KAUFFMAN

The Foundation of Entrepreneurship

KAUFFMAN DISSERTATION EXECUTIVE SUMMARY

Part of the Ewing Marion Kauffman Foundation's Emerging Scholars initiative, the Kauffman Dissertation Fellowship Program recognizes exceptional doctoral students and their universities. The annual program awards up to fifteen Dissertation Fellowship grants of $20,000 each to Ph.D., D.B.A., or other doctoral students at accredited U.S. universities to support dissertations in the area of entrepreneurship.

Since its establishment in 2002, this program has helped to launch world-class scholars into the exciting and emerging field of entrepreneurship research, thus laying a foundation for future scientific advancement. The findings generated by this effort will be translated into knowledge with immediate application for policymakers, educators, service providers, and entrepreneurs as well as high-quality academic research.

Kauffman Dissertation Fellowship Program KDFP Kauffman Dissertation Fellowship Program KDFP

www.kauffman.org/kdfp

Huyen Pham
University of Notre Dame

Abstract

My dissertation focuses on dynamic firm competition and academic entrepreneurship. The first essay studies the dynamics and equilibrium outcomes of a duopoly in which firms make decisions about both capacity expansion and cost reduction. The second essay is an extension of the framework used in the first essay to study the strategic roles of exogenous spillovers and absorptive capacity. The third essay examines the effects of the Bayh-Dole Act (1980) and the Pasteur's Quadrant effects on a faculty's research efforts over a career life cycle, taking into account research preferences and productivities, spillovers among different types of research knowledge, and monetary payoffs. The last essay further looks at a professor's transition between academia and entrepreneurship.

Huyen Pham
University of Notre Dame

The growing entrepreneurship literature has pointed to research universities as a hub of human capital and other resources that facilitate innovative entrepreneurial activities. The concentration of the most technologically innovative firms around the largest research universities in the Silicon Valley and Boston Route 128 areas suggests at least a highly interdependent relationship between universities and technological progress. Knowledge spillovers between universities and the industry come in various forms and most likely in both directions. However, we are specifically interested in the case where university professors themselves become entrepreneurs and lead their start-up firms.

The topic becomes even important with the increasing involvement of university researchers in the patenting and licensing of their inventions since the passage of the Bayh-Dole Act in 1980. Under the Act, researchers are entitled to innovations under federally funded research projects which would otherwise belong to the government under the previous law. The facilitation of faculty ownership creates incentives for professors not only to dedicate more time to entrepreneurial work but also to become involved with starting up or consulting new firms in order to further develop the relevant technologies and make their inventions applicable and profitable. In a study of 5,811 patents filed by university faculty, Thursby et al. (2009) find that 9.4 percent inventors were also the principals of the firms to whom the patents were assigned. While this fraction does not in any way translate to an undesirably large amount of faculty commitment to commercial work, its magnitude is certainly not negligible. To understand this link between academics and entrepreneurship, this necessitates a model that incorporates not only the trade-off between basic and applied efforts for a professor but also the trade-off on a career level between being a professor and being an entrepreneur.

Therefore, my first chapter on academic entrepreneurship coauthored with Richard Jensen and Marie Thursby examines the trade-offs a university researcher faces when deciding her effort levels in basic and applied work, which essentially determines her choice to whether remain in academia, found a start-up firm, or pursue both over the researcher's career life. At the beginning of each time period, the researcher's choice between continuing her professorship and embarking in entrepreneurship is based on the expected return of each option. If she remains a professor, she allocates her time between basic and applied work and earns a salary which depends on both of her knowledge stocks. If she becomes an entrepreneur, she only dedicates her time to entrepreneurial work and enjoys the profit of her start-up firm. If she decides to remain at the university while starting up her own firm, she dedicates her time to both research and entrepreneurship and earns the firm's profit in addition to her university salary.

