An Annotated Bibliography of the Literature Related to Investigating the Role of

Development Stage in University Technology Transfer and the Implications for Public Policy

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Introduction

This annotated bibliography summarizes literature related to a planned study of the role of development stage in university technology transfer. The preliminary research question to be examined is whether development stage helps to explain why private sector companies choose not to pursue university-created technologies that seem to align with their missions and profit motives even when the companies appear to have the resources to do so.

This annotated bibliography summarizes the related literature in the context of the three perspectives that I will use to investigate the research question. The first perspective is public sector economics to understand why government involvement and intervention is appropriate and necessary in the market for university-created technology. The second perspective is organization theory and behavior to understand how organizations function in the context of university technology transfer. The third perspective is descriptive decision theory to understand how organizations make decisions to acquire university-created technology.

Because of time constraints, this annotated bibliography focuses on literature related to the first perspective. It specifically focuses on literature related to (1) the definition of technology, (2) the definition of university technology transfer, (3) the role of the federal government in university technology transfer, and (4) determinants of success in university technology transfer.

The literature reviewed included books published by reputable third-party publishers and peer-reviewed scholarly journal articles. This annotated bibliography summarizes more than 10 books and 20 journal articles identified through database searches of various key terms including “technology”, “technology transfer”, “knowledge transfer”, and “technology commercialization”.

Annotated Bibliography

Anatan, L. (2015). Conceptual issues in university to industry knowledge transfer studies: A literature review. *Procedia - Social and Behavioral Sciences, 211*, 711-717. doi:10.1016/j.sbspro.2015.11.090

This paper discusses university to industry knowledge transfer in the context of alliances. Anatan reviews literature related to understanding why organizations enter alliances for the purposes of university to industry knowledge transfer. Three major theories she identified in the literature used to explain this phenomenon were transaction cost economic theory, resource-based view, and knowledge-based view. Anatan proposed institutional theory as an alternative framework for explaining factors that affect the university to industry knowledge transfer process. She argued that external environmental forces pressure organizations to form alliances to enable university to industry knowledge transfer. This paper has implications for how technology transfer is defined in the planned study. It is also relevant to understanding approaches that have previously been used to study university technology transfer, which informs the research design of the planned study.

Arshadi, N., & George, T. F. (2008). The Economics of University Research and Technology Transfer. *Research Management Review, 16*(1), 1-19. Retrieved from http://lib.slu.edu

This paper presented the results of an analysis of various aspects of university research and technology transfer conducted by faculty of the University of Missouri – St. Louis. Arshadi and George hold doctorates in financial economics and chemistry, respectively. They discussed empirical data about a variety of aspects about technology transfer including university research and technology transfer activity, the structure of university research, patterns of patenting and licensing among universities, the microeconomic factors that influence choices between licensing to an established company or forming a new business venture to pursue commercialization, and determinants of licensing activity by universities. Using regression analysis, Arshadi and George found that the number of licenses and options executed by universities was positively correlated with the number of licensing agents and cumulative research expenditures for the institution. However, they found no association between the number of licenses and options and the amount of licensing income generated. The adjusted R-square was 66 percent for their model that used licenses and options as the dependent variable and 86 percent for their model that used research expenditures as the dependent variable. However, the authors did not address causality in their analysis and they did not recommend future research paths related to the topic. This source is relevant to understanding factors that are exogenous to the technology transfer process. It also provides evidence that the role of development stage in university technology transfer has not be adequately investigated in the literature.

*Barriers to domestic technology transfer: Hearing before the Subcommittee on Oversight and Investigations of the Committee on Energy and Commerce, House of Representatives*, 102nd Congress, First Session (1992).

This book contains congressional hearing testimony about impediments to transferring taxpayer funded technologies developed by federal laboratories to the private sector. The witnesses that testified consisted of representatives from several federal agencies as well as executives from a couple of Fortune 500 companies, an industry association, and a state economic development organization. Most of the witnesses seem to primarily offer anecdotal evidence to support their arguments with little, if any, supporting empirical data or analysis. There are several key points relevant to investigating the role of development stage in university technology transfer. The testimony from the Michigan Biotechnology Institute (MBI) discussed its efforts to advance technology from the pre-competitive stage to a stage that is useful to industry. This suggests a relationship between development stage and successful technology transfer. The testimony of the undersecretary of commerce for technology pointed out that on the demand side technology transfer is fundamentally a business decision. Many witnesses cited threats to national economic competitiveness in the global market as the primary reason that more effort to reduce barriers to technology transfer were needed. The president of the National Tooling and Machining Association discussed the impact of repealing the investment tax credit that was enacted to encourage technology modernization efforts of the private sector as well as the proper role of government. The director of Hewlett-Packard Laboratories briefly mentioned the challenge of measuring the return on investment from research. This source is relevant to establishing *prima facie* justification for the proposed research study and using organizational theory and behavior and decision theory as perspectives from which to analyze the issue.

Bozeman, B. (2000). Technology transfer and public policy: A review of research and theory. *Research Policy, 29*(4,5), 627-655. Retrieved from http://lib.slu.edu

This paper reviewed the literature on technology transfer from universities and government laboratories in the United States that was considered recent at the time it was published. Bozeman, then a professor of public policy at Georgia Institute of Technology, examined how ambiguities associated with various technology transfer concepts affected research and theory on the topic. He used a contingent effectiveness model of technology transfer to organize the related literature. A major premise of this model is that effective technology transfer has multiple meanings. The author noted the challenge that defining technology and measuring the technology transfer phenomenon poses for scholars. He summarized the major technology transfer-related policy legislation from the two prior decades. He also identified market failure, mission, and cooperative efforts as the three major paradigms for technology policy. Additionally, Bozeman summarized the various criteria used in the literature to evaluate technology transfer effectiveness and discusses the major advantages and disadvantages of each. He concluded that research on technology transfer has been focused on evaluation, which has both helped and hindered theory development. The evaluation focus of technology transfer research is helpful because it generally requires empirical analysis, which supports development of explanatory theory. But it also typically means that research design is dictated by sponsor interests rather than theoretical considerations. Bozeman points out several topics that are prime candidates for future research including the politics of technology transfer, critical impacts on the technology transfer process, distributional outcomes of technology transfer-based economic development, and the impact of technology transfer on institutions. This source provides useful insights regarding the tasks necessary for investigating the role of development stage in university technology transfer, specifically defining technology and technology transfer and formulating the research design.

