OUT OF CONTROL TECHNOLOGY: CONTROLLING UNIVERSITY-BASED TECHNOLOGICAL COMMERCIALIZATION

How can the university-industry technology transfer (UITT) efforts be managed more effectively? In trying to answer this question, this paper discusses the effects of organizational controls on the performance of at each stage of a multi-stage process, ending in commercialization.

On its way towards commercial development a technology invented within a university lab will go through various stages and may be managed by various organizational entities. The way in which the process is managed is critical to the successful advancement of the technology through each stage of development and eventually to its successful commercialization. Ultimately, the management of new technologies relies on organizational control (Cardinal, 2001; Eisenhardt, 1985). As such, organizational control theory is important to the university industry technology transfer (UITT) process. Indeed it is demonstrated in this paper that the incorrect use of organizational controls, or lack thereof, have led to mismatches that negatively affect the outcome of technology commercialization efforts. For example, the analysis presented in this paper helps to explain the persistence of major extant problems at many university technology transfer offices (UTTOs); e.g., issues of low invention disclosure and the disclosure of less efficacious or desirable technologies by those scientists that do disclose (Jensen et al., 2003; Markman et al., 2004, 2005). These conundrums have only grown such that a gray market has been found with university researchers often going outside the ‘controls’ of the university environment and UTTO in attempting to commercialize their technologies (Markman et al., 2008)- in essence creating a ‘out of control’ UITT process.

Furthermore, while the nascent and growing literature in the area has provided important and useful findings from inductive grounded research, these have resulted in ad hoc recommendations that lack theoretical justification (Siegel et al., 2003c). Better use of theory is important to move the field towards a greater scientific understanding of the entities and processes involved in the UITT process. Despite the growing literature on UITT, there exists a dearth of conceptual development to help the progress of future research (see comments by numerous researchers in the area: e.g., Markman et al., 2005; Phan & Siegel, 2006; Rothenberg et al., 2007; Siegel et al., 2003c). For example, in a recent review of ‘University Entrepreneurship’ Rothenberg et al. (2007) argued from a Kuhnian perspective that more conceptual development is needed to move the area towards a mature scientific stage (Kuhn, 1970). For example, their survey of 173 articles suggested that only 2% were theory-only and 5% specific literature reviews, leading them to state: “The large number of articles focusing on the description of the university entrepreneurship phenomena is indicative of a highly fragmented field in the early stages of development. This is also echoed in the small number of categorization attempts, which can bring more focus to the research on university entrepreneurship.” (% 70-706). As psychologist Kurt Lewin (1890-1947) once stated, “There is nothing so practical as a good theory” (Lewin, 1951: 169). In this light, the purpose of this paper is to move toward a better understanding of the UITT commercialization phenomenon by using the lenses of organizational control theory to examine the UITT process. Toward this goal, a theoretically-driven review and integration of what is known about this important research area is developed in order to improve the efficacy of this multi-organizational process. Though this is by no
The next section of the paper reviews organizational control theory, which has a rich conceptual and empirical history. It is followed by a section describing each of the five generic stages of a technology’s development as extracted from the inductive empirical literature on the UITT process. Advancing through each stage of the process model predicates a change in the antecedent conditions of organizational control utilization. This stems from grounding in the extant literature of both traditional organizational control theory and the primarily empirical research on the UITT process. The empirical evidence that supports the theoretical conceptualization is given when appropriate. This is encapsulated in the performance contingency model depicted in Figure 1 at the end of the section, which ties the conceptualization together. The last section discusses the implications of the analysis for the management of the process and for further research.

