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Entry, Investment and Exit in Response to an Industry Shock: Effect of Firm Limited Foresight and Myopic Discounting

James A. COSTANTINI 2010/70/ST Entry, Investment and Exit in Response to an Industry Shock:

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Abstract

The question of whether firms may successfully adapt top a change in technology has led to divergent perspectives. I consider this issue in the context of a model of firms in an industry facing a shift from a legacy to a new technology. I allow for firm heterogeneity through entry and gradual accumulation of resources corresponding to the technologies. I show this is sufficient to lead some incumbents not to adapt and others to adapt, with consequent effects on entry. Further, I find incumbent firms adapt their strategy at different points in time and entry varies over time due to spikes and periods with limited entry, as firm strategy is partly determined by inter-temporal considerations. Indeed, I highlight how the degree of myopic discounting of the future affects firms flexibility to respond to the shock by changing the extent of firm specialization in the legacy resource, and foresight of the forthcoming shock affects the spread over time of firm response, particularly for large incumbents. Overall, the results suggest the value of considering not just the long-run change due to a shock to an industry but also the transition over time, which is importantly shaped by firm myopia and foresight.

Keywords: Firm and Industry Dynamics; Foresight; Myopia; Resources; Entry; Exit

1 Introduction

Understanding how a firm responds to a technology shock has received much attention. Within an industry, a change in technology may lead to a long run shift from firms primarily using the existing legacy technology to firms using a new technology. A major focus is on which firms comprise the industry in the long-run; in particular, whether these are current incumbent firms. On this issue a wide range of perspectives has been highlighted. On the one hand incumbent flexibility and adaptability has been emphasized (Tushman and Romanelli 1985, Tushman and O'Reilly 1997), but on the other hand incumbent firms are viewed as subject to substantial inertia and thus not likely to successfully adapt (Hannan and Freeman 1977). In between these extremes, incumbent firms may be viewed as not being able to adapt successfully the existing organization but nonetheless able to establish a new organizational unit to address the opportunities presented by the new technology (Bower and Christensen 1995, Christensen 1997). Also, there is recognition that incumbent firms may be best served adapting yet remaining focused on the legacy technology, not necessarily switching to the new technology (Dew, Goldfarb and Sarasvathy 2006, Adner and Snow 2009). Hence, there is a rich set of alternative responses for firms to pursue when facing a technology shock.

Indeed, the response to a common shock need not be the same across incumbent firms due to some degree of heterogeneity across firms within the industry. I consider the shock render the new technology superior to the legacy technology but without making the legacy technology immediately obsolete, which includes a broad range of technological changes, for instance, the development of an internet-based service as substitute for a current product, such as for news, movie rentals or books, or change a key underlying technology, such as the switch from sail to steam in shipping (Foster 1986, Cooper and Smith 1992, Adner and Snow 2009). Firms in the industry may differ in the extent of resources accumulated to exploit the legacy technology. Also, some firms may have made exploratory investments in the new technology, which may be leveraged once the firms know that the new technology is indeed promising. Consequently, understanding how the pattern of responses to a common technological shock may differ across firms within an industry is important, as it need not be optimal for firms to respond in a similar manner.

Not only, firms may also differ in the timing of response to the shock. For instance, amongst

incumbent firms that do switch to the new technology, the extent of legacy resources and initial investments in the new technology may also influence when the firm chooses to focus investment on the new technology. In addition, the pattern of entry is unlikely to be uniform over time, as potential entrants face a competitive landscape evolving due to incumbent response that varies across firms and over time. Hence, firm response to a technological shock is in part determined by inter-temporal considerations that include weighting current and future returns from alternative strategies and forming a view of future conditions in the industry.

However, the issue of how forward-looking firms are in setting strategy is not at all settled. In general there is recognition that strong assumptions of rational, forward-looking policy setting place onerous burdens on firm decision making, which do not seem reasonable given the reality of strategic decision-making. Yet, assumptions of highly myopic policy setting may not reflect some degree of firm response in anticipation of future conditions. Consequently, there is interest in considering intermediate assumptions so as to have a better match between models and empirical patterns and as there is concern that strategy recommendations based on the more extreme assumptions may not be robust (Ghemawat and Cassiman 2007, Ghemawat and Levinthal 2008, Gavettti and Levinthal 2004, and Sterman, Henderson, Beinhocker and Newman 2007). In the context of a technology shock the extent to which firms set strategy in a forward-looking manner has been highlighted as a relevant factor, in addition to other demand and supply side features of the situation (Tushman and Anderson 1986, Christensen 1997, Tripsas 1997, Adner 2002, Adner and Snow 2010). In particular, two relevant aspects of setting strategy in a forward-looking manner are: the degree to which firms place weight on current versus future outcomes (Laverty 1996, Levinthal and March 1993), which I refer to as myopia; and how far in advance of the shock occurring are firms aware of the shock and thus able to respond in anticipation (Gavettti and Levinthal 2000, Gavettti, Levinthal and Rivkin 2005, Makadok and Barney 2001), which I refer to as foresight.¹

In this paper I develop a formal model in which firm strategies within an industry in response to a common technology shock encompass the range of potential strategies highlighted above. In

¹The terms foresight and myopia are often used with varying, though related, meanings. I use the terms foresight and myopia with fairly narrowly defined meanings, which are distinct. To illustrate, a firm may myopically heavily discount future outcomes while having some foresight of future developments: for instance, this could be a firm with good planning processes but with managerial incentives skewed to emphasize near-term results. Alternatively, a firm may have limited foresight but nonetheless place high weight on long-run outcomes: for example, this could be a relatively unsophisticated family-run business that does care substantially about passing on the firm to the next generation.

the model firms are heterogeneous and the extent to which firms set strategy in a forward-looking manner may be varied. I introduce firm heterogeneity by having entry into the industry, with entrants starting with relatively low levels of resources and growing these over time. Firms choose whether to accumulate one or both of two resources, one related to the legacy technology and the other to the new technology. Thus at any point in time firms may vary in the level and mix of resources accumulated, reflecting the combination of firms at different stages of resource accumulation.

I model the technology shock as a change in how fast firms may accumulate the resources. Before the shock the legacy resource is easier to accumulate than the new technology resource. After the shock this is reversed. The aim is to represent in a stylized manner a disruptive technology that leads to the emergence of a replacement technology but not an immediate obsolescence of the prior technology. In the long-run there is a transition from an industry in which most firms accumulate the resource related to the legacy technology to an industry in which most firms accumulate the resource related to the new technology. Hence, an incumbent firm responding to the shock an incumbent firm faces a choice of whether and when to switch to accumulating the new resource. The strategy response may vary across incumbent firms due to heterogeneity in resource levels. In turn, entry patterns may vary over time, as the attractiveness of entry in part depends on incumbent strategy choices. Consequently there may be a relatively complex industry transition, even though the initial trigger is a shock common to all firms.

A first contribution I make is to highlight how the heterogeneity in legacy and new technology resources is sufficient to generate different types of responses in a competitive context even though all firms face the same shock. I find that amongst incumbent firms with substantial legacy resources the extent of initial investments in the new technology resource result in firm response varying from remaining focused on the legacy resource through to switching to the new technology resource as soon as the firms know of the forthcoming shock. In contrast, most incumbent firms with moderate levels of legacy resource switch strategy once the shock takes effect, irrespective of the degree of foresight of the shock. I highlight that myopia has two effects that reduce incumbent flexibility in response to a shock. Myopia affects investment decisions once the shock occurs and, not surprisingly, with more substantial myopia more incumbent firms remain stuck on the legacy resource. In addition, the extent of myopia affects the industry structure before the shock is known about. With more substantial myopia more firms specialize in one resource leaving them less able to adapt once the shock takes effect, as compared to firms that invest in both resources. Thus myopia affects flexibility to a shock by conditioning investment patterns before the shock, not just in response to the shock.

With regards to entry, I find there may be two spikes in entry, one some time after firms first know of the forthcoming shock and one when the shock takes effect, with typically little or no entry in between. Longer foresight brings forward the first spike, but with diminishing effects as foresight increases. A greater degree of myopia reduces the spikes, in particular the spike in anticipation of the shock. Hence, the degree of foresight and myopia are sufficient to affect the extent of first-mover advantage in entry. As a consequence, for a potential entrant other firm's foresight and myopia in part determines the attractiveness of entry at a point in time, even though there may be little of no effect on the long-run change in the industry.

More generally, I highlight the importance of considering the evolution of an industry in response to a shock not only by considering what the long-run change is likely to be but also the transition over time. Indeed, I find that the more firms have some foresight and take a long-term perspective, the more varied the firm dynamics during the transition.