Concession of patent rights to university researchers under the Bayh-Dole Act raises a legitimate concern that the higher returns of applied work may distract professors from basic research which is part of their primary educational mission. On this note, the existing literature provides mixed results. On the one hand, those in favor of the Bayh-Dole Act generally indicate that it is innocuous to productivity in basic research. Lowe et al. (2007) suggests that entrepreneurship affects neither a professor's peer-reviewed publications nor her research productivity relative to her non-entrepreneurial colleagues. Thursby et al. (2003) finds an increase in disclosure rate and a constant level of basic research. On the other hand, results such as Cohen et al.'s (1998) that are less optimistic about financial rewards for university inventors hinge on the secrecy of the industry since the inventors are often discouraged from disclosure during the development and commercialization process of their inventions. This exclusiveness most likely suppresses any form of knowledge sharing including research publications. However, Cohen et al. stresses that the findings are confined to research projects that are sponsored by firms. Therefore, the degree of firm influence may differ substantially should the financial dependence be replaced with the inventor's autonomy in a start-up. In that case, our model renders a theoretical framework for future empirical studies that specifically investigate effort allocations of faculty entrepreneurs.

Both Lowe et al. (2007) and Thursby et al. (2003) find a relationship between publications and career age. Lowe et al. observes an increase in publications in engineering, biochemical, and chemistry for both faculty entrepreneurs and their colleagues over a 10-year period spanning equally before and after the birth of a start-up. Similarly, Thursby et al. finds that “publications first rise and then fall (after age 35-45).” Thus, it is important to account for the lifetime trend of research productivity in examining both research and career decisions since even the same professor will behave differently depending on the current stage of her career.

Thursby et al. (2007) and Jensen and Pham (2012) are among the few theoretical works that characterize the life cycle of a researcher. Our paper incorporates several key aspects. First, we extend the scope of a researcher's career to include both professorship and entrepreneurship. This inclusion removes the confinement of the researcher in academia since, as discussed previously, her optimal choice may solely entail being an entrepreneur. Second, research efforts in our model are stochastic – there is a chance that the research will succeed and a chance it will fail – reflecting the inherent nature of research. Third, we differentiate basic knowledge from applied knowledge. Using information from surveys and existing research, we can specify the complementarity between basic and applied work to tailor the model to the life cycle of a professor of a particular discipline. For example, within the pharmaceutical industry, biology only comprises 11 percent of the total number of cited basic research while chemistry citations surpass 22 percent (Mansfield, 1995). A biology professor may display a different exiting pattern from a chemistry professor. Therefore, having two types of knowledge stocks may help reconcile differences in previous and future empirical results on faculty research behaviors from various departments. Finally, since a faculty entrepreneur is first and foremost a researcher, it is important to design a model that captures the trade-off related to foregone utility from doing research should she devote her time solely to entrepreneurial work at a start-up firm. We therefore allow research efforts to directly affect the researcher's preferences (utility).

In each period, the researcher has to choose to whether remain in academia, become a full-time entrepreneur, or do both. The utility of being a professor depends on three main factors. The first one entails preferences for applied and basic work to capture the inherent nature of a researcher. The second one comes from a professor income which is increasing in both applied and basic knowledge. The last determinant is the expected value of future utility given that the researcher chooses the optimal career decision in every subsequent period. The probabilities that influence the expected utility are increasing functions of both research efforts and knowledge stocks in an attempt to capture the life cycle patterns suggested by Thursby et al. (2003) and Lowe et al. (2007). Both knowledge types positively affect the probability of success of each effort type in accordance with the complementarity between basic and applied research in Mansfield (1995).

We study the model for a range of parameterizations in order to examine the life cycle of a researcher in different disciplines. There are various channels regarding how faculty entrepreneurship affects research productivity and what discipline characteristics are most inducing to the commercialization of inventions while minimizing, if any, the sacrifice of the pedagogical mission. In this sense, a researcher who is highly skilled in business can succeed in entrepreneurship at the least expense of research production. This is because time is constrained, such a researcher can achieve the same or a higher chance of success in a task without having to devote a lot of time to that task. Thus, she most likely pursues a hybrid career whenever she comes up with an innovation as opposed to focusing solely on her start-up. Furthermore, when experience in the private sector generates ideas for applied and basic research as suggested in Mansfield (1995), this feedback effect results in an increase in the stocks of all types of knowledge. The largest increase occurs in the stock of the research knowledge that benefits directly from entrepreneurial experience. Due to spillovers, the remaining stock of research also increases but to a lesser extent.