Organizational Controls in Innovation

Organizational controls are defined as the processes and mechanisms utilized by managers to direct the attention and motivation of organizational members to act in desired ways to meet the organization’s objectives (Cardinal, 2001; Eisenhardt, 1985; Govindarajan & Gupta, 1985; Jaeger & Baliga, 1985; Kerr, 1985; Langfield-Smith, 1997; Ouchi, 1977, 1979; Snell, 1992). Several forms of control have been identified in the literature. These have sometimes been labeled: structural, also called bureaucratic or behavior control (Blau & Scott, 1962; Lebas & Weigenstein, 1986), input control (Merchant, 1985; Mintzberg, 1979, 1983), output control (Jaworski, 1988; Merchant, 1985), market control (Ouchi, 1979; Williamson, 1975), cultural control (Wanous, 1980), and integrative control (Roth et al., 1994). Traditionally, control is seen as an imperative of all organizations (including inter-organizational partnerships (Das & Teng, 1998)) implying an ‘ordered arrangement of individual human interactions’ (Tannenbaum, 1968, 3).

Why should we be concerned about control in the UITT process? Control is a particularly salient feature in the management of innovation and technology transfer because of the need for coordination and order in what is often a complex and ambiguous multi-stage process involving many actors. For example, field studies in the UITT area have shown anecdotally, and a study by Van Dierdonck et al. (1990) specifically, that university researchers often fear there will be too much control by administration in their interactions with industry. On the other hand, recent research in the area has demonstrated cases in which technology development have escaped the control of the university via the gray market (Markman et al., 2008). It seems apparent that systematic studies of the elements of control in the UITT process are in order. Towards that goal the conceptual development presented here posits that the amounts and types of organizational controls used in managing any particular university-based technology will have an effect on the success of the UITT process. This helps to explain some of the findings of inductive empirical research studies on UITT and the anomalies associated with the use of incentives and outcomes on university entrepreneurialism. It may also help managers deal with technological projects that have gotten ‘out of control’ or prevent this situation entirely.

The literature on organizational control has a long history but only a few studies have taken a specific look at control in innovation settings like the R&D process (Cardinal, 2001; Kirsch, 1996; Snell, 1992). Feldman (1989), for example, argued that innovation required the simultaneous regulation of autonomy and control to promote creativity. A parsimonious model of organizational control can be created using the categories of control mechanisms: i.e., input, behavior and output (Cardinal, 2001). This model of three categories of control mechanisms is used here as other manifestations such as cultural control and market control, etc. can be incorporated within this parsimonious model. For example, the
former may be managed as part of input controls and the latter by output controls. Traditionally the focus of research has been on the behavior control perspective (Barker, 1993).

Input control involves mechanisms used to control the initial introduction of a (human) resource into the organization. It “can be considered a form of resource allocation because it regulates the antecedent conditions of performance” (Cardinal, 2001: 22). In the setting of university technology transfer, input controls can consist of the introduction of specific skills, experiences and attitudes of individual members (Mintzberg, 1979, 1983). This may include, for example, the introduction of a ‘surrogate entrepreneur’ to a new firm venture (Franklin et al., 2001; Lockett et al., 2003). Input controls relate to the notion of clan control or socialization (Ouchi, 1980) because by controlling what inputs are brought into the process the overall culture and belief system of those within the process might be better managed. This is the fundamental aspect of hiring the ‘right’ people, who will ‘fit in’ at an organization, during the HR hiring process. As such, the notion of ‘professionalization’ in which the agent takes on the beliefs and practices of a profession also become important to input control. Higher levels of professionalism can indicate increasing input control (Cardinal, 2001).

Behavior control emanates from an agency theory treatment of the organization involving the monitoring of organizational members’ activities and behaviors and stipulating the means of production (Eisenhardt, 1985; Ouchi, 1977; Snell, 1992). Behavior control has a long history of research and has traditionally been associated with having a negative effect on innovation and creativity in R&D settings (Adler & Borys, 1996). It is usually associated with rules and regulations designed to ensure that the behavior of organizational members align with the goals of managers (in terms of classic agency theory, management’s behaviors align with the goals of the principals or owners of the firm). Two major aspects of behavior control are formalization and centralization. The former refers to the extent to which rules are made explicit and codified into rules and regulations and the latter to the extent to which decision making authority is granted to agents. Strong bureaucracies are considered highly formalized and centralized in their behavior controls. Particularly in terms of radical innovation, formalization and centralization are expected to have a negative effect because of the complexity and dynamics of the R&D situation (Henderson & Cockburn, 1994; March, 1991). However, a ‘formalization paradox’ has emerged from some work on the innovation process and some early research even suggested that strong behavior controls can be good in the R&D setting, particularly involving the early stages of scientists’ careers (Barlyn, 1985; Jelinik & Schoonhoven, 1993). Also, a recent empirical investigation has shown that in the pharmaceutical industry, formal behavior control may actually improve the outcomes of radical innovation ventures (Cardinal, 2001).