Bush, V. (1945). *Science, the endless frontier. A report to the President on a program for postwar scientific research*. Washington, D.C.: U.S. Government Printing Office.

This report outlined the framework for federal funding of research conducted by universities in the United States and laid the groundwork for what would eventually become the National Science Foundation (NSF). Its findings were developed through a process that consisted of several specialized committees comprising mostly scientists and scholars who debated specifically assigned topics and presented recommendations to Bush, who subsequently used those recommendations to develop a final official recommendation to the President of the United States. Bush describes the relationship between government and science and between science and the public welfare. He primarily presents a normative argument. Among Bush’s findings and recommendations is that the functions, powers, and duties of the government as embodied in a new agency should include improving the transition of research discoveries to practical applications by industry. He specifically notes that members of the committee on science and the public welfare either strongly believed or were sympathetic to the idea that government should encourage the formation of “new scientific enterprises” but were not able to agree on solutions for achieving this end. This book is particularly relevant to understanding the role of the government in university technology transfer.

Carlsson, B., & Fridh, A.-C. (2002). Technology transfer in United States universities: A survey and statistical analysis. *Journal of Evolutionary Economics, 12*(1/2), 199. doi:10.1007/s00191-002-0105-0

This paper presents the results of an examination of the role of university technology transfer offices in transferring the research results produced by university faculty as measured by patents, patent licenses, and new venture formation. Carlsson and Fridh, both professors of industrial economics, used survey data from 12 U.S. universities they collected themselves to study the role of university technology transfer offices within the organizational structure of their institutions. They conducted multiple regression analysis using survey data from 170 U.S. universities collected by the Association for University Technology Managers (AUTM) to identify factors associated with successful technology transfer. Based on their analysis, Carlsson and Fridh conclude that university technology transfer outcomes are only partially reflected in measures of income generation and new business venture formation. Moreover, they found that success in technology transfer as measured by patents, patent licenses, and new business venture formation is dependent on community receptivity; the amount of aggregate research expenditures of the university; and the culture, organizational structure, and employee incentives of the universities. The authors suggest several topics for future research including the absorptive capacity on the demand side of the technology transfer process and environmental factors that support technology transfer. This paper provides insight into the factors associated with successful university technology transfer. It provides further evidence that the role of development stage has not been adequately investigated in the literature. Additionally, it helps in understanding how academic scholars have typically studied technology transfer and potential research designs for the planned study of the role of development stage in university technology transfer.

Dolmans, S. A. M., Shane, S., Jankowski, J., Reymen, I. M. M. J., & Romme, A. G. L. (2016). The evaluation of university inventions: Judging a book by its cover? *Journal of Business Research, 69*(11), 4998-5001. doi:10.1016/j.jbusres.2016.04.070

This paper presents the results of a study of the influence of inventor appearance on how university technology licensing officers assess the commercial potential of disclosures of potential new inventions. The authors conducted a randomized experiment with a 2x1 between-subjects design using technology licensing officers at Carnegie I rated research universities in the United States as subjects. They randomly assigned experiment participants to two groups. They asked each group to evaluate an invention disclosure that contained a picture of the inventor and rate its value to industry. The disclosure presented to each group was identical except for inventor appearance. For one group the inventor pictured was a well-groomed man in a business suit. The other group was presented with the same disclosure but with a picture of a less well-groomed man in casual clothing. The results of the study were significant at the 0.05 level and demonstrated that technology licensing officers perceived technology from faculty with a more well-groomed professional appearance to be more commercially valuable. The study raises the question of whether a similar phenomenon may occur with decision makers in private sector firms regarding perceptions of market potential as influenced by the development stage of the technology. The study also provides a model for a potential research design to investigate the role of development stage in university technology transfer.

Feibleman, J. K. (1961). Pure science, applied science, technology, engineering: An attempt at definitions. *Technology and Culture, 2*(4), 305. Retrieved from https://www.jstor.org/stable/pdf/3100886.pdf

In this paper, Feibleman makes a reasoned argument to define three distinct kinds of scientific pursuits. He defines pure science, both theoretical and experimental, as a systematic effort to describe nature and discover natural laws with no concern for potential application. He defines applied science as the application of pure experimental science for improving human means and ends. However, scientific pursuits are not entirely pure science or applied science. Fiebleman defines technology as the improvement of instruments used to extend applied science. He argues that the distinction between applied science and technology comes down to a difference in approach. According to Feibleman, applied science uses theory to deduce hypotheses while technology is the result of trial-and-error and skilled approaches derived from experience and intuition. Fiebleman defines engineering as technology applied to particular cases. He goes on to argue that applied science and technology have essentially merged. He further argues that pure science has come to dominate both applied science and technology. However, Fiebleman does note that applied science and technology often reveal previously unknown scientific principles and natural laws. This source is relevant to defining technology for the purposes of conducting the planned study of the role of development stage in university technology transfer as well as public policy formulation.