Thus, we observe an increase in the probability of exiting academia when a researcher is moderately skilled in the business world. That is, she has a chance of successfully operating a start-up but this probability is not high enough to allow her to remain in academia and spend little time in entrepreneurial work. The second scenario where we also observe an increase in exits from academia is when business experience generates research ideas. In this case, it is beneficial for the researcher to put more time in entrepreneurial effort and this promotes the case of a complete exit.

Our findings point to an important policy implication. If a researcher's entrepreneurial skilled can be enhanced, it will actually facilitate entrepreneurship without sacrificing research output. Programs that provide innovators with the necessary funding for their start-ups may not at all hamper the growth of research and instead boost their entrepreneurial productivity to the point where the researchers can afford pursuing both career tracks simultaneously. In industries where exposure to the business world helps bring about new ideas in the research world, the exit rate increases due to the additional functionality of entrepreneurial experience. Therefore, it is important to consider these countervailing effects of different industry characteristics in future studies on academic entrepreneurship.

My second chapter on academic entrepreneurship coauthored with Richard Jensen focuses exclusively on the issues regarding the growth of licensing of university research in the

Huyen Pham
University of Notre Dame

last thirty years. Some are concerned that this increased focus on research projects with more apparent commercial potential has had adverse effects on basic research in universities. However, empirical tests have found limited, if any, effects (Thursby et al., 2007; Thursby and Thursby, 2011). It has also been argued that the distinction between basic and applied research has become blurred in the sense that "basic" scientific advances have arisen from "applied" research (e.g., research in Pasteur's Quadrant, Stokes 1997).

For all of the analyses, we consider nine benchmark cases depending on the preferences and productivities of the faculty researcher/inventor. These correspond to those faculty who have a strong preference for applied research, a strong preference for basic research, and are indifferent between them, and to those who are more productive in applied research, more productive in basic research, or are equally productive. To consider the effect of the Bayh-Dole Act, we consider a researcher with and without the possibility of licensing. We also consider her behavior with and without the effect of Pasteur's Quadrant.

The effects of the Bayh-Dole Act on the allocation of time are interesting. We compare the outcome with and without license income for our benchmark cases. In all cases, faculty respond to an increase in license income by increasing the time they spend in applied research, in the range of one to five percent, and decreasing the time they spend in both basic research and leisure throughout the entire life cycle. Moreover, in every case, the reduction in leisure stays rather constant over the entire life cycle at about two percent, so time in basic research decreases only when the increase in time in applied research surpasses two percent. That is, researchers seem to increase time in applied research by first decreasing their time in leisure, then basic research. The reduction in time spent in basic research is the greatest (in percentage terms) for those with a strong preference for it. The magnitudes of these changes, however, vary with the researcher's productivity. They are largest for those faculty who are more productive in applied research, and smallest for those who are more productive in basic research. These results are contrary to those of Thursby, Thursby, and Gupta-Mukherjee (2007). In their model, the increase in time in applied research due to the Bayh-Dole Act comes solely at the expense of time in leisure, not basic research.

Huyen Pham
University of Notre Dame

The effects of the Bayh-Dole Act on the knowledge stocks are surprising. Although the patentable knowledge stock is greater throughout the entire life cycle in all cases, as expected, the scientific knowledge stock is not always smaller. It is smaller for those with a strong preference for basic research, whatever their productivity, with magnitudes in the two to six percent range. The changes in the scientific stock are negligible for those who are indifferent between applied and basic research. Finally, the scientific stock is also greater toward the end of the life cycle for those who both have a strong preference for and are more productive at applied research. The increased growth in the patentable knowledge stock leads these faculty to reallocate some of their time back from applied to basic research because the marginal utility from the scientific knowledge stock is greater.

Finally, the effects of research of the Pasteur's Quadrant type are examined by comparing the outcomes when there are spillovers between both types of research and when there are only spillovers from basic to applied research. When we move from the traditional "linear" R&D model with only spillovers from basic to applied research to a model where spillovers from applied to basic research are also important, the primary first-order effect is that applied research becomes more productive by contributing, in expectation, to the growth of both knowledge stocks. This generally results in a reallocation of time from basic to applied research. However, because research is stochastic, this increase in productivity is merely a small increase in the probability of success, so the resulting changes in time allocation are very small, usually less than one percent and always less than two percent. Nevertheless, allowing spillovers from applied to basic research does result in increases in the stock of scientific knowledge throughout the entire life cycle, even if these increases are not large in percentage terms.