Output control defines the mechanisms utilized to regulate the outcomes and results of an endeavor (Eisenhardt, 1985; Ouchi, 1977; Snell, 1992). They are most associated with the use of outcome-based incentives but may also consist of punishments for failure in goal attainment (Merchant, 1985). Because they do not specify the means by which outcome will be achieved, output controls can be difficult to manage as they require the ability to determine the right incentives that will lead to behaviors that are likely to result in outcomes that match the goals of management. Creating mechanisms based on easily measured outcomes (as opposed to controls that are harder to measure but more associated with actual goals) is commonplace and leads to the problem of control displacement (Kerr, 1975; Merchant, 1985). Tying the outcomes of the venture to the reward structure of the scientists involved in the UITT process may be an effective way of motivating innovative behavior. This is indeed the rationale behind profit-sharing and equity stakes utilized in many UITT ventures. For example, a recent study of profit sharing plans showed that such plans enhanced a firm’s profitability but only for those profit drivers under the control of employees (Magnan & St-Onge, 2005). This is similar to the advice given by Merchant (1985) for R&D projects, who stated that the results must be: 1) within the control of the person being managed; and, 2) measured effectively, with 3) feedback provided and success rewarded in a timely manner. All of these aspects present problems for the drawn out and complex UITT process where many
of the goals of the process may be difficult to measure, particularly with timely feedback. For example, the ultimate goal of revenues from commercialization of the technology is particularly difficult to gain a sense of in the earlier stages of development.

As such, other types of output control may include quantifying outputs such as patents granted or the number of licenses issued and rewarding appropriately for achieving these goals. The actual type of output chosen is important due to the risk of control displacement. Choosing to focus on patent production, for example, may boost the number of patents issued but decrease the energy and focus on the actual technologies that have the most promise of development and eventual commercialization. This, for example, may help to explain why the UTTO administration at many universities involved in UITT complain about the poor quality of invention disclosures (Jensen et al., 2003). For example, if disclosure is not fully rewarded but still encouraged, people will bring forth low potential ideas that are not fully developed resulting in a large number of poor quality disclosures.

An agency theory perspective exists when utilizing an organizational controls framework. That is, it is implied in organizational control theory that a principal engages agents to perform services on their behalf which involve delegating some decision making authority and that this is managed through the use of controls and monitoring mechanisms (Eisenhardt, 1989; Jensen & Meckling, 1976). That is, the principal creates organizational controls in order to motivate or dictate agent behavior. One thing to keep in mind is that this is a constantly changing perspective such that the role of agent and principal can shift as time and circumstances change. In the simple example of the university department, the scientist professor can at first be seen as an agent who is delegated certain powers via the department administration, primarily in terms of the traditional employer-employee relationship. However, in the complex UITT process the agency perspective can change such that the scientist can later in the process take on the role of principal as owner of the new technology (at least in universities that allow scientists to own (or partially own, which is often the case) their inventions). This leads to a potential for a dual-(or multiple) principal problem (Morck & Yeung, 2003; Phan et al., 2005, 178) discussed later. For purposes of clarity, the principal is defined as the actor(s) in the UITT process that presently ‘owns’ or has an ownership stake in the technology being developed. Ownership can be defined at the right to future income streams from the commercialization of the technology.