A second contribution is to develop a formal model that comprises three levels of analysis: resources, firms and industry. The levels of analysis are linked, as firm choice of which resources to accumulate is determined by the costs of resource accumulation, how firms may combine resources in production, and the product market competition resulting from the choices of all firms in the industry, including whether to enter or exit the industry. In this regard the paper aims to contribute to the growing literature developing formal models to address strategy issues, in line with the call by Adner, Polos, Ryall and Sorenson (2009) and Ghemawat and Cassiman (2007). A key feature of the model set up is that the response of firms to a shock is tracked over successive time periods, as firms adapt to the shock and its knock-on effects. The model enables focus on the firm dynamics during the transition, not just the initial and final long-run equilibrium. The model structure could be leveraged to address other types of industry transitions due to a variety of types of shocks.

Following I describe the model set up, and then the numerical solutions, with detailed description of the algorithm in the appendix, for the firm strategies before the shock is known and the firm response to the shock.

2 Model Setup

Before describing the specific model set-up, I highlight four key aspects of the model that provide points of linkage and distinction relative to other related models. A first aspect is how the model allows for variation in key aspects of firm forward-looking strategy setting: the extent of myopic discounting of future profits and foresight of the shock. Myopic high discounting of the future, with consequent emphasis on the near-term, could reflect a range of institutional arrangements, economic incentives, or cognitive reasons (Laverty 1996, Levinthal and March 1993), with temporal myopia of a focal firm, absent competitive interactions, affecting policy choices (Miller 2002). I refer to the extent of discounting of future profits relative to current profits as myopia. The extent to which firms have foresight of a forthcoming shock clearly depends on the type of shock considered: a natural disaster may have no warning, whereas some institutional changes may be announced well in advance, such as a deregulation. In this regard technology changes may vary substantially, though likely to often include some degree of anticipation. For instance, firms may purposefully invest to acquire relevant information of strategic value (Makadok and Barney 2001) or engage in activities to help envision the future (Gavettti and Levinthal 2000, Gavettti, Levinthal and Rivkin 2005), thus facilitating some degree of foresight and factoring in of future shocks and competitive dynamics.

A second aspect is firms' strategy choice set. I have incumbent firms within each time period choose which of two resources to accumulate, or whether to exit. Potential entrants choose whether to enter. As firms set strategy based on some degree of forward-looking considerations, the strategy choice is effectively about the pattern of resource accumulation over time. The gradual accumulation of resources is in line with a stream of literature that emphasizes how resource accumulation takes time due to time-compression diseconomies, uncertain outcome of investment, and effect of competitive interactions (Barney 1986, Dierickx and Cool 1989, Pacheco-de-Almeida, Henderson, and Cool 2008, Pacheco-de-Almeida and Zemsky 2006).

A third aspect is that I introduce firm heterogeneity by having ongoing entry, gradual accumulation of resources, and eventual exit of firms. This generates firm dynamics in line with empirical evidence (Dunne, Roberts and Samuelson 1988, Bartelsman, Scarpetta and Schivardi 2003), and results in a distribution of firms across resource levels, as at any point in time some recent entrants have low resource levels, whereas some long established incumbents have accumulated substantial resources. Consequently, the response to a common exogenous shock potentially varies across firms.

A fourth aspect is the performance consequences of resource accumulation. I have the profits generated within a time period depend on the distribution of resources across firms in the industry: hence, the value of resources depends on product market competitive conditions (Barney 2001). The competitive landscape, the distribution of firms across resources, evolves endogenously due to firm entry, investment and exit. Hence, firm strategy is affected by competitor strategy choices.

Hence, relative to the stream of literature emphasizing the complexity of choices within firms and the extent to which firms achieve optimal policy configurations over time (Porter 1996, Rivkin 2000, Ghemawat and Levinthal 2008, Porter and Siggelkow 2008), I have firms face a simpler strategy choice but over a competitive landscape that evolves based on the shock to the industry and the endogenous strategy choices of other firms. In contrast, NK based models typically do not have competitive interactions affect firm strategy, with Lenox, Rockart and Lewin (2007) an exception in combining a NK model and Cournot competition to consider long-run industry evolution. Nonetheless, my model set up shares with the typical NK set-up the absence of firm-to-firm oligopolistic competitive interactions. I abstract from oligopolistic interactions by having firm performance depend on the distribution of resources across firms in the industry, and not the specific resource configuration of particular firms. Typically, oligopolistic competitive interactions with a dynamic element rapidly become very complex, as firm strategy is typically set with high degree of rationality and thus full consideration of ensuing firm-to-firm competitive interactions over time (Ericson and Pakes 1995, Pacheco-de-Almeida and Zemsky 2006, Zott 2003, Casadesus-Masanell and Yoffie 2007). An exception is provided by Sterman, Henderson, Beinhocker, Newman (2007) that in a duopoly setting relax the assumption on the accuracy of firm forecast of future demand, finding that this substantially affects optimal firm policy. In contrast, the literature on industry evolution often has firm policies affected by current performance, with current performance in part driven by concurrent competitive interactions, but not by forward-looking considerations (Jovanovic 1982, Klepper 1996, Knott 2003, Jacobides, Winter and Kassberger 2007). In part, this reflects a focus on the emergence and long-run development of new industries, which are situations in which firms may be least expected to have well-formed perspectives on the future evolution of the industry. In contrast, I consider the situation of an established industry that faces a shock: consequently, some

degree of forward looking strategy setting is of relevance to consider.

In the model there are three inter-connected levels, illustrated in Figure 1: firms are characterized by a combination of resources; the resource combination determines the firm's production in a time period; and firm profits in a time period depend on the competitive landscape faced in the product market, with the competitive landscape determined by the distribution of resources across other firms. Below I first describe the resources available to firms. Next I focus on the firm strategy decisions relating to resource accumulation, exit and entry, and how foresight and myopia affect these policy choices in the model. Then I describe the production and product market competition set-up that determines firm profits in a given time period. Finally, I describe the equilibrium conditions that pertain in response to the shock. I emphasize those parts of the model that are most relevant to consider the effect of foresight and myopia on firm response to a technology shock that affects resource accumulation, with the appendix containing specific functional forms.

Resources

The firms in the industry are distinguished by the stock of the firm's resources at a point in time, denoted by (r_{1t}, r_{2t}) : hereon I omit the time subscript where this does not cause confusion. In each time period, each resource depletes at rate γ and the firm may invest to increase resource 1 or 2 or neither. The benefit of investing is an η_{1t} percent growth in the stock of resource 1, at cost I_1 , or η_{2t} for resource 2, at cost I_2 . Hence, the evolution of resource 1 stocks, and similarly for resource 2, is:

$$r_{1t+1} = \begin{cases} (1-\gamma)r_{1t} & \text{if no investment in resource 1} \\ (\eta_{1t}-\gamma)r_{1t} & \text{if invest in resource 1} \end{cases}$$
(1)

A firm may not grow faster than η_{1t} or η_{2t} within a time period: a simple, strong form of time-compression diseconomies of resource accumulation. I assume that firms stop accumulating resources at some level due to diminishing returns. Also, the scarcity and inimitability of a firm's resource position reflects the evolution of the competitive landscape, which depends on the rates η_{1t} and η_{2t} at which firms may grow resources, the rate γ at which resources deplete, as well as the risk of exit and potential entry. The resource accumulation process is kept relatively straightforward as the focus is on how firms respond to a shock that changes the relative ease of resource accumulation. The choice of investment could be generalized, for instance to allow simultaneous investment in both resources, or with choice of investment level. Despite being relatively simple, this set up allows the firm to choose, over successive time periods, alternate investment strategies: for instance, to invest in just one resource, or to first invest in one resource and then the other so as to accumulate both resources.

Firm strategy decisions

The firms set strategy each period based on considering the effect of alternative policy choices on the value of the firm $V_t(r_{1t}, r_{2t})$. At the start of a time period, firms decide whether to whether to stay in the industry or exit by comparing the value of continuing, $V_t^C(r_{1t}, r_{2t})$, to the value of exit which is set to zero for simplicity:

$$V_t(r_{1t}, r_{2t}) = \max\{V_t^C(r_{1t}, r_{2t}), 0\}$$
(2)

For firms choosing to continue in the industry, the strategy choice is whether to invest in one of the resources or not. Once these policies are set, the firms remaining in the industry plus any entrants compete in the product market, based on current resource levels, which results in the firm generating per-period profits of $\pi_t(r_{1t}, r_{2t})$. At the end of the period investment choices take effect that determine resource stocks for the next period. Also, all firms are subject to an exogenous death shock with exogenous probability δ of exit, independent of resource levels. The firms then start the next period. Firm strategy choices satisfies the Bellman equation:

$$V_{t}^{C}(r_{1t}, r_{2t}) = \pi_{t}(r_{1t}, r_{2t}) +$$

$$\max_{\substack{\{\text{Not invest;}\\ \text{Invest in } r_{1};\\ \text{Invest in } r_{2}\}} \begin{cases} [+\beta (1-\delta) V_{t+1}((1-\gamma)r_{1t}, (1-\gamma)r_{2t})] & \text{if not invest} \\ [-I_{1} + \beta (1-\delta) V_{t+1}((\eta_{1t} - \gamma)r_{1t}, (1-\gamma)r_{2t})] & \text{if invest in resource 1} \\ [-I_{2} + \beta (1-\delta) V_{t+1}((1-\gamma)r_{1t}, (\eta_{2t} - \gamma)r_{2t})] & \text{if invest in resource 2} \end{cases}$$
(3)

Hence, the distribution of firms in the industry across resource levels will be divided into regions depending on which of four strategies firms pursue: exit; continue and not invest; continue and invest in resource 1; or continue and invest in resource 2. The policy choice varies across resource levels: for instance, a sufficiently high level of resources leads to no further investment due to diminishing returns, whereas a sufficiently low level of resources results in exit.