The second part of my dissertation consists of two chapters on dynamic firm competition. The first chapter pertains to the observation that firms in oligopolies compete on many dimensions including price, capacity, and productivity. However, there is no theoretical model in the literature that explicitly studies an industry in which all three are endogenously determined. I develop a dynamic framework where firms simultaneously set prices and decide on investments in cost-reducing R&D and capacity accumulation in a duopoly market. In doing so, I examine the relationship between these firm-level characteristics and their influence on investment strategies and industry equilibrium outcomes.

Huyen Pham
University of Notre Dame

Case studies show it is possible that a firm first gains a cost advantage under some circumstances and a capacity lead under others before arising as the industry leader. For example, in the titanium dioxide industry, a series of events on the supply side and stricter environment regulations in the early 1970s increased production costs for all titanium dioxide producers except for Du Pont (Ghemawat, 1984). Du Pont, motivated by a relatively lower production cost, intensified its capacity expansion to capture a greater market share and emerged as the industry leader. Conversely, in the petroleum refining industry, Mansfield (1963) and Enos (1962) report that process innovations are, for the most part, seen in large refineries who have sufficient production scales to finance and profit from R&D. In my model, both of these scenarios can arise endogenously depending on the effectiveness of R&D investment.

Specifically, when there is a low probability that R&D investments will succeed in reducing production costs, one is more likely to observe the case where a firm secures a cost advantage prior to acquiring dominance in capacity. In this case, firms start out by investing aggressively in both races until the divergence in production costs places the low cost firm in a leading position. In contrast, when there is a high chance that R&D investments succeed, a dominant firm is more likely to first establish a capacity lead since capacity investment success has become more difficult to achieve relative to cost reduction. Hence, a capacity lead is more advantageous to a firm's overall success. In both cases, I observe a positive relationship between capacity and productivity. That is, in the steady state the industry leader ends up with a lower production cost and a larger capacity regardless of the type of advantage it initially secures.

Specifically, I build a model endogenizing productivity via cost-reducing stochastic R&D investment based on the Besanko and Doraszelski (2004) framework. Since the firms in my model can differ in both capacity and productivity, it is intuitive to expect more capacity asymmetry. I show that whether the incorporation of endogenous production costs generates more capacity asymmetry than in the Besanko and Doraszelski model depends on the effectiveness of R&D investment. On the one hand, the contribution of R&D investment to capacity asymmetries is least noticeable when the probability that R&D investment reduces production costs is very low or very high. In these cases, the realized cost differentials are minimal; both firms are most likely to produce at either the highest or the lowest cost.

On the other hand, a probability of cost reduction in an intermediate range makes it profitable for only one of the two firms to pursue R&D efforts. The industry gravitates towards a monopoly in the long run. In equilibrium, a strong positive relationship between being the capacity leader and having a lower cost arises endogenously, i.e., a cost advantage is only observed in a firm that is also larger. In my paper, since the dynamic process allows for repeated competition, a firm is able to continually exploit the advantage it achieves and advance to dominate the overall industry. Therefore, as opposed to the equilibrium duopoly observed in Allen et al., I observe a duopoly only in the short run and a monopoly in the long run when endogenizing productivity matters in the intermediate range of R&D success. This means some of the equilibrium configurations described in Allen et al. are only transitory phenomena in my model.

On the lower end of the intermediate range of R&D success, a firm with a cost advantage invests aggressively to expand if it has not yet also captured capacity dominance. On the higher end of this range, a larger firm is propelled by a cost advantage to pursue cost reduction aggressively while remaining unaffected by a cost disadvantage. In the first case, having its cost advantage secured in a probabilistic sense, the smaller firm no longer retreats in the capacity race to be a follower. That is, when the smaller firm has a sufficiently large cost advantage, the benefit of competing for capacity leadership outweighs the benefit of retreating in an attempt to avoid a price war. Thus whether a cost advantage or a capacity lead is crucial to a firm's dominance depends on the likelihood of R&D investment success.