Aspects of the Task Environment

All three types of controls mentioned earlier are used to some extent by the principal. In fact, a balanced approach to controls has often been prescribed in the literature (Cardinal et al., 2004; Bradach & Eccles, 1989). However, a major premise of organizational control theory is that aspects of the task environment will dictate the appropriateness and efficiency of controls in different contexts (Ouchi, 1979; Thompson, 1967). One element of this is task programmability, which is the ability to explicitly define and readily measure the behaviors for a certain task. The other element is related to the goals of any task. This is the outcome or output measurability, which is the ability to clearly state and measure the outcomes of any particular task. A simple strategic outline suggests that behavioral controls are most useful (i.e. efficient) whenever the task programmability is high and particularly when outcome measurability is low. Output controls are useful, obviously, when outcome measurability is high but particularly when task programmability is low. When both elements of the task environment are poor, the organizational control theory suggests input controls, or control via socialization, might be most efficient (Eisenhardt, 1985: 135).

Performance ambiguity and goal incongruence are two other aspects of agency and transaction cost economics (TCE) approaches (Alchian & Demsetz, 1972; Coase, 1937; Williamson, 1975), which are useful in understanding issues of effective control choice. Performance ambiguity may be correlated with the inverse of task programmability. That is, performance is ambiguous when it is difficult to
determine the connection between an action and the outcome. Goal congruence refers to the “agency problem” in agency theory in which there exists a potential for differences between the goals of principals and agents.

The TCE approach leads to the specification of one of three ‘modes of control’ based on organizational structures: 1) market; 2) bureaucracy; and, 3) clan (Das, 1989; Ouchi, 1980). These modes roughly correspond to the three control mechanisms, respectively: 1) output; 2) behavioral; and, 3) input. Ouchi’s (1980) original theory specified the most efficient modes based on both the performance ambiguity and goal incongruence of the task environment. Table 1 depicts the appropriate contingencies (adapted for our purposes) with regard to performance ambiguity and goal incongruence.

Table 1

Contingencies: performance ambiguity and goal incongruence (Adapted from Das, 1989)

<table>
<thead>
<tr>
<th>Goal Incongruence</th>
<th>Performance Ambiguity</th>
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<tr>
<td></td>
<td>High</td>
</tr>
<tr>
<td>OUT OF CONTROL</td>
<td>Control Difficult to Establish-Unstable; Cooperation Not Likely</td>
</tr>
<tr>
<td></td>
<td>&quot;Market&quot;/&quot;Bureaucracy&quot; Output and Behavioral Control Mechanisms Dominate</td>
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<tr>
<td>IN CONTROL</td>
<td>&quot;Market&quot; Output Control Mechanisms Dominate</td>
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Gray Shade is area of managed projects; Outside of gray area is either out of control technology projects (Cell 1) or unproblematic ones (Cell 9). Management must be reestablished for OUT OF CONTROL projects, particularly in terms of goal incongruence (See Table 2).

Type of Organization is in quotes. In general, there are three types (Ouchi, 1980):
Clan = focus on minimizing goal incongruence by using strong input controls
Bureaucracy = focus on minimizing performance ambiguity with secondary attention to goals by using strong behavioral controls
Market = focus on mitigating performance ambiguity by using strong output controls

Output controls essentially deal with performance ambiguity by focusing strict attention only to the outcome and ignoring the process or actions used to reach the outcome. These types of controls effectively deal with bringing under control projects that have high goal incongruence when performance ambiguity is lowered. Orthogonal to this scenario is the situation where performance ambiguity is high and goal incongruence is low, in which the clan mode is most efficient and thus the relative use of input controls will predominate. Here input controls help ameliorate the effects of high performance ambiguity by minimizing goal incongruence and thus rendering the high performance ambiguity less problematic (Das, 1989).
The two polar positions of high levels or low levels of both performance ambiguity and goal incongruence create problems because it is unclear what controls are best used in these cases. By introducing the other aspects of the task environment, task programmability and output measurability, we can determine appropriate mechanisms for getting an out of control technology development project back under control. The organizational control theory suggests the most effective controls are as depicted in Table 2 depending on these two aspects of the environment. If the argument that performance ambiguity is correlated with the inverse of task programmability is held then this suggests that Cell 1 of Table 1 can be controlled by greater use of output controls given greater output measurability but this only holds when the ownership of the technology is closely held (i.e. goal incongruence is held in check). Situations where goal incongruence is high will require appropriate input controls to drive goal congruence to those levels of Cells 2 and 3 in both Tables 1 and 2. Thus, to deal with the case of ‘out of control’ UITT depicted in Cell 1 of Table 1- an appropriate mix of output and input controls is warranted. The case of Cell 9 in Table 1 simply suggests that behavioral controls will be used though no real agency problem exists.