Fraser, J. (2010). Academic technology transfer: Tracking, measuring and enhancing its impact. *Industry and Higher Education, 24*(5), 311-317. Retrieved from http://lib.slu.edu

This paper discussed various trends in the way U.S. universities pursue technology transfer and explored developments in measuring the effectiveness and impact of university technology transfer. Fraser, a former president of the Association of University Technology Managers (AUTM), used then recently published statistics to support his argument. He stated that success in technology transfer should be measured by more than just commercialization as determined by the amount of licensing income generated. According the Fraser, the trend in measuring technology transfer success has migrated from input metrics to output indicators to outcome and impact measures, which technology transfer practitioners believe are more appropriate. He did mention the impact of technology transfer activity on the area surround the institution as a consideration and offers a few other suggestions for metrics such as the number of lives saved, improvements in the lives of patients, and increases in competitiveness. Notable examples of new approaches to measuring technology transfer success included academic impact, economic impact, financial impact, and societal impact metrics created by the University-Industry Liaison Office at the University of British Columbia in Canada and a macroeconomic study conducted on behalf of the Biotechnology Industry Organization. Regarding the methods used by universities to pursue technology transfer, Fraser noted that the role of new business venture formation is increasing. Companies with less than 500 employees account for the bulk of licenses for university-created technology. Fraser also pointed out the increasing use of gap funding to help make the transition from research and development to the market – the so called “Valley of Death.” These observations are particularly relevant to the planned study. They inform how technology transfer should be defined, provide support for the notion of development stage as an important explanatory variable, and provide insight about the factors that should be considered in the research design.

Frické, M. (2019). The Knowledge Pyramid: the DIKW Hierarchy. *Knowledge Organization*, 46(1), 33-46. doi:10.5771/0943-7444-2019-1-33

This journal article discussed the difference between data, information, knowledge, and wisdom. Frické doesn’t describe a methodology for his analysis. It is essentially a normative argument that uses the DIKW framework. Frické’s main argument is that the DIKW hierarchy is insufficient and should include document and sign as two additional concepts. He argues that documents are culturally-specific tools for communicating knowledge, information, and data. This harkens to the cultural school of thought regarding the definition of technology. Additionally, Frické points out that the DIKW framework is relevant to organizational learning, which is an important aspect of organizational decision making. He mentions Müller and Maasorp (2011) and their use of the DIKW hierarchy as a theory of decisions flows within the context of organization behavior. Frické does not provide any recommendations for future research on the topic. While this source is primarily relevant to defining the construct of technology for the planned study, it is also relevant to understanding how organizations function in the context of university technology transfer and make decisions to acquire university-created technology.

Heisey, P. W., & Adelman, S. W. (2011). Research expenditures, technology transfer activity, and university licensing revenue. *Journal of Technology Transfer, 36*(1), 38-60. doi:10.1007/s10961-009-9129-z

This paper investigated the association between revenue from licensing of university-created technology and various factors exogenous to the technology transfer process including the aggregate amount of research expenditures for the institution and characteristics of universities. The authors combined data from the annual licensing survey for years 1991 through 2003 conducted by the Association of University Technology Managers (AUTM) with research and development expenditure data from the Survey of Research and Development Expenditures at University and Colleges for years 1981 through 2003. Their analysis concluded that there was a statistically significant association between certain characteristics of the technology transfer offices of the universities and the amount of revenue generated from licensing university-created technologies. They found a weak relationship between the aggregate amount of short-term research expenditures for universities and the amount of licensing revenue generated. In justifying their study, Heisey and Adelman discussed various economic factors related to university technology transfer. They note that scientific knowledge has a public good nature and the difficulty of measuring the societal benefits of the production of scientific knowledge. The authors also discuss two opposing hypotheses about the impact of increased use of property rights as a mechanism to stimulate technology transfer. One states that increase use of property rights by universities would increase the transfer of technology and subsequently increase social welfare. The other posits that increase use of property rights by universities would increase transaction costs and cause university administrators to favor academic areas they perceive to have greater potential to produce revenue generating intellectual property, which would decrease social welfare in the long run. The authors suggest technology transfer office performance, modeling technology transfer office performance, and the channels used to convert university research outputs to desirable societal outcomes as possible areas for future research. This source is relevant to establishing the economic rationale for government intervention in university technology transfer. It also provides support for the position that development stage has not been adequately studied in the literature.

Herschbach, D. R. (1995). Technology as knowledge: Implications for instruction. *Volume 7 Issue 1 (fall 1995)*. Retrieved from https://vtechworks.lib.vt.edu/bitstream/handle/10919/8589/herschbach.pdf?sequence=1

This paper explores the notion that technology constitutes a type of formal knowledge that can be structured as a course of study. Herschbach argues that this is not so because technology has distinct characteristics that distinguish it from formal knowledge. He cites Emmanuel Mesthene’s 1969 essay *The Role of Technology in Society* in which Mesthene defined technology as “organized knowledge for practical purposes.” Herschbach acknowledged that technology embodies knowledge. What is at issue is the kind of knowledge that technology embodies and how that knowledge fits within the broader context of human knowledge. Herschbach used reasoned analysis to make the case that the knowledge embodied in technology only has meaning in the context of human activity whereas scientific knowledge is independent of human activity and reflects phenomena found in the physical world. As such, the knowledge embodied in technology cannot be effectively codified. Therefore, it cannot be considered a discipline. This source is relevant to defining technology for the purposes of public policy formulation and the planned study of the role of development stage in university technology transfer.

Hishida, K. (Ed.) (2013). *Fulfilling the promise of technology transfer: Fostering innovation for the benefit of society*. Tokyo: Springer.