My second chapter on dynamic firm competition shows that in an environment where firms compete repeatedly in prices and can only supply up to their capacities in a price competition, they will have asymmetric capacities and production costs in equilibrium and spillovers have different effects on individual R&D and industry R&D. These effects depend on industry characteristics, in particular the effectiveness of R&D investment. The R&D investment effectiveness consists of two components. The first one is exogenous and reflects the nature of industry technology; the second depends on endogenous factors such as the pool of spillovers defined by the difference in the firms' productivity levels and a firm's own knowledge that governs how effectively it can take advantage of spillovers.

Huyen Pham
University of Notre Dame

A second important feature in this paper is that R&D investment is disentangled from the R&D stock, that is, the dynamic element of the model allows for R&D investment to be distinguishable from past successful R&D efforts that result in actual cost reduction. This feature allows for asymmetric knowledge transmission from a low-cost firm to a high-cost firm that cannot be incorporated in static models. Therefore, two novel and significant features of the paper are the consideration of a capacity-constrained price competition in the study of spillovers and the introduction of an asymmetric spillover flow.

In an environment where asymmetric capacities and production costs arise in equilibrium, spillovers have a negative effect on a low-cost firm's equilibrium productivity from which technological knowledge is absorbed while exerting a positive effect on that of the high-cost beneficiary. This leads to more symmetry in productivity. In an industry where technological advances are inherently difficult to obtain, these effects on equilibrium productivity result in more symmetry in capacity since the low-cost firm loses a substantial competitive edge. In an industry where technological conditions are more favorable for successful cost reduction, capacity asymmetry increases due to a more fierce capacity race. The low-cost firm needs to enhance its capacity lead to compensate for a weakened cost advantage and the high-cost firm can compete more aggressively due to spillovers.

This chapter of my dissertation considers the effect of spillovers modeled in the probability of R&D investment success under two scenarios. One assumes that a firm can tap into the spillover pool without having any knowledge of the technology while the other assumes that a firm's ability to benefit from its rival's technology depends on how much it knows. For brevity, the former case is referred to as the exogenous spillovers case and the latter the absorptive capacity case.

When R&D effectiveness is moderate in the absorptive capacity case, the asymmetric knowledge flow in the present paper preserves the disincentive strategic effect on R&D investment of the low-cost firm as observed in the existing literature while exerting a non-negative effect on that of the high-cost firm. The effect on the R&D investment of the high-cost firm is zero when technological advances are difficult to obtain and a cost advantage remains the driving force in achieving market dominance in the presence of spillovers. This is not surprising since the high-cost firm exclusively enjoys the direct positive effect of spillovers. Overall, since spillovers have a negative effect on a low-cost firm and a non-negative effect on a high-cost firm, they facilitate symmetry in productivity. In contrast to the existing literature, absorptive capacity in this setting attenuates the positive effect of exogenous spillovers on productivity symmetry by delaying the absorption process of the high-cost firm.

When cost asymmetry decreases for intermediate values of the exogenous effectiveness of R&D investment, a low-cost larger firm's competitive edge is reduced more in the case where a cost advantage is the driving force in achieving market dominance than in the case where a capacity lead plays a central role in gaining leadership. Therefore, capacity asymmetry is more likely to decrease in the first case due to a weakened leading firm. In contrast, an increase in capacity asymmetry is more likely in the second case since a reduced cost advantage does not rid a low-cost firm completely of its dominance. The firm accumulates more capacity to fortify its overall dominance in response to a weaker lead in the R&D race.

Together, these findings emphasize that the underlying industry characteristics play an important role in determining which implications of spillovers apply to a specific industry. Changes in equilibrium outcomes in an industry with a quantity competition in the product market differ from those in an industry with a price competition. In this paper where there is price competition, although the effect of spillovers on productivity asymmetry is negative for intermediate values of the exogenous effectiveness of R&D investment, the effect on capacity asymmetry depends on which type of advantage is the driving force in achieving market dominance. A low-cost firm responds to spillovers with less aggressive capacity investment if a reduction in cost asymmetry weakens its dominance significantly. Otherwise, it intensifies its capacity investment to compensate for the diminished cost advantage. The extent to which a firm adjusts its investment due to spillovers decreases when prior knowledge is required for the absorption of external knowledge.