit an existing one. Firms capable of this trade off are often termed ambidextrous. Early work in the area of ambidexterity notes that firms needed to be able to shift resources towards new projects, in order to both innovate new products and exploit these innovations (Duncan [1976]). Fundamental work by March [1991] highlights the importance of firms being able to both explore new products and markets, as well as exploit current products and markets given the rapidly changing economic environment. Further, O'Reilly and Tushman [2008a] argue that the firm must be able to do both simultaneously in order to be able to benefit. A firm with the ability to simultaneously explore and exploit provides it with an enhanced ability to sustain higher than average performance in the face of rapidly changing markets (Franco et al. [2009]). The model will also allow for the possibility that the seizing capability is not about a trade-off between new and old projects, but an enabling of new projects by old ones. We expand on that idea in the "transforming" model below.

In order to discuss concepts like ambidexterity, we introduce two generations of products, with profit levels π_1 and π_2. The firm has two potential sources of profits: one from the product which it has already developed and marketed, which we denote π_1, and the possible profits from a new product that the firm may gain through innovation, corresponding to π in the prior section, which we now denote π_2.[5]

[5] Note that we do not explicitly discount payoffs from the second market, despite the fact that it comes later, since such discounting can be taken to be subsumed in the specification of π_2.

The firm must determine how much to invest in the new product, which is denoted by q_2. The idea of ambidexterity is that the cost of innovating comes, at least partially, through a lower ability to profit from existing lines of business. In other words, the firm's profits from existing activities now depend on the resources it devotes to the new market, which we denote by $\pi_1(q_2)$ and assume that the more the firm invests in the new product, the less profits it receives from its existing product: $\partial\pi_1/\partial q_2 < 0$. The magnitude of this partial derivative reflects ambidexterity: the closer it is to zero, the less the firm loses in current profits from investing in innovative activity so that it is easier for the firm to simultaneously explore and exploit.

More generally, $\partial\pi_1/\partial q_2$ measures what we will term the seizing dynamic capability. The higher is the partial derivative, the more the firm earns in existing lines of business when it succeeds at new things. In the case where the partial derivative is positive, rather than a trade-off, existing lines of business and new ones have complementarities. The first order condition for the firm's investment in a new product, q_2, is now given by

$$q_2 = \frac{\partial\pi_1}{\partial q_2} + 1 - \sqrt{\frac{\theta}{\pi_2}}.$$

The firm's ambidexterity (measured by $\frac{\partial\pi_1}{\partial q_2}$), or its level of complementarity, acts in a manner similar to a change in θ: higher levels of ambidexterity lead to higher q_2.

The seizing capability also shows up in profits from the first generation product, but when there is a trade-off between new and old lines of business, the measurement of the dynamic capability from profitability is difficult. Ambidextrous firms lose less current profitability from a given level of innovativeness, but as a result choose higher q_2. Therefore whether or not π_1 is higher or lower for a more ambidextrous organization is ambiguous. It is also not sufficient to condition on innovative level q_2 and measure profitability, since firms that differ in ambidexterity but choose the same q_2 must also differ in another characteristic (like θ), and therefore such conditional profitability differences would not stem just from ambidexterity. Formally, we summarize these results in the following proposition:

Proposition 2. *Suppose firms have differ in their seizing dynamic capability, so that* $\frac{\partial\pi_1}{\partial q_2} < \frac{\partial\pi_1^{DC}}{\partial q_2^{DC}}$ *for all* q*, where* $\frac{\partial\pi_1^{DC}}{\partial q_2^{DC}}$ *is the effect on current profits for firms with the dynamic capability and* $\frac{\partial\pi_1}{\partial q_2}$ *for those without it. Moreover,* *suppose that the costs and second-market opportunities are the same for all firms. Then*

a) The firms with the dynamic capability invest more in the second generation, $q_2^{DC} > q_2$.

b) Even if for every investment level q_2 *the firms with dynamic capabilities have a higher profit,* $\pi_1^{DC}(q_2) \geqslant \pi_1(q_2)$, *under the optimal investment strategies, the firms with the dynamic capability may have lower profits from the first-generation product.*

To finish this subsection, we use this model to illustrate the relation between ambidexterity and the phenomenon of technological lock-in. At the same time, we illustrate that dynamic capabilities can be difficult to define, let alone measure.