This book is a collection of essays on key technology transfer topics that were prepared for a symposium held at Keio University in Japan in 2012 that was focused on international university-industry collaborations. In general, the contributors are technology transfer practitioners although many have doctoral degrees. Several essays are relevant to the proposed study of the role of development stage in technology transfer. Benjamin Chu discussed technology transfer from the perspective of a public university by describing activities at the Los Angeles campus of the University of California. He discussed a program the university implemented to close the gap between the state of a technology where federal funding ends and the point where the private sector is willing to partner to make use of the technology. This is strong anecdotal evidence of a relationship between development stage and successful technology transfer. Ruth Herzog and Christopher Wasden discussed holistic performance measures for managing the transfer of life science innovations produced from publicly funded research. They presented a production model of research that might prove useful in defining technology and technology transfer. Mark Spearing gave a talk on exploiting university-created intellectual property. In his comments, Spearman specifically used the concept of technology readiness levels (TRLs) to describe development stage and the point where it becomes more difficult to advance the technology to where it is useful and can be transitioned to the private sector for commercialization. He argued for the importance of mechanisms that bridge this gap. This provides more *prima facie* anecdotal evidence of an association between development stage and successful technology transfer.

Ismail, M., Hamzah, S. R. a., & Bebenroth, R. (2018). Differentiating knowledge transfer and technology transfer: What should an organizational manager need to know? *European Journal of Training & Development, 42*(9), 611-628. doi:10.1108/EJTD-04-2018-0042

This paper examined the difference between knowledge transfer and technology transfer and the implications for managing knowledge within an organization. The authors used signaling theory as the basis for their definitions of the two phenomena. They analyzed the content of international publications on the topic. The authors attempted to make the case that knowledge transfer and technology transfer are distinct but their argument did not seem sound. They didn’t so much define knowledge transfer as specify elements required for knowledge transfer to occur. Their definition of technology transfer is more akin to technological diffusion. Ismail, Hamzah, and Bebenroth identified differences between knowledge transfer and technology transfer along six dimensions. These dimensions were information characteristics, usage in national development, sender and receiver roles, transfer boundary, impact on foreign direct investment, and the effect of worker mobility. The authors make several suggestions regarding future research including the generation of empirical evidence for the differences they identified, the speed at which industrialized countries receive and absorb technologies from abroad, the influence of personal and organizational factors on the transfer process, predictors of transfer “stickiness”, the influence of cultural and leadership factors on the transfer process, and the roles of higher education in worker mobility. This source is relevant to defining university technology transfer for public policy formulation and the planned study of the role of development stage in university technology transfer.

Kochenkova, A., Grimaldi, R., & Munari, F. (2016). Public policy measures in support of knowledge transfer activities: A review of academic literature. *The Journal of Technology Transfer* (3), 407. doi:10.1007/s10961-015-9416-9

This paper systematically reviewed the literature related to knowledge transfer from academia to the private sector. The authors indicated that the main justification found in the economic literature for government intervention in university knowledge transfer was market inefficiencies, particularly the lack of private sector funding for technology transfer activities, as well as systemic failures such as communication difficulties and differences in priorities, goals, and objectives of actors in the transfer process. The authors examined 46 studies that either explicitly referenced public support mechanisms to facilitate university knowledge transfer activities or conducted investigations of single policy measures or sets of measures aimed at technology transfer. Based on this review, the authors classified the literature along two dimensions. The first was the type of policy measure studied. The second was the type of study conducted. The authors then summarized the findings from those studies and identified gaps in the literature. They found that the primary public policy measures studied in the literature included legislative and institutional measures, direct financial measures, and competence-building measures. In general, all the studies were focused on either policy design or impact assessment. A significant number of the studies focused on the design of intellectual property rights. The authors suggested several areas for future research such as the design, characteristics, and effectiveness of legislative measures other than intellectual property rights, factors that influence the impact of specific funding-related initiatives, the optimal structure for competence-building policies, and the impact and effectiveness of measures meant to increase technology transfer. This source provides a succinct summary of the discourse on public policy regarding university technology transfer and the public sector economic issues relevant to the topic. It also provides insights that are relevant to the research design of the planned study of the role of development stage in university technology transfer.

Kundu, N., Bhar, C., & Pandurangan, V. (2015). Managing Technology Transfer: An Analysis of Intrinsic Factors. *South Asian Journal of Management, 22*(3), 69-95. doi:Retrieved from http://lib.slu.edu

This paper examined the intrinsic factors of technology transfer in the context of economic development. The authors argued that most studies of technology transfer have focused on extrinsic factors and that intrinsic factors have been inadequately investigated. They cited the inability of private sector organizations to ever satisfy all their technology needs through internal activity as the primary explanation for why private sector organizations engage in technology transfer. They defined technology transfer as “the process by which technology, knowledge, and information developed in one organization for one purpose is applied and utilized by another area in another organization, for another purpose.” This definition seems somewhat labored. Kundu, Bhar, and Pandurangan structured the technology transfer process into three phases comprising pre-transfer activities, transfer activities, and post-transfer activities. To conduct this study, the authors used content analysis of the literature located from searches on specific key terms. They identified and grouped 13 classes of barriers to technology transfer found in the literature. They then identified potential intrinsic barriers that have been overlooked in the literature. The authors argued that the extrinsic barriers are essentially symptoms of intrinsic barriers. In many cases, the factors they described are intrinsic primarily relative to the individual actors and not necessarily the technology transfer process. The authors identified three topics for further research. One is the degree to which extrinsic barriers play a role in successful technology transfer. The second is the importance of intrinsic barriers to successful technology transfer relative to extrinsic barriers. The third is whether focusing on intrinsic barriers increases organizational capabilities or the likelihood of successful technology transfer. This source is relevant to the planned study because it provides further evidence that development stage has been overlooked in studies of university technology transfer. The paper also suggests that development stage is a worthwhile topic for study given that it is intrinsic to the technology transfer process.