Firm myopia is represented by the rate β used by firms to discount future profits. Limited myopia is represented by β close to 1, whereas substantial myopia by lower β .

The shock affects the time path of the resource growth rates. Before the shock, $\eta_{1t} > \eta_{2t}$ and after the shock the reverse, with $\eta_{2t} > \eta_{1t}$. Firm foresight is captured by how much in advance of the shock the firms are aware of the forthcoming shock. I set the shock to take effect at the start of time period t = 1. Hence, for instance, a foresight of eight time periods would correspond to firms knowing at the end of period t = -8 that from t = 1 onwards the resource growth rates will reverse. With some foresight of the forthcoming shock firms may change strategy in the current period in anticipation of the change. As this anticipation effect depends on an inter-temporal consideration it also depends on the degree of myopia, β . Consequently, there are a joint effects due to the extent of foresight and myopia, not just separate effects.

For potential entrants, at the start of each time period the strategy choice is whether to enter the industry at that point in time. If entering, an entrant pays a sunk cost of entry, S, and then discovers its initial resource levels, which are a random draw based on a probability distribution $G_E(r_1, r_2)$ that does not change over time. Thereon, entrants are indistinguishable from incumbent firms with the same resource levels. Averaging over possible initial resource configurations, a prospective entrant faces an expected net value of entry

$$V_t^E = \int_{r_1', r_2'} V_t(r_1', r_2') dG_E(r_1', r_2') - S$$
(4)

The entry decision is forward-looking in that a prospective entrant considers the value V_t , and not, for instance, just current period profits. Thus, entry may occur in response to an anticipated shock to the industry. As with incumbents, the degree of myopia and foresight, which affect the value V_t , determine the extent to which entry decisions reflect future changes in the industry.

Firm profits within a time period: Product market competition

The link from resources to profits comprises two steps, with key aspects highlighted here and with specific functional forms provided in the appendix. A firm's resource levels determine the marginal cost of production as given by the firm's production function. The resources are assumed to be partial substitutes: hence firms benefit from specializing in one resource. Also, an increase in either resource level reduces marginal cost: hence firms benefit from accumulating both resources. Thus investment choices reflect both static trade-offs, due to resource substitutability, and dynamic trade-offs, due to resource accumulation. In addition firms incur a fixed cost each period. This results in exit of firms with sufficiently low resource stocks, as current profits are negative and substantial investment over time would be required to accumulate resources to generate positive future profits.

Firms strategy choices lead to a distribution of resource levels that determine profits generated in the product market for each resource combination. In turn, expected profitability feeds back to affect firm investment, entry and exit decisions. Hence, the value of the firm's resources is endogenous, as driven by the profits generated in the product market in current and future time periods. Also, the competitive landscape is endogenous as changing due to the strategy choices of the firms. I use a demand system which leads to monopolistic competition which has the attractive feature that from the perspective of a firm the competitive landscape is summarized by a price index P_t , in effect a sufficient statistic from the perspective of the firm for the current level of competitive pressure. A firm need only consider the change in the price index P_t , and not the specific moves of each other firm as in oligopoly settings, to factor in the changing competitive landscape when setting strategy. This feature of the model greatly reduces the potentially complex feedback from the choices of individual firms to the choices of other firms while still preserving competitive interactions through the endogenous evolution of the competitive landscape.

Equilibrium conditions

Three equilibrium conditions ensure there is consistency across firm choices and over time. The first condition requires incumbent firms to set strategy in a manner consistent with the firms maximising value, satisfying (2) and (3). The second condition requires entry to be set to reflect the value of entry given by (4) and the unbounded pool of potential entrants. This free entry condition means that before the shock is known, in an initial stationary equilibrium, there is sufficient entry to drive the value of entry to zero and to offset ongoing exit.² In contrast, in response to the shock, the

 $^{^{2}}$ If the value of entry were positive there would be additional entry until the value of entry falls to zero, since there is an unbounded pool of prospective entrants. If the value of entry were negative, no firms would enter yet some firms would exit due to the exogenous death shock: this would lead to a net decline in the total number of firms which is

industry may evolve through periods with the value of entry negative leading to zero entry, as there is no requirement for the number of firms to be stable over time. The third condition is that the distribution of firms over resource levels generated by the firm strategy choices yield the same price index P_t that firms used to set strategy.

The equilibrium conditions do not impose stability over time, even though ensuring consistency across the firm choices and over time, and hence the equilibrium may well include rich firm dynamics and major changes in the industry as firms respond to the shock. I solve for the equilibrium based on numerical solutions, as due to the presence of fixed and sunk costs no analytical solution is possible. In the appendix, I describe the algorithm used to generate the solutions and include a more formal statement of the above equilibrium conditions.³ Next I discuss the numerical solutions.

3 Numerical Results

I first consider firm strategies and the distribution of firms across resource levels for a scenario with firm myopia set at $\beta = 0.95$ and with firms having a two year foresight of the forthcoming shock, which corresponds to eight time periods as I set each period to be a quarter. Following this I consider the effect of different degrees of myopia and foresight.

I set the growth rate of resources initially at $\eta_1 = 25\%$ and $\eta_2 = 5\%$ per year (Figure 2). I set the other parameters of the model, Table 1, with the aim of reflecting the typical patterns of firm dynamics within industries. The growth rates and other parameters are such that for an entrant to accumulate a resource to the point of diminishing returns takes about 4 years at 25% growth and 14 years at 5% growth.

Firm dynamics before firms know of the shock

Before firms know of the forthcoming shock firms expect the rates η_{1t} and η_{2t} of resource accumulation to be constant over time. Also, other parameters do not change over time. These pre-shock

not consistent with a stationary equilibrium.

³In equilibrium the firms respond to the shock and there is convergence over time towards the new long-run industry equilibrium. In the model successive time periods are distinct from successive iterations performed by the algorithm to converge to equilibrium. Each iteration of the algorithm corresponds to a guess as to the transition path of the overall price index P. Successive iterations seek a transition path that better fits the equilibrium conditions. I iterate until sufficiently close to equilibrium conditions. These methods have also been used to study the effects of credit constraints, trade opening, and other types of shocks on industrial evolution (Costantini 2006, Costantini and Melitz 2008, and Costantini 2010).

conditions are assumed to have been going on long enough that the industry has reached a stationary equilibrium in which firm strategy choices conditional on resource stocks, including entry and exit, are invariant over time. For instance, the set of resource combinations that lead to investment in resource 1 do not change. Hence, the overall number of firms and distribution of firms is constant over time, which generates a stable price index. Despite the aggregate stability, the stationary equilibrium comprises substantial firm dynamics, as there is entry, exit, and investment in resources.

Across resource levels there are four types of strategy regions corresponding to the strategy choices of exit, invest in resource 1, invest in resource 2, or not invest, as illustrated in Figure 3 panel (a). Over time a firm's resource stocks may change, which may lead to a change in strategy, such as from investing in resource 1 to investing in resource 2. In Figure 3 panel (a) this corresponds to a growth path that crosses regions. Next I highlight key features of the stationary state through a set of remarks.

• Firm strategy is generally to accumulate first resource 1. Subsequently, the firm accumulates resource 2 if the firm's level of resource 2 remaining after accumulation of resource 1 is sufficiently high.

The exit region is the combination of low resource levels for resource 1 and 2 (Figure 3, panel (a)). Firm strategy for most firms just outside the exit region is to accumulate more of resource 1, the resource with the higher growth rate, and to let the other resource stock deplete.⁴ Over time these firms become increasingly specialists in just resource 1, eventually reaching the point of diminishing returns to further investment in the accumulation of resource 1. At this point, firm strategy depends on how much of resource 2 remains after ongoing depletion. If the stock of resource 2 is low enough, then the firm strategy is not to invest. If the stock of resource 2 remains sufficiently high, then the firm now starts to invest in this resource, again up to the point of diminishing returns. At high levels of both resources there is a no investment region due to diminishing returns to resource accumulation. In summary, there are two typical growth paths of

⁴The exception are firms just outside the exit boundary with high resource 2 specialization: these firms first accumulate more resource 2 before starting to accumulate resource 1. For these firms immediately accumulating resource 1 is not optimal as the resulting growth trajectory would risk taking the firm into the exit region due to ongoing depletion of resource 2.

entrants: accumulation of one resource (specialist), and accumulation of first one resource and then the other (initially a specialist and eventually a generalist).

• The shape of the exit region primarily reflects the degree of resource substitutability, and most entrants are small with resource combinations close to the exit boundary.