Table 2

Contingencies: task programmability and output measurability

<table>
<thead>
<tr>
<th>Task Programmbility</th>
<th>Output Measurability</th>
<th>Moderate</th>
<th>Low</th>
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<tr>
<td>Low</td>
<td>&quot;Market&quot;/&quot;Clan&quot;</td>
<td>&quot;Market&quot;/&quot;Clan&quot;</td>
<td>&quot;Clan&quot;</td>
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<td></td>
<td>&quot;Output Control Mechanisms Dominate&quot;</td>
<td>&quot;Output Control Mechanisms Dominate&quot;</td>
<td>&quot;Input Control Mechanisms Dominate&quot;</td>
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<tr>
<td>Moderate</td>
<td>&quot;Market&quot;/&quot;Bureaucracy&quot;</td>
<td>&quot;Bureaucracy&quot;/&quot;Clan&quot;</td>
<td>&quot;Bureaucracy&quot;</td>
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<td>&quot;Output and Behavioral Control Mechanisms Dominate&quot;</td>
<td>&quot;Behavioral Control Mechanisms Dominate&quot;</td>
<td>&quot;Input and Behavioral Control Mechanisms Dominate&quot;</td>
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<td>High</td>
<td>&quot;Market&quot;/&quot;Bureaucracy&quot;</td>
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<td>&quot;Output and Behavioral Control Mechanisms Dominate&quot;</td>
<td>&quot;Output and Behavioral Control Mechanisms Dominate&quot;</td>
<td>&quot;Behavioral Control Mechanisms Dominate&quot;</td>
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A major implication of these organizational control contingencies based on aspects of the task environment is that as the task environment changes over the course of the UITT process different controls will be more or less effective and should change as well. With this in mind, the next section applies organizational control theory to the stages of technological development to demonstrate how the context of each stage dictates the use of different controls and the differential effect on the successful outcomes at each stage.

Stages of Technological Development and Organizational Control

UITT can be illustrated as an abstract process involving a number of stages and actors (Markman et al., 2004, 2005; Siegel et al., 2003b). For example, Siegel et al. (2003b) describes a process ‘according to theory’ as consisting of 7 stages and involving three main actors: 1) university scientist (University Departments); 2) technology transfer officers (UTTOs); and, 3) Entrepreneurs (Firms) (: 114). More recently, Markman et al. (2005) inductively describe the UITT process from the ‘technology point of view’ as one involving four technology stages flowing from an ‘early stage’ to ‘proof of concept’ to ‘reduction to practice’ to ‘prototyping, formulation and compound’. This latter framework is adopted here (with the addition of the scientific discovery stage) because it specifically describes the technology itself
as the basis for each stage in the process. The ‘technology’ is taken as the unit of analysis or boundary condition for this conceptual model in order to give focus in this multi-actor and multi-organizational process. A knowledge-based perspective leads to a definition of technology as systemic knowledge with the potential for some sort of utilitarian purpose. Of course, technologies are discovered, developed and commercialized within organizations and may involve a number of actors or stakeholders in the process over time. Furthermore, technologies themselves evolve over time. However, following the knowledge-based definition, the underlying knowledge or idea behind a ‘technology’ (and its interconnections with other technologies) that is eventually incorporated in a commercial product can be followed over time. Thus, the technology and the UITT process can be illustrated by the metaphor of a river that is at once in constant flux while also remaining a ‘whole’ and seemingly still when viewed from different perspectives. These changing elements are brought into the analysis when appropriate. However, to give the analysis a specific boundary and allow us to make sense of the process, it must be emphasized that the focus is from the perspective of the technology (as systemic knowledge) itself. For example, a technology to encode security data will evolve over time but we can track its development through the UITT stages by focusing on the systemic knowledge surrounding the technical notion of ‘encoding security data’ that is developed over time. When organizational entities like the UTTO are discussed in the analysis, they are discussed from the point of view of the technology. Our interest in the organizational entities (including projects and people within them) involved at each stage is primarily in how they manage the development of the technology itself. The process and its stages are also discussed as generically as possible to illustrate the common conceptual elements of the UITT process. Of course, specific technologies have idiosyncratic aspects to their development such as perhaps the time spent in each of the development stages but all university-based technology developments are expected to share these common generic stages as illustrated by inductive empirical research in the area (Markman et al., 2005).