Kuo, P. S., Lin, Y. S., & Peng, C. H. (2016). International Technology Transfer and Welfare. *Review of Development Economics, 20*(1), 214-227. doi:10.1111/rode.12212

This paper investigated the effects of international technology transfer on welfare under the conditions of Bertand and Cournot competition. The authors defined international technology transfer as “the process of transferring new technology from a firm in one country to a firm in another country.” They used a model of two domestic firms that produced products differentiated on quality that licensed cost-reducing technology from a foreign licensor under a fixed-fee arrangement. The authors demonstrated that under Bertrand competition the licensor will execute an exclusive license for the technology with the domestic competitor producing the higher quality product. This will result in a decrease in welfare if the quality of the new technology is only slightly better than the existing domestic technologies and not above some minimum threshold. Their analysis indicated that under Cournot competition the licensor will execute non-exclusive licenses with both firms, which will increase welfare. The authors did not offer any suggestions for future research. This paper informs the planned study in several ways. The definition of international technology transfer is informative to the planned investigation of the role of development stage in university technology transfer. The study described in the paper examined technology transfer primarily from the supply side. It provides another datum to suggest that demand side factors have not largely ignored in the literature. The assumptions of the model described in the paper are overly restrictive. Universities may engage in international technology transfer but it appears that neither they nor private sector firms take social welfare into consideration when making technology transfer decisions.

Lall, S. (Ed.) (2001). *The economics of technology transfer*. Northampton, MA: Edward Elgar Publishing, Inc.

This book is a collection of papers by various authors that focus on technology transfer across countries. At the time of publication, the editor was a professor of development economics at the University of Oxford in the United Kingdom. The introduction by Lall is quite informative and perhaps the section of the book that is most relevant to the planned study of the role of development stage in university technology transfer. Lall discussed the market for technology and explained how technology has some features of public goods. She touched on some of the market failures in the technology market as well as challenges with quantifying costs and benefits of technology transfer. Lall also provided insight about the different modes of technology transfer and their impact on the process of transferring technology from one setting to another. Lall commented about important research issues in the field of technology transfer as it relates to international development. These issues focus on foreign direct investment. This source has general significance to understanding the role of the federal government in university technology transfer and the rationale for government intervention. The section authored by Lissoni and Metcalfe is specifically germane to understanding the role of development stage in the dissemination of technology.

Lee, Y. S. (Ed.) (1997). *Technology transfer and public policy*. Westport, CT: Quorum Books.

This book is a compilation of papers that explored the technology transfer-related collaborative interactions of research universities, federal laboratories, and private sector firms. The book was the product of the 1993 symposium titled “Technology Transfer and Public Policy: Preparing for the 21st Century” that was held at Iowa State University. At the symposium, more than 300 participants from universities, governments, and private sector firms discussed a variety of technology transfer issues. A key finding relevant to the planned study is that scientific research conducted at universities produces very early stage technology with significant amounts of risk regarding commercial exploitation even when universities conduct the research with an application in mind. Private sector firms are unlikely to invest in commercializing such technologies unless the they are significantly de-risked. Another key finding germane to the planned study is that even focused applied research requires significant funding to de-risk the resulting technology. Universities do not have this funding and private sector firms are unwilling to spend such funds to de-risk technology. This creates a funding gap that poses a major impediment to technology transfer. These findings were generated from participant observation and case study analysis of firms that were part of an Iowa State University pilot program to access the feasibility and efficiency of technology-push and market-pull approaches to technology transfer.

Libecap, G. D. (Ed.) (2009). *Measuring the social value of innovation: A link in the university technology transfer and entrepreneurship equation* (Vol. 19). Bingly, United Kingdom: Jai Press.

This book discussed the potential social, ecological, and economic value of university innovations that may result from their adoption by the private sector. The editor pointed out that only scant ad hoc assessments of the social and ecological benefits of university technology transfer exist in the literature. The 26 contributors to the book included scholars in the areas of economics, sociology, and higher education policy; senior level university administrators; and global leaders in the field of technology transfer. The book covers (1) establishment of a formal protocol for measuring social value, (2) relevant metrics and measures, and (3) pilot program structure. The introductory chapter noted that current methods for assessing the value of university technology transfer primarily rely on tangible direct metrics such patents and patent licenses. It also highlighted the shortcomings of such approaches. Other forms of noncommercial benefits explored in this book include spillover effects, human capital development, and increases in quality of life. This source informs the potential research design for the planned study of the role of development stage in technology transfer. Development stage is generally considered in the context of commercial benefits. This book raises the question of whether development stage is relevant in the context of noncommercial benefits of university technology transfer.

Link, A. N., & Scott, J. T. (2019). The economic benefits of technology transfer from U.S. federal laboratories. *The Journal of Technology Transfer* (5), 1416. doi:10.1007/s10961-019-09734-z

This paper described the economic benefits that accrue to private sector firms when they engage in technology transfer with federal laboratories. The authors provided a general overview of relevant public policy measures that were implemented since 1945 to encourage technology transfer. They used microeconomic analysis to argue that there is an increase in social welfare if federal laboratories can provide technology more efficiently than private sector firms can create it for themselves. The increase in social welfare results from increased profits for the private sector firms and lower prices for consumers. The authors proposed that the history and application of public sector initiatives and examinations of the social benefits that can be attributed to technology transfer as areas for future research. Their analysis seemed flawed because it assumed that technologies transferred from federal laboratories to the private sector are cost-reducing, which may not be the case. Moreover, it assumed that private sector firms will pass along cost savings they derive from adopting technology transferred from federal laboratories to consumers, which doesn’t necessarily occur. This source is relevant to the research topic because many of the issues and challenges of transferring technology from federal laboratories applies to university technology transfer.

Link, A. N., Siegel, D. S., & Wright, M. (Eds.). (2015). *The Chicago handbook of university technology transfer and academic entrepreneurship*. Chicago, IL: The University of Chicago Press.