Suppose that firms differ only in terms of profits from the exploitation of past innovations (π_1) and profits are $a(q_2)\pi_1$, where $a(q_2)$ is a decreasing function and common to all firms (that is, $\pi_2, \theta, a(q_2)$, and F are the same for all firms, but π_1 differ). In this formulation innovating into a new product has disruption costs that are proportional to current profits. The reason could be that investment q_2 disrupts profits from the existing line and that disruption could be deterministic, so that profits go down for some time, or stochastic, so that with a positive probability the firm experiences a drop in profits. In either case, the expected reduction in first-generation profits depends on how hard the firm works at innovation q_2, as in Holmes et al. [2012]. Even if all firms have the same ambidextrous dynamic capability (i.e. the function $a(q_2)$ is the same for all firms), firms with greater π_1 will be less innovative because they have more to lose from the disruption, and therefore will appear less ambidextrous, simply due to their greater profitability. Formally this occurs because $\frac{\partial \pi_1}{\partial q_2} = a'(q_2)\pi_1$.

This version of the model has two takeaways. First, firms with lower operational capabilities at the first generation (i.e. lower π_1) are more likely to innovate and therefore the model has the feature that overtaking is likely. Second, one might think of the firm with lower operational capabilities as having more “seizing” ability, since their $\frac{\partial \pi_1}{\partial q_2}$ is closer to zero; however it does not have any particular capability except the fact that it has less to lose from lost focus on existing product lines, since those product lines are less valuable. More generally, having the ability to continue to exploit while simultaneously exploring can occur for many reasons, including (but not limited to) an explicit dynamic capability to “seize.”

3.3 Transforming: Experience-driven dynamic capabilities

In this subsection we consider the third type of dynamic capability - the ability to transform or reconfigure current resources to innovate and produce new products. Extant empirical work has pointed to this dynamic capability providing a benefit to firms with past experience in a related submarket. For instance, both Buenstorf and Klepper [2010] and Franco and Filson [2006] note that new submarkets are related to innovation at leading incumbents. Further, King and Tucci [2002] find that firms with higher sales in the previous generation of products are more likely to enter the next generation. Finally, Scott Morton [1999] shows that firms with past experience in production, distribution and marketing in similar markets to new ones are more likely to enter the new markets. In keeping with this evidence from both strategy scholars and economists, we consider the possibility that the transforming dynamic capability may be due to experience in earlier generations.

Since the model is about prior experience, we continue to use two generations of products, with profit levels π_1 and π_2. Now, some firms are incumbents in the first generation of products and try to innovate to enter also in the second one, while some firms may choose only to enter the second generation.[6]

The idea of the transforming dynamic capability is captured by assuming that firms with successful generation 1 products have lower F and/or θ, denoted F' and θ'. One explanation for this is that past experience provides the firm with the ability to transform existing resources. In order to focus on the impact of transformation, we analyze this dynamic capability in isolation (assume that there are no sensing or seizing dynamic capabilities), but of course in practice these forms of dynamic capabilities are likely to co-exist.

If we take the profits of each generation as exogenously given, we can apply our analysis from Section 2 to obtain a prediction that the if the dynamic capability is marginal (lower θ), then the incumbent firms will invest more. If the cost advantage is in fixed costs, the dynamic capability will not affect innovation intensity, but only profits and possibly whether any new entrants try to enter the second generation of products.

To take the analysis one step further, we next use the model to endogenize

[6] As in the discussion of ambidexterity, profits from the second generation product are not explicitly discounted.

profits from the two generations of products and address the natural question: how would such dynamic capabilities impact industry evolution? The analysis is consistent with the infinite horizon model introduced in Mitchell and Skrzypacz [2015].

3.3.1 Industry Equilibrium with Incumbency Advantage

To discuss the industry evolution, and in particular entry of new firms, we now introduce the idea that the profits per producer of a generation of a product depend on the amount of the producers in that generation. In particular, let the present discounted value of profits from successfully innovating and producing a new product in generation t be $\pi_t(N_t)$, where N_t is the measure of successful firms producing the product. We assume that $\pi_t(N_t)$ is decreasing due to competition, although it is sufficient that it is merely decreasing for large enough N.[7]The way we interpret $\pi_t(N_t)$ is that N_t firms sell differentiated products and earn positive profits despite (oligopolistic) competition. We take N_t to be a continuous variable, as in the case where firms are small, to avoid integer issues when we discuss equilibrium with free entry. We assume that the profits per generation of a product are the same for all firms, but that the incumbents in $t = 1$ generation have cost advantage in innovation to enter into the second generation, as discussed above.[8]

To describe equilibrium in the industry with free entry, we work backwards, first focusing on the de novo entrant's problem. A new entrant will choose to innovate as long as the expected return from innovation in the second generation product is greater than the cost. Using our previous analysis, a de novo entrant will make profits if and only if

$$\pi_2(N_2) - F - 2\sqrt{\pi_2(N_2)\theta} > 0$$

or

$$\sqrt{\pi_2(N_2)} > \sqrt{\theta} + \sqrt{\theta + F}.$$

We assume that profits in the second generation are large enough that, even if all first generation firms enter into the second generation market, some new entry in the second period would be required to keep entry in the

[7]Profits $\pi(N)$ may be increasing for small N for example due to positive network benefits between firms.