The exit region has a fairly square shape due to the degree of resource substitutability (Figure 3, panel (b)). The initial random distribution of entrants' resource levels places some entrants in the exit region, with these firms exiting immediately (and hence not shown in the figure), and the other entrants (shown in the figure) fairly close to the exit boundary. Thus, the simulations replicate the robust empirical findings that recent entrants are on average smaller, and exhibit higher exit rates than incumbent firms.

In a stationary equilibrium, each successive cohort of entrants has the same initial distribution and follows the same strategies as prior cohorts. The summation of firms surviving from successive entry cohorts comprises the distribution of firms across resource levels in a time period.

• The distribution of firms across resource levels has two main peaks: one with firms with high level of just resource 1; and the other with firms with high level of resource 1 and moderate level of resource 2.

The distribution of firms across resource stock levels, Figure 3, panel (c), comprises mostly firms that have accumulated enough of resource 1 to reach the point of diminishing returns: the mass of firms is along the upper edge of the region of investment in resource 1. Due to the investment patterns described above, within this mass there is a peak of firms specialized in just resource 1 and a peak of generalist firms that have some of both resources.

The shock leads to a switch in the growth rates of resources 1 and 2. Consequently, in the longrun the firm policies and firm size distribution are a mirror-image of those in Figure 3, reflected along the 45° line. Hence the transition requires both the disappearance of the mass firms with high resource 1, as well as the emergence of an equivalent mass of firms with high resource 2, achieved through a mix of incumbent exit and adaptation to the shock, and growth of new entrants. I next characterize this transition over time from the initial stationary state to the post-shock long-run stationary state.

Incumbent response to shock to ease of resource accumulation

In this section I highlight the patterns of incumbent response with firm myopia set at $\beta = 0.95$ and with firms having a two year foresight of the forthcoming shock: in subsequent sections I consider the effect of different levels of foresight and myopia on incumbent response and entry patterns. Once firms know the shock is forthcoming firms reset their future expectations for the rates η_{1t} and η_{2t} of resource accumulation. No other parameters change. The shock is unexpected by firms, as their strategies up to then presume a continuation of the stationary equilibrium. Though the equilibrium conditions hold throughout the transition from the initial stationary equilibrium through to eventual convergence towards the new long-run stationary equilibrium, this does not necessarily mean the transition is smooth or gradual.⁵

With foresight of the shock firms know of the future change in ease of resource accumulation. Although there is no immediate effect on resource accumulation, some of the firms start to adapt strategy once the shock is known but before the shock takes effect: that is, from when firms know of the shock at the end of t = -8 to when the shock takes effect at t = 1. The evolution of firm strategy choices and of the distribution of firms is in Figure 4 with, due to space limitations, selected time periods shown: the periods before firms know of the shock; the first period after the forthcoming shock is known (t = -7); mid-way through the anticipation period (t = -3); when the shock takes effect (t = 1); eight quarters after the shock (t = 9); and the final post-shock long-run stationary state. I next highlight key features of how firm strategies evolve over time.

• Before the shock takes effect (t = -7 to t = 0) incumbent strategies start to shift immediately, but not for all firms. Amongst large incumbents, which have already accumulated resource 1, an increasing proportion of firms start to accumulate resource 2 as the shock becomes more imminent. However, firms specialized in resource 1 continue to focus on just resource1.

Two sets of firms change strategy in anticipation of the shock. One set are firms that have accumulated resource 1 and have some of resource 2. Once the shock is known, a greater proportion start to invest in resource 2: In (Figure 4 panel (a), contrasting the period before the shock is known

⁵In the stationary equilibrium, the resulting distribution of firms must be the same as in the prior period. The net effect of entry, investment and exit is to leave the firm size distribution unchanged over time. In contrast, in response to the shock, entry and firm strategy, conditional on resource levels, may vary over time and hence the distribution of firms may also change over time.

to t = -7, the top left not invest region shrinks). For these firms once the shock is known it is worth starting to invest in resource 2 even if at the current slow growth rate, as this builds up the stock of resource 2 which makes subsequent investment at the faster growth rate, after the shock takes effect, more valuable. In particular, note that for these firms the alternative is not to invest, as these firms have already accumulated a high level of resource 1.

The second set of firms to change strategy are those with very low levels of resource 1 and high levels of resource 2, initially a small set of firms. As the shock makes long-run accumulation of resource 1 harder, firms with a very small initial base of resource 1 now do not start to invest (Figure 4 panel (a), contrasting the period before the shock is known to t = -7, the bottom-right not invest region expands).

• Once the shock takes effect more incumbent firms switch strategy; in particular smaller firms that had only partially accumulated resource 1 prior to the shock. However, incumbent firms that were initially specialized in resource 1 may never switch to invest in resource 2.

Once firms know of the shock, smaller firms, with limited stocks of resources 1 and 2, generally continue to invest in resource 1, taking advantage of the higher resource growth rate, until switching to resource 2 once the shock takes effect. Though with foresight of the shock, these firms do not switch strategy in anticipation of the shock taking effect, the dynamic benefit of fast resource accumulation of resource 1 and then resource 2 outweighs the static benefit of resource specialization.

The incumbent firms specialized in resource 1 may never switch to start investing in resource 2. Hence there is a remaining, but declining in size due to ongoing exit, peak of resource 1 specialist firms even after the shock has taken effect (Figure 4, panel (b) at t = 9).⁶

• In summary, the extent and timing of response to the common shock varies across incumbent firms. Larger incumbents, with high levels of legacy resource 1, respond with a wide range of timing dependent on the stocks of resource 2, from responding in anticipation to never switching focus to invest in resource 2. Smaller incumbents, with moderate levels of resource

⁶With more myopic firms more of the peak of specialist firms remains focused on resource 1. With less myopic firms all of the firms may eventually switch to focus on resource 2, nonetheless, switching strategy after the incumbents with high stocks of resource 1 and some stocks of resource 2.

1, mostly switch strategy to invest in resource 2 during a narrow window of time around the time the shock takes effect.

Incumbent response: effect of different levels of foresight and myopia

The prior section highlights how within an industry there may concurrently arise a range of incumbent response to a common shock. In this section I consider how different levels of foresight and myopia affect this pattern of incumbent response. In the subsequent section I consider entry patterns.

A summary of incumbent response is the proportion of firms investing in resource 2, versus resource 1 or not investing, as shown in Figure 5 panel (a). With some foresight, as discussed above, during the time from when firms first know of the shock through to when the shock takes effect a rising proportion of firms switch to invest in resource 2. Once the shock takes effect the proportion of firms investing in resource 2 first rises sharply and then gradually declines to the long-run proportion. Hence, there is a peak of firms investing in resource 2 around the time the shock takes effect.

Consequently, a measure of the effect of foresight and myopia is the proportion of firms investing in resource 2 just before the shock takes effect, as this captures the extent of the anticipation effect in shaping incumbent strategies, in particular for large incumbents. Figure 5 panel (b) shows how this measure varies with different degrees of myopia and foresight.⁷

With no foresight this is the same proportion of firms that invest in resource 2 before the shock is know to firms. A moderate degree of foresight increases substantially the proportion of firms investing in resource 2, however further increases in foresight bring diminishing effects: in Figure 5, at a given level of myopia, the lines tend to become horizontal with longer foresight, especially with stronger myopia. Once the foresight is sufficiently in advance of the shock even if firms know about the forthcoming shock it is too remote to affect current strategy, due to the combination of discounting and the ongoing risk of exit.

The effect of more limited myopia on the proportion of firms investing in resource 2 depends on the extent of foresight. With no foresight, there is a monotonic pattern with more substantial firm

⁷For reference, the range of discount factors used result in a wide range of discounting of year 3 profits of $(0.95)^3 = 0.86$ versus $(0.60)^3 = 0.22$, and year 10 profits by $(0.95)^{10} = 0.60$ versus $(0.60)^{10} = 0.01$. The foresight is shown for zero to seven years, as this is sufficient to highlight key patterns.

myopia leading to a lower proportion of firms investing in resource 2: in effect, a greater proportion of firms are specialists in resource 1. With some foresight, the pattern may not be monotonic: in Figure 5 this is seen by the crossing of the lines for $\beta = 0.90$ and $\beta = 0.95$. The reasons for this is that entry patterns vary with foresight and myopia. A wave of entrants once in the industry typically invests in a different manner to large incumbents: hence, the proportion of firms investing in resource 2 is sensitive to when waves of entry occur, which is the focus of the next section. Before turning to consider entry patterns, in summary the effect of foresight and myopia on incumbent patterns is:

• The proportion of firms investing in resource 2 in anticipation of the shock taking effect increases: with greater foresight but with levelling off of effect as foresight lengthens, at a given level of myopia; or with more limited myopia, if there is no foresight. With some foresight, a more limited myopia may not increase the proportion of firms investing in resource 2 as with less myopic firms the entry wave may occur earlier and such entrants initially invest in resource 1.