This handbook attempted to combine scholarly research on university technology transfer and academic entrepreneurship into a single unified framework for understanding the phenomenon. The chapter by Audretshc and Goktepe-Hulten examined why university technology transfer is less active in Europe than in the United States. An insightful finding is that European technology transfer appears less active than U.S. technology transfer because more informal technology transfer occurs in Europe than in the United States. This informal technology transfer is simply not reflected in the metrics used to examine the phenomenon. This has implications for how technology and technology transfer are defined for public policy formulation as well as the planned study of the role of development stage in university technology transfer. The chapter authored by Marion, Dunlap, and Friar discussed several determinants of successful academic entrepreneurship, which is a specific form of university technology transfer. Most of the determinants examined are related to organizational structure and are exogenous to the technology transfer process itself. Some of the chapters offered recommendations for future research but they are narrowly defined relative to the specific chapter topics. What is more insightful is what is not included in the handbook. The handbook, which claims to be the first definitive source of major academic research on the topic, did not include any research from the perspective of the demand side of the university technology transfer process. This source is relevant for establishing the gap in the literature on university technology transfer that the planned study seeks to fill.

Markman, G. D., Gianiodis, P. T., & Phan, P. H. (2009). Supply-Side Innovation and Technology Commercialization. *Journal of Management Studies, 46*(4), 625-649. doi:10.1111/j.1467-6486.2009.00835.x

This paper used hierarchical multiple regression analysis to study the role of research universities in the United States as suppliers in a market for innovation. The authors used reasoned analysis based on agency theory and real options theory to argue that technology transfer outcomes as measured by licensing revenue and startup creation are a function of licensing strategy, the degree of autonomy of the technology transfer unit, and the incentives provided to various actors in the technology transfer process. They controlled for the age and size of the technology transfer unit, the quality of the faculty, the existence of a business incubator within the institution, and whether the university was public or private. The study used data from surveys administered by the Association of University Technology Managers (AUTM) as well as telephone interviews and content analysis of the websites of licensing units conducted by the authors. Markman, Gianiodis, and Phan found that there was a statistically significant positive association between licensing revenue and the size of the technology transfer unit, faculty quality, and financial incentives for departments. There was a statistically significant negative association between licensing revenue and use of licensing agreements strategy, use of sponsored research strategy, low-autonomy of the technology transfer unit, and financial incentives for faculty inventors. The model explained 13 percent of the value of the dependent variable. Using startup creation as the dependent variable, the authors found statistically significant positive relationships with public institutions, faculty quality, high-autonomy of the technology transfer unit, and salary of the staff of the technology transfer units. There were statistically significant negative associations with the age of the technology transfer unit and financial incentives for faculty inventors. This model explained 7 percent of the value of the dependent variable. The authors pointed out that licensing and startup creation are only two of many methods that knowledge (i.e., technology) is disseminated by universities. The authors suggested that understanding how private sector firms integrate the innovations they source from outside the organization is a potential area for future research. Another potential area for future research that the authors recommended include studies of whether private sector firms source external innovations when expanding beyond their areas of expertise. This source helps establish the need to examine the role of development stage in university technology transfer.

Mitcham, C., & Schatzberg, E. (2009). Defining technology and the engineering sciences. In A. W. Meijers (Ed.), *Philosophy of technology and engineering sciences* (Vol. 9, pp. 27-63). Burlington, MA: Elsevier.

This paper examined the definition of technology in the context of the philosophy of technology. The authors noted that reaching agreement on the definition of the subject of investigation is often a central point of debate in various disciplines. This is true of the philosophy of technology. The authors identified five approaches to definition. These approaches are etymological, conditional, prescriptive, linguistic, and pragmatic. The authors reviewed the discourse on technology to identify the various definitional strategies employed in science and engineering, the humanities, and the social sciences. They found that there were two distinct terms in European languages both of which were translated as *technology* in English. One of the European terms referred to the discussion about practical, material arts. The other referred to the actual processes and methods of the practical, material arts. This inadequate translation is a root cause of the difficulty in defining technology. It has resulted in three distinct and somewhat incompatible modern definitions of technology in English speaking cultures. The first definition is applied science, which is used in science and engineering. The second is knowledge about the practical arts and the material artifacts produced by such methods, which is used in the humanities. The third definition is means used to achieve ends, which is used primarily in the social sciences. The authors argued that the definition of technology should be contextual reflecting common language usage and natural phenomena.

Müller, Hans & Maasdorp Christiaan. 2011. “The Data, Information, and Knowledge Hierarchy and its Ability to Convince.” In *2011 Fifth International Conference on Research Challenges in Information Science Proceedings*. Colette Rolland and Martine Collard (eds). Piscataway, NJ: Institute of Electrical and Electronics Engineers. doi:10. 1109/RCIS.2011.6006851

This paper examined why the data-information-knowledge (DIK) hierarchical framework is the dominant model among information science and knowledge management practitioners. Müller and Maasdorp argued that the DIK hierarchy is an inappropriate approach to addressing the core issues of knowledge management within an organizational context. This is because DIK was derived from information theory (i.e., communication theory) but information science and knowledge management are organizationally driven, which puts them in the realm of the social sciences. Müller and Maasdorp further argued that information systems should be conceptualized as flows of decisions within an organizational context. They concluded that data and information depend on knowledge. Moreover, knowledge starts with organizational objectives, meaning, and the means of realizing those objectives. One of several conjectures that Müller and Maasdorp offered to explain the dominance of the DIK model in information sciences and knowledge management is its simplicity which facilitates organizational decision-making. This source is relevant to establishing a definition of technology for the planned study of the role of development stage in university technology transfer. It also provides insight into organizational decision-making, which is one of the perspectives the planned study will employ.