[8]Although we analyze here an industry with only two-generations of goods, the logic can be extended to the infinite horizon case, as in Mitchell and Skrzypacz [2015].

first period from being attractive. This assumption fits the experience of new products, where even when prior experience benefits firms entering in new submarkets, some de novo firms enter (Agarwal et al. [2004], Helfat and Lieberman [2002], Klepper [2002]). Under this assumption, for the industry to be in equilibrium, the amount of firms selling second generation products, N_2, must be large enough to so that expected profits per successful entrant are zero, i.e.,

$$\pi_2(N_2) = \left(\sqrt{\theta} + \sqrt{\theta + F}\right)^2. \tag{2}$$

Since $\pi_2(N)$ is decreasing, equilibrium N_2 must be decreasing in both θ and F.

With second generation profits in hand, we can analyze investment decisions of the incumbent firms (those which entered in the first generation) . Their optimal choice is as in (1), thus an incumbent's optimal innovative effort is:

$$q_2 = 1 - \sqrt{\frac{\theta'}{\pi_2(N_2)}} = 1 - \frac{\sqrt{\theta'}}{\sqrt{\theta} + \sqrt{\theta + F}}.$$

Recall that incumbent firms, by assumption have both lower F and θ denoted by F' and θ' (which are the source of their dynamic capability).

We turn to the first-generation innovation and assume that at this point all firms are symmetric. The expected profits of a successful first-generation incumbent, including profits on both generations of products, are given by

$$\begin{aligned} \Pi &\equiv \pi_1(N_1) + q_2\pi_2(N_2) - c(q_2) \\ &= \pi_1(N_1) + \left(\sqrt{\theta} + \sqrt{\theta + F}\right)^2 - F' - 2\left(\sqrt{\theta} + \sqrt{\theta + F}\right)\sqrt{\theta'}. \end{aligned} \tag{3}$$

For a forward-looking firm, investment in the first market generates expected profits given by

$$q_1\Pi - c(q_1).$$

So the optimal investment is

$$q_1 = 1 - \sqrt{\frac{\theta}{\Pi}}.$$

For a firm entering in the initial period, the reward is Π. Since the firm has not yet acquired the dynamic capabilities, its marginal cost level is θ. The firm does, however, foresee the benefits of dynamic capabilities in terms of the benefit of higher Π. The expected profits from successful entry in the first generation goods, Π, have to be high enough that on average expected profits of potential entrants are zero (free entry). The same is true for the profits of second generation goods for the de novo entrants in the second period.

As a result, N_1 is determined by free entry:

$$q_1 \Pi - c(q_1) = 0.$$

This means, that N_1 must be large enough that

$$\sqrt{\Pi} = \sqrt{\theta} + \sqrt{\theta + F}. \tag{4}$$

We can now make several observations about this industry equilibrium. First, as θ' is reduced, i.e. dynamic capabilities captured by variable costs are improved, both q_1 and q_2 increase. On the other hand, the impact of dynamic capabilities via reduced F', which in turn improves Π, come only through higher q_1. For example, suppose the dynamic capabilities accrue due to sharing of a common R&D resource between the first and second generation of products, reducing F. Then, an outside observer measuring innovativeness of firms would notice that they manifest themselves in increased innovation in the early generations of the products, but less in the later ones. In other words, dynamic capabilities of incumbents would manifest themselves in investment *before they actually acquire the dynamic capabilities*, making the measurement difficult. Second, we can use this analysis to characterize how, driven by endogenous entry, profits from the first generation relate to second generation profits, and how they are impacted by dynamic capabilities:

Proposition 3. *Suppose there are dynamic capabilities, i.e.* $F' \leq F$ *and* $\theta' \leq \theta$, *with strict inequality for at least one. Then in a free-entry industry equilibrium*

(a) $\pi_1 < \pi_2$ *and*

(b) π_1 *is increasing in both* F' *and* θ'.