Entry patterns: effect of different levels of foresight and myopia

I first compare entry patterns at different levels of myopia, with foresight fixed, and then at different durations of foresight, with myopia fixed. The entry decision is set forward-looking (equation 4) based on the specific dynamics of the transition, not just concurrent industry conditions or performance⁸, or long-run changes in number of firms. This is evident in considering the pattern of entry at different levels of myopia (Figure 6), with foresight at two years.

• With some foresight, substantial myopia leads to a peak of entrants when the shock occurs, with these firms generally pursuing a strategy of investing in resource 2. In contrast, with limited myopia the entry wave is earlier, when firms know of the shock, and with firms typically following a different investment pattern of first accumulating resource 1 and then resource 2, which leads to a greater proportion of generalist firms.

⁸For instance, the value of entry at a point in time does not necessarily reflect average profits per firm at that point in time, as some weight is given to future profits.

A factor affecting the timing of the entry peak is the growth path of firms. Small incumbents generally prioritize resource accumulation for the resource that is currently easiest to accumulate so as to grow fast away from the exit region. Hence entry in anticipation of the shock taking effect leads to near-term resource 1 accumulation, followed by post-shock resource 2 accumulation. This growth path leads to generalist firms with high levels of both resources, a valuable resource position but that takes time to build. Hence, with substantial myopia this makes entry unattractive until the shock takes effect: once the shock is known there is period of no entry followed by a spike once the shock takes effect. The size of the spike in part reflects the prior periods of zero entry and thus net decline in total number of firms.

In contrast, with limited myopia the entry path leading to generalist firms with high levels of both resources is attractive, leading to an early entry wave: this is seen in Figure 4 for time period t=-7 which shows the entry wave that initially accumulate resource 1. In addition, as discussed above, with limited myopia a high proportion of large incumbent firms also shift to accumulate resource 2, in addition to their legacy resource 1 stocks The increase in number of firms, due to the entry wave, and investment patterns increase the competitive pressure in the industry which makes subsequent entry unattractive. The period of zero entry lasts until the ongoing process of exit has reduced the number of firms and thus relieved the competitive pressure.

The extent of foresight affects the pattern of entry at intermediate levels of myopia (Figure 7), less so at more extreme levels of myopia.

• With substantial myopia the entry peak is when the shock occurs, whereas with limited myopia the entry peak is when the shock is first known. With intermediate levels of myopia there is a peak when the shock takes effect. In addition, as foresight lengthens a second peak emerges at the time when the shock is first known. With even greater foresight there is an increase in entry, but not a sharp peak, sometime between when the shock is first known and when the shock takes effect.

With intermediate levels of myopia the entry pattern is sensitive to the degree of foresight. With limited foresight, entry in anticipation of the shock is unattractive as resulting in limited resource 1 accumulation before switching to resource 2 accumulation. With sufficiently long foresight the relevance of the shock is not so material at the time when the shock is first known about: the change in entry pattern is at some point during the anticipation period. In contrast, with intermediate levels of foresight the shock is known with sufficient time to make sequential accumulation of resource 1 and then resource 2 attractive, leading to a marked early entry peak when firms first know of the shock. These firms pursue a strategy to grow into generalist firms, whereas subsequent entrants, around the time the shock, pursue a different strategy mostly focused on accumulation of resource 2.

Evolution of distribution of firms

Firms select strategies with some degree of forward looking considerations, depending on firm myopia and foresight, but the effects of the strategies take time to feed through. The distribution of firms over resource levels at a point in time reflects prior period incumbent firms' gradual adjustment of resources through investment and any eventual entry. Consequently:

• The evolution of the distribution of firms need not shift as rapidly as the changes in firm strategy, and the distribution of firms across resources during the transition may be markedly different from either the initial or long run distribution of firms.

This is evident in the example in Figure 4 during which a peak of generalist firms with high levels of both resources emerges (see period t = 9), which is neither like the initial or final long-run equilibria. The peak arises from large incumbents increasingly investing in resource 2 and an entry wave that occurs when firms know of the shock, in anticipation of the shock taking effect (see period t = -7), as discussed in the prior sections. Also, as incumbent and entry strategies vary with firm foresight and myopia, so does the evolution of the distribution of firms during the transition also vary with firm foresight and myopia.

4 Discussion

I develop a formal model for the response of firms to a technology shock to the industry. The model comprises three levels of analysis: resources, firms and industry. Within the model firms choose how much of each of the two resources to accumulate and whether to enter or exit, while competing with other firms facing similar choices in responding to an industry-wide shock. The particular aspect of the model set up is that the response of firms to a shock is tracked over successive time periods, as firms adapt to the shock and its knock-on effects, with emphasis on the firm dynamics during the transition, not just the initial and final long-run equilibrium. In this regard the paper aims to contribute to the call for developing formal models to address strategy dynamic issues (Adner, Polos, Ryall and Sorenson (2009) and Ghemawat and Cassiman (2007)). The set-up is complementary to other modeling approaches, such as two-period oligopoly models which are well-suited to consider specific firm-to-firm competitive interactions but with more limited inter-temporal dynamics, longrun models of industry evolution that encompass several stages of the long-run industry evolution, or NK models of search for optimal organizational configurations that allow for rich variation in firm strategies but typically have limited or no competitive effects.

In considering the results several limitations should be highlighted. The model set up is more general than the specific solutions discussed: however the non-linear dynamics require numerical solutions (e.g., due to potential periods of zero entry) and the algorithm is computation intensive. I have contrasted selected scenarios, though I have varied the key parameters to check that the basic patterns discussed hold beyond the specific solutions highlighted in the paper.

I have considered the gradual accumulation of two resources as this is already sufficient to generate a range of firm responses and to highlight the effects of foresight and myopia. I motivated the slow-moving stocks primarily through time-compressing diseconomies in resource accumulation (Dierickx and Cool 1989). The assumption of gradually adjusting resource stocks is important to the results, as highlighted by Sterman, Henderson, Beinhocker and Newman (2007) with respect to capacity adjustment, and is consistent with models of industry evolution that have gradually evolving firms. Also, adding a complementary, resource would be of interest (Tripsas 1997) though this would considerable complicate the model.

The shock is meant as a specific example representative of a broader technology shock that leads to a long-run change in the resources of firms. Though the model is more general and allows for various forms of shocks, for clarity I have chosen to analyze a shock that switches the growth rates of the resources, as this leads to initial and long-run industry conditions that are mirror-images of one another, with resources 1 and 2 switched. Also, I have a clear point in time at which the shock occurs as this helps highlight key features of the transition. I focus on shocks that affect the relative ease of resource accumulation. An alternative formulation could be for the shock to affect the cost of resource accumulation or the rate of obsolescence. Throughout I have foresight and myopia uniform across firms so as to highlight the effect on overall patterns of firm strategy. For instance, this could correspond to differences in foresight and/or myopia across countries or industries due to variation in, for instance, institutions or firm governance (Laverty 1996). A clear extension for future work would be to introduce firm heterogeneity in foresight and myopia.

With these limitations in mind, I find that during the transition firm strategy varies across firms due to heterogeneity in legacy resources and initial investments in the new resource: both incumbent adaptation (Tushman and Romanelli 1985, Tushman and O'Reilly 1997) and incumbent rigidity (Hannan and Freeman 1977) occur concurrently.

Further, the timing of response also varies across firms. Even for firms that eventually switch to focus on the new resource the optimal switch in strategy need not be as soon as the shock is known. Hence, the interest in strategies for firms remaining focused on legacy resources (Dew, Goldfarb and Sarasvathy 2006, Adner and Snow 2009) is not only relevant to firms that indeed stay focused on legacy resources but also applicable to firms that optimally delay switching to focus on the new resource.

Overall, I find that the firm dynamics and industry evolution in response to the shocks are not necessarily smooth, gradual changes. During the transition there is a substantial period during which the main firms are generalists with high levels of both resources, though these firms are not prevalent neither at the start nor in the long-run: to illustrate, this is akin to the hybrid sail and steam boats that operated for almost a century (Foster 1986). This is consistent with empirical evidence that firm response to uncertainty is not uniform and takes material time to unfold, relative to the underlying competitive dynamics, for instance with firm investment in new technology diffusing slowly across firms (Greve 2008). Consequently the importance in these types of situations of the relative timing of key processes affecting firm dynamics and industry evolution, including the rate of accumulation and depletion of resources, exit decisions, and shifts in market shares across providers. An implication of the results is that considering the effect of a shock on an industry just by contrasting the change from the current to the long-run situation, a typical expedient, is likely to miss much of interest that occurs in between, within a meaningful time frame from a strategy perspective.

Also, not surprisingly, foresight and myopia matter in a dynamic context. In particular, with

foresight of the shock the response of large incumbent firms is spread over time, whereas smaller incumbents mostly switch at a similar time. As most technological change is not likely to have a sudden impact, as say some natural disasters may, this suggests the opportunity to empirically test how the timing of incumbent response varies with the extent of foresight of technological change.