Munteanu, R. (2012). Stage of development and licensing university inventions. *International Journal of Management and Enterprise Development, 12*(1). doi:10.1504/IJMED.2012.046796

This paper presented the results of a correlational analysis between the stages of development of inventions and the licensing activity of startup and established firms, patent activity of universities, and royalty generation by universities. The study used a decidedly economic approach and sought the examine whether comparative advantage or information asymmetries influenced firm decisions to license university-created inventions. Based on an examination using multinomial logistic regression analysis of a dataset of 700 inventions disclosed to the University of California – San Diego between 1986 and 2003, the author concluded that startup firms were more likely to license early-stage inventions and established firms were more likely to license later-stage inventions. He argued that these results are consistent with the principle of comparative advantage between startup and established firms. He put forward the effects of comparative advantage and information asymmetry on licensing decisions of startup and established firms as possible directions for future research. This paper is directly related to the proposed examination of the influence of development stage on university technology transfer outcomes. It elucidates many of the challenges that the proposed dissertation study presents including how to define technology, measure development stage, and identify instances of technology transfer. However, this paper does not answer the question of why private sector organizations choose not to pursue the acquisition and use of university-created technologies that appear to align with their mission and objectives even when they appear to have the resources to do so. Moreover, there are several confounding factors that the author does not address.

Rowley, J. (2007). The wisdom hierarchy: representations of the DIKW hierarchy. *Journal of information science, 33*(2), 163-180. doi:https://doi.org/10.1177%2F0165551506070706

This paper presented a theoretical examination of the data-information-knowledge-wisdom (DIKW) hierarchy. The author’s objective was to understand the popular expressions of the hierarchy to which students and professionals are exposed. Rowley reviewed how the hierarchy was explicitly and implicitly formulated in several recent textbooks for information systems and knowledge management. She found that there was general agreement about the elements of the hierarchy, their definitions, and their ordering. There was more disagreement about the processes that transformed an element to the next higher element in the hierarchy. Moreover, Rowley observed that wisdom was generally neglected. Additionally, she concluded that consideration of meaning and structure was necessary to distinguish between data and information, which influences where information is embodied. Knowledge cannot be any more or any less than information because it is dependent on human mental faculties. Rowley argued that the definitions of information and knowledge was an area for further research because current popular definitions overlap. Moreover, she indicated that the wisdom element of the hierarchy warranted further research because it is largely ignored in the literature. This source is relevant to defining technology for the purposes of public policy formulation and the planned study of the role development stage in university technology transfer.

Schatzberg, E. (2018). *Technology: critical history of a concept*. Chicago, IL: University of Chicago Press.

This book examined how the meaning of the term *technology* has changed throughout history. Schatzberg didn’t explicitly describe his methodology for examining this topic. It appeared that he essentially used content analysis within a history of concepts framework and the Foucoult approach to review the meaning of the term in historical text and scholarly papers. There were two main points to Schatzberg’s argument. First, there are two schools of thought when it comes to defining what is technology. One views technology as instrumental reason. The other views technology as “creative expression of human culture” (p. 3). The second point is that the modern concept of technology in English speaking cultures has significantly narrowed over time. The major finding of Schatzberg’s analysis is that the modern definition of technology in fact has three distinct primary meanings that are incompatible in the grand scheme of things (p. 212). The first is applied science, which has come to be the predominant meaning. The second is an independent body of knowledge, practices, and artifacts (i.e., industrial arts). The third is the use of reason as an instrument to determine the most appropriate means to achieve an end (i.e., instrumental reason or technique). Schatzberg does not provide any recommendations for future research on the topic. This source is useful and timely. It is relevant to defining technology as a construct, which is a key aspect of the planned study of the role of development stage in university technology transfer. How technology is defined also has significant public policy implications.

Speser, P. L. (2012). *The art and science of technology transfer*. Hoboken, NJ: John Wiley & Sons.

This book is essentially a how-to manual for practitioners of university technology transfer. The author holds a Ph.D. in political science and political philosophy and Juris Doctor. She has over 30 years of experience in the field of technology transfer. This included work as a lobbyist involved in science and technology legislation and serving two terms on the Board of the Technology Transfer Society. The book basically described a theoretical model of the technology transfer process from the supply side. Speser derived this model from reflection on her experiences. She used Max Weber’s method of ideal types to describe key constructs of the model. Speser defined technology transfer as “the transfer of technology from one person to another across organizational lines” (p. xxiii). This definition seems somewhat circular. Moreover, the definition of technology used in the model is more narrow in practice. Technologies are ideas that can be embodied in such a form that their creators can secure property rights and rely on the coercive powers of the state to enforce those rights. Financial gain is assumed as the goal in the approach that Speser outlined. The primary relevant insight that Speser offered is that technology transfer is about deal making which is driven by human behavior. Although presented from the supply side, this source also provides insight into the university technology transfer process from the demand side, which will inform the research design of the planned study.

Stokes, D. E. (1997). *Pasteur's quadrant: Basic science and technological innovation*. Washington, D.C.: Brookings Institution Press.

This book examined the core paradigm that provides the framework for federally-funded research and development as well as the implications that framework has for public policy. Stokes presented an argument, based on both experience and reasoned analysis, that the static and dynamic variants of the predominant linear paradigm relating science and technology is fundamentally flawed. This paradigm posits that pure basic research is the fountain from which all technological progress springs forth. In the dynamic linear paradigm, basic research leads to applied research that gives way to development that subsequently results in production and operations technologies. Stokes demonstrated that this one-dimensional linear model is inadequate and inaccurate in describing reality. He discussed several attempts by previous scholars to develop alterative models that more correctly described the interaction between understanding and use in scientific research and technological progress. Stokes offered a two-dimensional framework to comprehend the relationship between understanding and use in the pursuit of scientific knowledge. The vertical axis indicates the degree to which research strives for fundamental understanding of phenomenon and ranges from no concern for fundamental understanding to complete focus on developing fundamental understanding. The horizontal axis indicates the degree to which research is inspired by considerations of use and ranges from no consideration to completely use-driven. This framework produces a four-quadrant model of scientific research. Pure applied research is positioned in the lower right quadrant. Pure basic research is in the upper left quadrant. The upper right quadrant exemplifies use-inspired basic research. One might conceive of the lower left quadrant as descriptive research. Stokes also noted the trajectory of technology is not just dictated by technical considerations. Market considerations also have a profound influence on the development of technology. Stokes’ argument has significant implications for understanding the technology transfer process and how development stage is conceived in the context of university technology transfer.