Proof. (a) Since the marginal entrants in both generations do not have the dynamic capabilities and we assumed the cost of innovation is the same for both generations for such firms, the de novo entrants choose the same investments in both periods and hence $\Pi = \pi_2$ (this can be also verified algebraically comparing (4) and (2)). Expected Profits from innovation for the incumbents in the second period are strictly positive (since they enjoy cost advantage over the zero-expected profit new entrants) and are equal to $Z \equiv \left(\sqrt{\theta} + \sqrt{\theta + F}\right)^2 - F - 2\left(\sqrt{\theta} + \sqrt{\theta + F}\right)\sqrt{\theta'} > 0$. Since by (3) $\Pi = \pi_1 + Z$, the result follows from combining the two previous observations.

(b) Using $\sqrt{\Pi} = \sqrt{\theta} + \sqrt{\theta + F}$ in (3) and solving, we get:

$$\pi_1(N_1) = -\left(\sqrt{\theta} + \sqrt{\theta + F}\right)^2 + F' + 2\left(\sqrt{\theta} + \sqrt{\theta + F}\right)\sqrt{\theta'}.$$

The claim then follows by inspection. Intuitively, profits in the first generation are decreased because firms are willing to sacrifice early profits to obtain dynamic capability. The less dynamic capability advantage incumbents receive, the less entry in the first generation, and the reduced competition increases first-generation profits. □

Because incumbents benefit from dynamic capabilities in period two, they must pay for that asset with lower first-period profits. Moreover, the greater is the magnitude of the dynamic capability (i.e. the lower is F' or θ') the lower are first-period profits. Therefore innovative incumbents in situations where dynamic capabilities are large, seem to "rise from the ashes" in the sense of being especially unprofitable in their early stages and enjoying higher profits later.

Transforming dynamic capabilities, as measured by lower θ and F, may show up in the data on the number of firms eventually competing in the industry. Intuitively, dynamic capabilities impact both the intensive margin (innovation per firm) and the extensive margin (number of firms innovating) in equilibrium, the latter because lower costs encourage more firms to participate. These effects all arise because equilibrium effects are considered. The single-firm view of dynamic capabilities is that, since they make innovation into new products easier to achieve, they increase innovation by incumbents. However, to the extent that those capabilities are generated from a well-defined set of prior activities, we have illustrated here another effect: they cause firms to compete to acquire the resource in the first place. In the most extreme case, where dynamic capabilities reduce only the fixed costs of innovation, the only evidence of dynamic capabilities in the data on innovation would be the indirect effect on innovation by entrants hoping to acquire the dynamic capability.

In some situations, this equilibrium effect can lead to the incumbents investing even less than new entrants without the dynamic capability. For example, add a generation 0 product to our model and assume that firms that are successful in generation 0 would maintain their dynamic capability for generation 2, even if they skip generation 1. Then, if π_1 is sufficiently low, because of the aggressive entry of new firms hoping to acquire the dynamic capability that would help them be successful innovating generation 2 products, the incumbents in generation 0 products may optimally decide not invest at all in generation 1. Such optimal response would make them appear innovative only in response of competitive entry of generation 1 producers. If the dynamic capability from generation 0 can be lost with some probability, this effect can contribute to the explanation of lock-in and over-taking that we discussed above.

3.4 Heterogeneous Dynamic Capability to Transform

Two features of the transformation model are perhaps unsatisfying. First, for simplicity, all incumbents enjoyed the dynamic capability. Further, so far dynamic capabilities were associated with incumbency, which conforms to some data, but is certainly not the only source of dynamic capability. Both assumptions can be relaxed.

One might imagine that only some incumbents have the dynamic capability. Suppose instead of simply all incumbents having (θ', F') and all entrants having (θ, F), every incumbent firm drew a cost vector θ, F from a distribution $G(\theta, F)$. Experience-based dynamic capabilities allow for G to lead to better costs on average, but not always. All of the results from the prior subsection section pertaining to firms who have the dynamic capability apply.

Non-incumbents could also be endowed with some dynamic capabilities, for instance by drawing from some alternative distribution on (θ, F). Some entrants would therefore have the same advantage as an incumbent though the frequency might differ. The sensing capability described at length in section 3.1 is one which could equally well occur in entrants and incumbents.

4 Conclusions

This chapter shows that a simple economic model can be used to formalize some ideas of dynamic capabilities put forth in the strategic management literature. In doing so, the implications of different sorts of dynamic capabilities, and how they might arise in the data, are clarified.

This chapter highlights three main types of dynamic capabilities: Sensing; seizing and transforming. The first type is associated with higher profits regardless of the form that sensing takes. However, the effect on innovation is ambiguous and depends on what the firm can forecast better than competitors. For example, if the firm has superior ability to forecast the profits of a new product line, the firm will invest less on average in new products. The second type of dynamic capability allows firms to explore new products at a lower cost to exploitation of its existing products. It is associated with higher investment in innovation, but the impact on profitability of current products is harder to determine since it may increase or decrease current profits compared with a firm without this dynamic capability. The third type of dynamic capability is associated with higher investment in the first generation product and lower profits from that product. Thus, firms are willing to invest in acquiring the dynamic capability for the future generation product.