The effect of foresight is tempered by the extent of myopia. The results highlight two effects of myopia. First the effect of myopia on investment decisions going forward: for instance, firms specialized in the legacy resource do not switch strategy if sufficiently myopic. Second, the extent of myopia affects the industry structure prevalent before the firms know of the shock. With greater myopia more firms specialize in the legacy resource: however, once the shock takes effect these firms are not as able to adapt. Thus myopia conditions investment patterns before the shock is known, not just in response to the shock, so as to make a greater proportion of firms less flexible. Hence, to understand why incumbent firms may remain stuck in legacy resources in response to a shock, a common line of enquiry, consideration should be given to how myopia has affected investment patterns prior to the shock as well as after the shock.

Further, entry patterns are sensitive to foresight and myopia, affecting the size and timing of entry peaks, and the duration of periods with little or no entry. Empirically, entry peaks have been documented in different types of industry evolution, in particular the development of new industries⁹, suggesting the opportunity to link such patterns to firm foresight and myopia. In particular, I find entrant's strategy varies depending on the time of entry, in line with evidence that early entrants not follow the same strategy as later entrants (Bayus and Agarwal 2007).

Consequently, the extent of first-mover advantage in entry depends on the foresight and myopia of firms in the industry. For instance, considering as a focal firm a potential entrant to the industry, the results highlight that the focal firm's assumptions about other firm's foresight and myopia are important in setting strategy.¹⁰ The focal firm could incorrectly assume that it has better foresight of the forthcoming shock than other firms in the industry. This would suggest the focal firm may enter at any time. However, if in fact the firm has no advantage in foresight entry is attractive only

⁹The non-uniform entry rates are not unusual as compared to empirical pattern of entry, in particular during the industry life cycle of a nascent industry that often includes a period of rapid growth and high entry, followed by a severe shakeout (Klepper and Graddy 1990, Klepper 1997, Anderson and Tushman 2001, Klepper 2002, Bayus and Agarwal 2007, De Figueiredo and Silverman 2007).

¹⁰I thank Michael Jacobides for suggesting to consider this issue.

at particular times (e.g., the peaks) but not at other times (i.e., when entry falls to zero).¹¹ Hence, whether the firm should enter in a given time period depends on other firm's myopia and foresight of the shock: the eventual long-run of the evolution is not a sufficient to guide whether to enter the industry at a given point in time.

Overall, the results highlight that myopia and foresight, two aspects of firms forward-looking strategy setting, have different and inter-related effects. Thus the middle ground between assumptions of strong forward-looking rationality and emergent myopic strategy setting is not a simple continuum but benefits from, at least, the separate consideration of extent of foresight and degree of myopia.

5 Conclusion

The question of whether firms may successfully adapt to a change in technology has led to divergent perspectives. I develop a formal model to consider this issue. I introduce firm heterogeneity through entry and gradual accumulation of resources corresponding to the legacy and new technologies. I show this is sufficient to lead some incumbents not to adapt whereas others incumbents do adapt when facing the same technology shock. Further, I find incumbent firms adapt their strategy at different points in time and entry patterns vary over time due to spikes and periods with limited entry. I highlight aspects of firm forward-looking strategy setting, myopic discounting of the future and foresight of the shock, affect firm response. In particular, I find the degree of myopic discounting of the future affects firms flexibility to respond to the shock by changing the extent of firm specialization in the legacy resource, and foresight of the forthcoming shock affects the spread over time of firm response, particularly for large incumbents. Overall, the results suggest that considering the effect of a shock on an industry just by contrasting the change from the current to the long-run situation, a typical expedient, is likely to miss much of interest that occurs in between, within a meaningful time frame from a strategy perspective. In focusing on the transition, the assumptions regarding firm forward-looking strategy setting are important, as the middle ground between assumptions of strong forward-looking rationality and emergent myopic strategy setting is

¹¹An alternative mistake a potential entrant could make is with regards to myopia. For instance, a focal firm with limited myopia, that takes the long term view, may assume other firms also have limited myopia: hence the entry peak is once firms first know of the future shock and thereafter there is a period during which entry is unattractive. However, if in fact the other firms set policy with substantial myopia the firm need not avoid entry at a later time.

not a simple continuum but benefits from, at least, the separate consideration of extent of foresight and degree of myopia.

References

- Adner, R. 2002. When are technologies disruptive? Demand-based view of the emergence of competition. *Strategic Management Journal* 23: 667-688
- [2] Adner, R., L. Polos, M. Ryall and O. Sorenson 2009. The case for formal theory. Academy of Management Review Vol 34, No. 2, 201-208.
- [3] Adner, R., and Snow, D. 2010. "Old" technology responses to "new" technology threats: Demand heterogeneity and graceful technology retreats." Forthcoming in *Industrial and Corporate Change*.
- [4] Anderson, P. & Tushman, M. L. 2001. Organizational environments and industry exit: The effects of uncertainty, munificence and complexity. *Industrial and Corporate Change* 10(3) 675-711
- [5] Atkeson, A., and A. Burstein. 2006. Innovation, Firm Dynamics, and International Trade. Mimeo.
- [6] Bartelsman, E. and Scarpetta,S. and Schivardi, F., 2003, "Comparative Analysis of Firm Demographics and Survival: Micro-level Evidence for the OECD Countries", OECD Economics Department Working Paper No. 348
- [7] Barney, J. 1986. Strategic factor markets: expectations, luck and business strategy. Management Science, 31(10):1231-1241
- [8] Barney, J. 2001. Is the resource-based "view" useful for strategic management research? Yes. Academy of Management Review, Vol. 26, No. 1, 41-56.
- [9] Bayus, B. L., and Agarwal, R., 2007. The role of pre-entry experience, entry timing, and product technology strategies in explaining firm survival. *Management Science*, Vol. 53, No. 12, 1887-1902.
- [10] Casadesus-Masanell, R., and Yoffie, D. B., 2007. Wintel: Cooperation and conflict. Management Science, Vol. 53, No. 4, 584-598
- [11] Christensen, C. M. 1997. The Innovator's Dilemma. Harvard Business School Press: Boston, MA.
- [12] Cooley, Thomas F and Vincenzo Quadrini "Financial Markets and Firm Dynamics" The American Economic Review, Dec 2001, Vol. 91, No. 5.

- [13] Cooper, A. C. and Smith. C. G. 1992. How established firms respond to threatening technologies. Academy of Management Executive, 6, 55-70.
- [14] Costantini, J. A. 2006, "Impact of Financial Development on Firm Growth and Firm Size Distribution". Working paper, INSEAD.
- [15] Costantini, J. A. 2010, "Which Resources to Accumulate? Firm Dynamics in a Changing Industry". Working paper, INSEAD.
- [16] Costantini, James, and Marc Melitz, (2008), "The Dynamics of Firm-Level Adjustment to Trade Liberalization," in E. Helpman, D. Marin, and T. Verdier (eds.), *The Organization of Firms in a Global Economy*, Harvard University Press.
- [17] Dew, N., Goldfarb, B, and Sarasvathy, S. 2006. Optimal inertia: When organizations should fail. Advances in Strategic Management, 23, 73-99.
- [18] De Figueiredo, J. M., Silverman, B. S. 2007. Churn, baby, churn: Strategic dynamics among dominant and fringe firms in a segmented industry. *Management Science* 53(4) 632-650.
- [19] Dierickx, I., and Cool, K. 1989. Asset stock accumulation and sustainability of competitive advantage. *Management Science* 35(2) 1504-1514.
- [20] Dixit, R. and Stiglitz, J., 1977, Monopolistic Competition and Optimum Product Diversity, *The American Economic Review*, Vol. 67, No. 3. (Jun., 1977), pp. 297-308
- [21] Dunne, T., Roberts, M., Samuelson, L., 1988. Patterns of firm entry and exit in U.S. manufacturing firms. *The RAND Journal of Economics*, Vol. 19, No. 4, 495-515.
- [22] Ericson, R. and Pakes, A., 1995, Markov-Perfect Industry Dynamics: A Framework for Empirical Work. *Review of Economic Studies*, 1995, Vol. 62, No.1, 53-82
- [23] Foster, R.N. 1986. Innovation: The attacker's advantage. Summit Books: New York, NY, USA.
- [24] Gavetti, G., D. Levinthal. 2000. Looking forward and looking backward: Cognitive and experiential search. Administrative Science Quarterly. 45, 113–137.
- [25] Gavetti G, Levinthal DA, Rivkin JW. 2005. Strategy making in novel and complex worlds: the power of analogy. Strategic Management Journal 26(8): 691–712.
- [26] Ghemawat, P. & Cassiman, B. 2007. Introduction to the special issue on strategy dynamics. Management Science 53(4) 529-536
- [27] Ghemawat, P. and Levinthal, D. 2008. Choice interactions and business strategy. Management Science 54(9) 1638-1651