Stoneman, P. (2002). *The economics of technological diffusion*. Malden, MA: Blackwell Publishers.

This book examined technological diffusion using an economic approach. Although distinct from technology transfer, technological diffusion is closely related. Technological diffusion is concerned with the dissemination of a technology throughout an industry or an economy after first incorporation whereas technology transfer has to do with the introduction and first incorporation of a technology. The essential question that Stoneman examined is why all potential users of a new technology do not adopt it immediately when the new technology is superior to previous technologies. Stoneman defined technology as “goods and services produced and the means by which they are produced in a firm, an industry, or an economy.” However, Stoneman also pointed out that technology has been defined as information or knowledge within the literature, which has certain analytical advantages. He described several different theoretical and empirical approaches that scholars have used to analyze the technological diffusion process. He also highlighted several factors that various models have found to impact the technological diffusion process including learning and information spread, acquisition costs, technology performance, firm characteristics, firm attitude toward risk, and first mover advantages. These factors may also impact technology transfer. Stoneman noted that uncertainty is one factor that has been largely ignored in studies of technological diffusion. He also discussed policy issues explored in the literature about technological diffusion including the rationale for why the government might intervene in the process, the instruments government might use to do so, and the consequences of such intervention. The book proposed several future research agendas, some of which appear relevant to technology transfer. This source seems relevant several aspects of the planned study of the role of development stage in university technology transfer such as defining technology and technology transfer as well as developing the research design for conducting the investigation.

Williams, F., & Gibson, D. V. (Eds.). (1990). *Technology transfer: A communication perspective*. Newbury Park, CA: Sage Publications.

This book examined the technology transfer process as a communication phenomenon. The contributors examined four basic research questions in a variety of ways. These research questions include (1) how does one define and identify technology transfer? (2) how does organizational form influence communication between actors in the technology transfer process? (3) what are the roles of state agencies, U.S. universities, and private sector firms as environmental factors in technology transfer? (4) What are the distinctive attributes of technology transfer as a communication process? The contributors used case studies and reasoned analysis to examine the technology transfer phenomenon. The book offered a definition of technology as “information that is put to use.” The section focused on the organizational setting of the technology transfer process also provided some insights that might be useful for the planned study. A key finding presented in this section is that there are four primary technology transfer situations each of which has different critical success factors. These four dimensions are the technological innovation; the geographical, cultural, and political context; the legal, ethical, and economic aspects; and the social infrastructure. The book also included a bibliography of the literature on technology transfer and technological innovation. The bibliography included sources that examined technology transfer along the four dimensions. This source seemed only tangentially related to the planned study of the role of development stage in university technology transfer. The definition of technology critical success factors offered are probably the most relevant content.

Wu, Y., Welch, E. W., & Huang, W.-L. (2015). Commercialization of university inventions: Individual and institutional factors affecting licensing of university patents. *Technovation, 36-37*, 12-25. doi:10.1016/j.technovation.2014.09.004

This paper examined the association of individual and institutional factors with successful university technology transfer. The authors used patents assigned to universities as the unit of analysis. They used hierarchical logistic regression analysis to analyze a dataset of 675 patents obtained by Universities in 2006 that was combined with survey data collected from the inventors listed on those patents. They categorized patents as either intention-based inventions or opportunity-based inventions. The authors found that individual factors, particularly researcher attitude toward technology transfer and their involvement post-disclosure, were more strongly associated with licensing of patents that institutional factors. However, only researcher attitude was statistically significant. A key finding relevant to the planned study was the positive correlation between additional research conducted by inventors post-disclosure and licensing of patents. This is suggestive of an association between development stage and success in university technology transfer. The authors concluded that stage of development must be considered when evaluating determinants of university technology transfer success. This paper is pertinent to the planned study of the role of development stage in university technology transfer. It provides empirical evidence that development stage is an influencing factor in university technology transfer.

York, A. S., & Ahn, M. J. (2012). University technology transfer office success factors: A comparative case study. *International Journal of Technology Transfer and Commercialisation* (1/2). Retrieved from https://www.researchgate.net/profile/Mark\_Ahn2/publication/264820471\_University\_technology\_transfer\_office\_success\_factors\_a\_comparative\_case\_study/links/5629991508aef25a243d818f/University-technology-transfer-office-success-factors-a-comparative-case-study.pdf

This paper presented the results of a study of factors found to be associated with university technology transfer success. The authors identify such factors found in the related literature and then analyzed them using a stratified sample of four comparative case studies of peer university technology transfer offices. They used semi-structured interviews and surveys to collect the data for the study. The authors supplemented this data with data from the Association of University Technology Managers (AUTM) and content analysis of the websites of 48 university technology transfer offices. Their analysis found two distinct clusters. One represented successful technology transfer practices and the other was indicative of unsuccessful technology transfer practices. Based on these results, the authors offered eight (8) theoretical propositions they believe are associated with success in university technology transfer. Most of these determinants are related to organizational structure. The authors offered two primary topics for future research. One is to examine multiple dimensions of institutional culture as potential explanatory factors in university technology transfer. The other is testing the propositions they offered in the paper against a larger set of sample institutions. This source provides further evidence that technology transfer studies tend to focus on the supply side. Moreover, it provides support for the notion that the role of development stage in university technology transfer has largely been ignored in scholarly research on the subject.