Our work provides a number of avenues for future research. First, the model is built using a specific cost function. We believe that this can be relaxed with little change to the main results. Future research could extend the model to determine whether different types of cost structures may lead to differences in results. Our applications take a very narrow view of these three types of dynamic capabilities. We hope that future research will expand the applications to model broader versions of dynamic capabilities. For instance, one could expand the model to better understand the value of sensing. In the case we developed, firms draw a precise signal about the costs or profits from the new product. However, it is possible that some firms may have both different signals of the values of their costs or profits along with differences in the precision of their signal. These differences may lead to differences in both the investment in innovation as well as the number of innovations.

In the models we present here, firms decide about innovation into new markets. However, in some industries, dynamic capabilities affect the firm's ability to profitably modify its production processes, for example integrate a cost-saving technology. A similar model can likely shed light on these capabilities as well. For example, if integration of a new technology is risky, one might reinterpret the "new product" in our models as introduction of the new technology. Working through that model, in order to see what might be different in dynamic capabilities in innovation in new products vs. production processes for existing products, is another possible channel for future work.

In the case of ambidexterity, our model focuses on the case where the firm is perfectly aware of the value of the new product and the cost of innovation. This leaves aside some of the issues that may lead to failures to transition to new markets or submarkets. There is a rich literature in strategic management that considers the interaction of environmental conditions on the value of ambidexterity including work on environmental uncertainty (Siggelkow and Rivkin [2005]), markets with increased competition (Bierly and Daly [2007]), asymmetric access to resources (Cao et al. [2009])), asymmetries in firm sizes (Lin et al. [2007]) as well as firm culture (Benner [2010]). Strategic management scholars have suggested that these may provide an explanation for some notable failures like Polaroid, Kodak and Smith-Corona (Danneels [2011], Sull [1999] and Tripsas and Gavetti [2000]). Our framework could provide a fruitful method to better understand how these may impact ambidexterity. Adding uncertainty would in a sense allow for combining both sensing and seizing in the same model and allow us to study potential nonlinearities proposed by Eisenhardt and Martin [2000]. One additional avenue would be to consider the impact of allowing exploration and exploitation to be complementary as suggested by Chen and Katila [2008]. This could be done by allowing the marginal impact of additional investment in exploitation on the profits of the firm's current offerings to include positive values. Finally, the model could allow for the firm's ambidexterity to vary across new submarkets to capture the view in Argote [2012] that some forms of existing knowledge may act as a disadvantage when exploring new submarkets.

There are natural linkages between the the dynamic capabilities that we have modeled separately here. There may be complementarities between them: firms need to not only identify opportunities, but also be able to invest in them appropriately and reconfigure when necessary. Managerial cognition might provide the link that allows the firm to both sense and seize new opportunities (Rosenbloom [2000],Taylor and Helfat [2009],Tripsas and Gavetti [2000],Helfat et al. [2007],Danneels [2011]): the firm's success in in transitioning from an established product to a newer product when facing a changing marketplace is often due to the manner in which the manager conceived of the firm's main business or if the manager misinterprets the value of the firm's current resources. O'Reilly and Tushman [2008b] emphasize the importance of senior managers' ability to ensure that new valuable opportunities are identified and when necessary to reconfigure and transform existing resources. Further, Helfat and Peteraf [2015] show how these constructs are related and how they affect firm performance. Integrating these capabilities into a single analysis in order to better understand the linkages between them is another avenue for future work.

Our work has important implications for empirical research. As Helfat et al. [2007] point out, there is a potential tautology in identifying dynamic capabilities purely through performance; they suggest a two-step process of identifying an intermediate outcome which can then be linked to firm performance outcomes. Our models show that the subtle interactions due to equilibrium outcomes can make the two-step process difficult. For example, Stadler et al. [2013] use lower costs or higher value of output as a proxy for dynamic capabilities. In our setting, in equilibrium, dynamic capabilities might not even lead to higher levels of these indices, and in fact may lead to identifying firms with a dynamic capability as having none. Further development of models of dynamic capabilities will further our ability to identify dynamic capabilities empirically.

Incorporating ideas from the dynamic capabilities literature in formal models will help to bridge the strategic management and economic literatures, allowing for these ideas to be further developed and explored. By starting this conversation, we hope to identify new avenues for research in both theoretical and empirical work. We are optimistic that this will benefit both communities.

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