- [28] Greve, H. R., 2008. Bigger and safer: The diffusion of competitive advantage *Strategic Management Journal*, forthcoming.
- [29] Hopenhayn, H., 1992, "Entry, Exit and Firm Dynamics in the Long Run", *Econometrica* Vol. 60, No. 5, (Sep. 1992), 1127-1150
- [30] Jacobides, M. G., Winter, S., and Kassberger, S. M. 2007. The dynamics of wealth, profit and sustainable advantage. Working paper, London Business School.
- [31] Jovanovic, B., 1982. Selection and the evolution of industry. *Econometrica* 50: 649-670
- [32] Klepper, S. and Graddy, E. 1990. The evolution of new industries and the determinants of market structure. RAND Journal of Economics Vol. 21, (1).27-44.
- [33] Klepper, S. 1996. Entry, exit, growth and innovation over the product life cycle. The American Economic Review Vol. 86 (3) 562-583.
- [34] Klepper, S. 1997. Industry life cycles. Industrial and Corporate Change 6(1): 119-143
- [35] Klepper, S. 2002 Firm survival and the evolution of oligopoly. RAND Journal of Economics Vol. 33, (1).37-61.
- [36] Knott, A. M. 2003. Persistent heterogeneity and sustainable innovation. Strategic Management Journal 24: 687-705
- [37] Laverty, K. J., 1996. Economic "short-termism": The debate, the unresolved issues, and the implications for management practice and research. Academy of Management Review, Vol. 21, No. 3, 825-860.
- [38] Lenox, J. L., Rockart, S., and Lewin, A. Y. 2006. Interdependency, competition, and the distribution of firm and industry profits. *Management Science* 52(5) 757-772
- [39] Lenox, J. L., Rockart, S., and Lewin, A. Y. 2007. Interdependency, competition, and industry dynamics. *Management Science* 53(4) 599-615
- [40] Levinthal, D. A. and March, J. G., 1993. The myopia of learning. Strategic Management Journal, Vol. 14, 95-112.
- [41] Makadok, R. and Barney, J.B. 2001. Strategic Factor Market Intelligence: An Application of Information Economics to Strategy Formulation and Competitor Intelligence. *Management Science* 47(12) 1621-1638
- [42] Miller, K. D., 2002. Knowledge inventories and managerial myopia. Strategic Management Journal 23: 689-706
- [43] Olley, Steven and Ariel Pakes, "The Dynamics of Productivity in the Telecommuncations Equipment Industry", *Econometrica*, Vol. 64, No. 6 (November, 1996), 1263-1297

- [44] Pacheco-de-Almeida, G., Henderson, J. E., Cool, K. O. 2008. Resolving the commitment versus flexibility trade-off: The role of resource accumulation lags. Academy of Management Journal 51(3) 517-536.
- [45] Pacheco-de-Almeida, G., and Zemsky, P. 2006. The timing of resource development and sustainable competitive advantage. Working Paper, INSEAD.
- [46] Pakes, A. and McGuire, P., 1994. "Computing Markov-Perfect Nash Equilibria: Numerical Implications of a Dynamic Differentiated Product Model," *RAND Journal of Economics*, The RAND Corporation, vol. 25(4), pages 555-589, Winter
- [47] Porter, M. E. 1980. Competitive strategies: Techniques for analyzing industries and competitors. New York, NY: Free Press
- [48] Porter, M. E. 1996. What is strategy? Harvard Business Review Nov-Dec 1996.
- [49] Porter, M. E., and Siggelkow, N. 2008. Contextuality within activity systems and sustainability of competitive advantage. Academy of Management Perspectives May 2008, 34-56.
- [50] Rivkin, J. W. 2000. Imitation of complex strategies. Management Science 46(6) 824-844
- [51] Sterman, J. D., Henderson, R., Beinhocker, E. D., Newman, L. I., 2007. Getting big too fast: Strategic dynamics with increasing returns and bounded rationality. *Management Science* 53(4) 683-696
- [52] Tripsas, M. 1997. Unraveling the process of creative destruction: Complementary assets and incumbent survival in the typesetter industry. *Strategic Management Journal* 18: 119-142
- [53] Tushman and Anderson 1986. Technological discontinuities and organizational environments. *Administrative Science Quarterly*, 31: 439-465
- [54] Zott, C., 2003. Dynamic capabilities and the emergence of intraindustry differential firm performance: Insights from a simulation study. *Strategic Management Journal* 24: 97-125

Table 1: Calibration: Model Timing and Productivity Grid, Demand and Production Parameters

Parameter		Parameter value
Parameters that vary depending on scenario		
Foresight	time period when firms first know of shock	Shock takes effect at t=1. Foresight is number of time periods (quarters) in advance of this that firms know of shock. Vary from no foresight (firms know of shock end of t=0) to firms have 7 years foresight (firms know of shock at end of t=-28). The total number of time periods is set long enough (50 years or longer) to ensure the industry converges to the new long-run equilibrium.
Discount factor	β	Myopia is discount factor used by firms: vary in the range of 0.8 and 0.95 per year
Parameters that change during a scenario: Shock to resource accumulation		
Resource growth rate if invest in resource	η	Resource 1 and 2 growth rates pre-shock are, respectively, [+25%,+5%] per year, and post-shock are the reverse [+5%,+25%] per year. Also, so as to smoothen the solutions, in the numerical solutions the growth rate of resources is stochastic these values the mean change in resources if invest.
Parameters that are fixed, not varying across scenarios or changing within scenarios		
Resources Resource 1 and 2	r_1 and r_2	Range of [0.5, 6] across a grid of 40x40 to allow a sufficiently broad range of firm sizes
Resource depletion if do not invest	γ	3% decrease per year
Cost of investment	I_1 and I_2	For resource level below 3.8 (grid point 30) set cost of investment = $p_r r_i(\eta - \gamma)$, with p_r =100. For resource level above this assume diminishing returns so that no investment.
Production Elasticity of substitution of resources	α	3.5
Fixed costs	F	12 per quarter
Wage per period	w	1
Demand Total industry revenues	R	100,000
Elasticity of substitution	σ	4
Exit		
Death shock	δ	10% per year
Entry		
Entrant initial resource levels		For each resource, entrant has random draw of resource level with lognormal distribution, with mean log(1) and std dev 0.5.
Entry sunk cost	S	60



Figure 1: Overview of key elements of model



Figure 2: Timing of shock to resource accumulation

(a) Strategies of firms



Legend for strategy regions: 1 (or 2) = invest in resource 1 (or 2); Not = not invest; Exit = exit Example growth paths generated by strategy choices for firms entering near exit region



(b) Distribution of entrants

Figure 3: Strategies of firms, distribution of entrants, and distribution of firms across resource stock levels before firms know of the shock, with myopia of firms set at $\beta = 0.95$.



Figure 4: Strategies of firms and distribution of firms across resource stock levels in response to a shock that takes effect at t = 1 and that firms know of with two years foresight (at end of t = -8), and with myopia of firms set at $\beta = 0.95$.

(a) Proportion of firms investing in resources over time, with myopia β =0.95 and two year foresight of shock that takes effect at t=1



Proportion of firms investing resource 2 increases in anticipation of shock from 36% before firms know of the shock to 55% just before shock takes effect (at t=0)

(b) Effect of different levels of myopia and foresight on proportion of firms investing in resource 2 at t=0 just before shock takes effect



Figure 5: Firm investment in resources (a) over time with two year foresight and myopia at $\beta = 0.95$, and (b) at t=0 for varying foresight and myopia



Figure 6: Entry patterns over time at different levels of myopia, with two year foresight of shock.



Figure 7: Entry patterns over time with different extent of foresight, with myopia at $\beta = 0.90$.

Appendix

A Profits within a time period

The determination of firm profits requires specification of the product market competition: the cost of production based on the resource levels and demand for the firms' products.

Production

Each firm is considered to produce a distinct variety of product with the firm's production determined by its resource stocks r_1 and r_2 . In each time period a firm produces the optimal level based on its resource stocks, hiring the necessary labor in a labor market with no frictions at a wage per unit of labor normalized to unity. The production technology has constant elasticity of substitution (C.E.S.) elasticity of substitution α between resources r_1 and r_2 . In period t, production, y_t , is given by:

$$y_t = [(r_{1t}l_{1t})^{(\alpha-1)/\alpha} + (r_{2t}l_{2t})^{(\alpha-1)/\alpha}]^{\alpha/(\alpha-1)}$$
(5)

where labor hired is l_{1t} and l_{2t} in period t. Based on standard derivations, marginal cost, c_t , is:

$$c_t = \left[(r_{1t})^{(\alpha-1)} + (r_{2t})^{(\alpha-1)} \right]^{-1/(\alpha-1)}$$
(6)

In addition, the firm incurs an overhead per-period fixed cost F. Thus in the model there is a direct link between resources and production, as given by the firm's production function.

Demand

The demand system is based on monopolistic competition. I assume consumer preferences across products in the industry have a constant elasticity of substitution $\sigma > 1$: a C.E.S. demand system with elasticity (Dixit and Stiglitz 1977). I assume there is a continuum of varieties produced by the firms, denoted by $\omega \in \Omega$. I assume consumers spend a fixed amount R on the products of the industry in each time period. Total industry revenues are given by $R = Q_t P_t$, where Q_t and P_t are, respectively, the aggregate quantity and price indices. Specifically, $P_t = \left[\int_{\omega \in \Omega} p_t(\omega)^{1-\sigma}\right]^{1/(1-\sigma)}$ is the C.E.S. price index for the aggregated differentiated good and $Q_t \equiv \left[\int_{\omega \in \Omega} q_t(\omega)^{(\sigma-1)/\sigma}\right]^{\sigma/(\sigma-1)}$ the C.E.S. quantity index at time t, where $p_t(\omega)$ and $q_t(\omega)$ are the price and quantity consumed of the individual varieties ω . With this demand system the firm's optimal price is a constant markup of $\sigma/(\sigma - 1)$ over marginal costs, $p_t = (\sigma/(\sigma - 1))c_t$, the firm's market share is $(P_t/p_t)^{\sigma-1}$ and hence revenue is $R_t P_t^{\sigma-1} p_t^{1-\sigma}$.

Profits

The firm per-period profits π_t are revenues less the marginal cost of production and the fixed cost:

$$\pi_{t} = R_{t} P_{t}^{\sigma-1} p_{t}^{1-\sigma} - q_{t} c_{t} - F$$

$$= R_{t} P_{t}^{\sigma-1} p_{t}^{1-\sigma} - (R_{t} P_{t}^{\sigma-1} p_{t}^{1-\sigma} / p_{t}) c_{t} - F$$

$$= (1/(\sigma-1)) R_{t} P_{t}^{\sigma-1} (\sigma/(\sigma-1))^{1-\sigma} c_{t}^{1-\sigma} - F$$
(7)

B Equilibrium Conditions

Let $\mu_{r_1,r_2,t}$ represent the measure function for the distribution of firms over states (r_1, r_2) in period t. A dynamic equilibrium is characterized by a time path for the price index $\{P_t\}$, the measure of firms in each state, $\{\mu_{r_1,r_2,t}\}$, and the mass of entrants $\{M_{E,t}\}$. Note that a choice of $\{P_t\}$ uniquely determines the time path for $\{V_t^C(r_1, r_2)\}$ and thus determines all the optimal choices for any firm, given its resource levels (r_1, r_2) . An equilibrium $\{P_t\}$, $\{\mu_{r_1,r_2,t}\}$, and $\{M_{E,t}\}$ must then satisfy the following three conditions:

- Firm Value Maximization All firms' choices for exit/continuation, and, if continuing, for investment, conditional on r_1 and r_2 , must satisfy (2) and (3). In the aggregate, this means that $\mu_{r_1,r_2,t}$ is entirely determined by $\mu_{r_1,r_2,t-1}$ and the choices for $\{P_t\}$ and $\{M_{E,t}\}$. Starting with a mass and distribution of firms at time t 1, a share δ of firms receive the exogenous death shock. The remaining (1δ) share of firms update resources based on choice of investment. To these firms are added the $M_{E,t}$ new entrants, with a distribution determined by $G_E(r_1, r_2)$. All firms then make their endogenous exit decisions. The remaining firms result in a distribution and mass of firms for every state. In equilibrium this must match the chosen $\mu_{r_1,r_2,t}$.
- **Free Entry** In equilibrium, the net value of entry V_t^E must be non-positive, since there is an unbounded pool of prospective entrants and entry is not limited beyond the sunk entry cost. Furthermore, entry must be zero whenever V_t^E is negative.
- Aggregate Industry Accounting The mass and distribution of firms over productivity levels (aggregating over states) implies a mass and distribution of prices (applying the profit maximizing markup rule to firm marginal cost). Aggregating these prices into the C.E.S. demand system price index must yield the chosen P_t in every period.

C Model Algorithm

Following I describe the algorithm for numerically solving the model, focusing on the equilibrium conditions required and the sequence of calculations performed. Given the demand system, each firm in each time period t need only know industry aggregate outcomes for industry price P from time t onwards, $\{P_t, ..., P_T\}$, to determine its specific policies conditional on its current resources

 (r_1, r_2) . Firm policy choices are whether to {*Continue*, *Exit*}, and, if continuing, whether or not to invest in one of the resources.

The algorithm comprise three steps. Step 1 is to set parameters. Step 2 is to compute the firm policies and firm-size distribution $\{\mu_{r_1,r_2,t}\}$ corresponding to the initial parameter values, the initial stationary state equilibrium at t = 1. Within Step 2, there is an iteration over the aggregate price for the stationary state P_1 . Step 3 computes the firm policies and firm-size distribution for the evolution from the initial stationary state through to period T. Within the Step 3, there is an iteration over the price path $\{P_2, ..., P_T\}$.

1) Set initial parameters, including for industry characteristics and grid structure.

- 2) P_1 iteration:
- Choose candidate value for P_1 .
- Firm Value and Policy Iteration: (i) Compute profit $\pi(r_1, r_2)$ at each resource combination $\{r_1, r_2\}$, based on the specific demand system and production function chosen; (ii) Pick a candidate value function $V_1(r_1, r_2)$; (iii) Determine $\{Continuation/Exit\}$ and choice of investment at each $\{r_1, r_2\}$; (iv) Iterate the value function: The set of firm policies over continuation and choice of policy state imply a next iteration value for the value function, $V'_1(r_1, r_2)$, based on computing the value of continuing and comparing to the value of exit; and (v) Check whether new $V'_1(r_1, r_2)$ is sufficiently close to $V_1(r_1, r_2)$. If not, continue iteration with $V'_1(r_1, r_2)$. If close enough, return to P_1 iteration.
- Check the value of entry. As seek equilibria with positive entry the condition should be close to zero. Compute firm-size distribution $\mu_{r_1,r_2,1}$: (i) If close enough to zero, P_1 iteration is complete; (ii) If not, then adjust candidate P_1 accordingly: if condition is positive lower P_1 , if negative raise P_1 .
- 3) $\{P_2, ..., P_T\}$ iteration:
- Choose candidate value for {P₂,..., P_T}: (i) Compute price corresponding to stationary state at final parameter values; (ii) Set initial guess for {P₂,..., P_T} based on prices corresponding to initial and final parameter values.
- Firm value and policy iteration for t = T: (i) Compute profit π(r₁, r₂) at each resource combination {r₁, r₂}, based on the specific demand system and production function chosen;
 (ii) Pick a candidate value function V_T(r₁, r₂); (iii) Determine {Continuation/Exit} and choice of investment at each {r₁, r₂}; (iv) Iterate the value function: The set of firm policies over continuation and choice of policy state imply a next iteration value for the value function, V'_T(r₁, r₂), based on computing the value of continuing and comparing to the value of exit;
 (v) Check whether new V'_T(r₁, r₂) is sufficiently close to V_T(r₁, r₂). If close enough, return to {P₂,..., P_T} iteration. If not, continue iteration with V'_T(r₁, r₂).

- Firm Value and Policy Iteration for $t = \{2, ..., T 1\}$: (i) Compute profit $\pi(r_1, r_2)$ at each resource combination $\{r_1, r_2\}$, based on the specific demand system and production function chosen; (ii) Iterate back to compute $V_{T-1}(r_1, r_2)$ based on $\pi_t(r_1, r_2)$ and $V'_T(r_1, r_2)$, and period T policies, based on computing the value of continuing and comparing to the value of exit. Hence, determine period T - 1 policies {Continuation/Exit} and choice of investment at each $\{r_1, r_2\}$; (iii) Iterate back to period t = 2.
- Compute value of entry in each time period $t = \{2, ..., T 1\}$.
- Compute the size-distribution of firms μ_{r1,r2} = {μ_{r1,r2,2},...,μ_{r1,r2,T}} consistent with the computed firm policies: (i) Compute μ_{r1,r2,2} based on μ_{r1,r2,1} and firm policies computed for t = 2. (ii) Determine number of entrants. Case 1: If the distribution of incumbents implies a price below P₂ then entry is zero, as adding entrants would further distance the firm distribution from the current value of price path Case 2: If the distribution of incumbents implies a price above P₂, then add entrants until the firm distribution (including entrants) implies a price equal to P₂. (iii) Iterate forward to compute μ_{r1,r2} = {μ_{r1,r2,3},..., μ_{r1,r2,T}}.
- Check whether price path {P₂,..., P_T} is close enough to an equilibrium. The objective function to assess equilibrium is the Euclidian distance of these two measures: ((P^{fe} P)² + (P^{max} P)²)^{1/2}. The first part measures the distance between the price path and firm distribution: (P^{max} P). The second part measures an equivalent gap based on the value of entry: (P^{fe} P), which is: zero if have negative value of entry; negative if have positive value of entry. I calculate P^{fe} as what the price in the time period in question would need to change to in order to close part of the gap in value of free entry. Hence, if value of entry is positive the price change is negative so as to lower profitability and thus lower the value of entry.
- If objective function not sufficiently small, construct new candidate price path. The suggested price adjustment is the average of $(P^{max} P)$ and $(P^{fe} P)$, scaled down by a factor to reduce the risk of cycling over successive iterations of the price path.

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