Scientific discovery

From a technology perspective, the UITT process starts when a new idea, a process or an entity such as a chemical is ‘discovered’ or invented in the university lab. This beginning stage is described as a ‘scientific discovery’. At this point, no utility (or productive use) of the scientific discovery may have been identified. That is, the ‘technology’ may only consist of the potentiality of the knowledge for technical development without any connection to a practical use. This is within the realm of traditional university research. The main actors are the university scientist and the university administrators. In terms relative to the other stages of the UITT process, this beginning stage involves tasks that are hard to precisely program and performance which is highly ambiguous in that it is very difficult to determine what actions might lead to what technological breakthroughs or new ‘know-how’. While goal incongruence between the faculty scientists and administration will depend somewhat on the culture of the university; in general, the relative potential for goal incongruence (compared with the other stages of the development) is on the low side. These characteristics of the task environment lead to the following observations on the types of controls utilized (also delineated in Table 3).

In terms of input controls, the focus is on scientific inputs; namely, the scientists themselves and graduate students as well as non-human resources specific to the research domain such as genetic plasmids and/or other equipment, etc. Thus, in the beginning input diversity is low in terms of human resources and domain specific in terms of non-human resources. Due to the specialist nature of these scientific developments, professionalism elements of input controls will be high. Bringing in the right people and equipment will influence the potentiality of the technology development. Behavior controls are often formal and centralized with the bureaucratic regulations of the university concerning things such as ethical research practices and declaration of professional practices. However, monitoring is difficult due to the low programmability so in general (before a specific technology is identified) formalization and centralization elements of behavior control are low- hence, the high degree of autonomy in the basic research objectives of university faculty members. Behavior controls related to technology development
that do exist are greater in public schools or whenever accountability to an external grant provider such as the federal government is involved (cf. Markman et al., 2005). Recall control displacement, which means that outputs that are more easily measured may take precedence in the control structure of the process. Tangible outputs are more likely to be taken as the target. At this early stage outputs primarily consist of research findings with the most widely emphasized rewards based on publication output in peer-reviewed journal articles. This is the traditional output at universities primarily because of the difficulty in determining the success of faculty members’ actions due to the high performance ambiguity in the many tasks performed.

One output associated with the next stage in the UITT process is ideas for new technologies or uses based on the scientific discovery. Here there is an important disconnect between the traditional process of research and scientific discovery of universities and the UITT process’ emphasis on the eventual commercial use of the discovery. As has been suggested, a key matter is the lack of properly-linked incentives (Markman et al., 2004), which is another way of stating that problems exist with output controls in the process. The main incentive is often on publication output, especially for new faculty scientists, rather than commercialization per se. For instance, Phan and Siegel’s (2006) estimate of the opportunity costs associated with academics turning entrepreneurial was eight peer reviewed papers for each patent filed (: 129) - meaning that academics who decide to enter the UITT process jeopardize their tenure and promotion status.

Conclusion on the first stage of scientific discovery: The organizational control framework suggests that at the scientific discovery stage, using organizational controls for specific technologies is difficult but necessary. The university environment will dictate behavioral controls to a large extent due to the employment nature of the work. With regard to technology developments, the most effective controls are input-based with a focus on scientific professionalism based on the specific areas of research.

**Early stage invention.** At this point, the scientific discovery may progress to the next technology stage of early stage invention. Here it may be disclosed to the UTTO, though this is unlikely due to the early stage of development. For example, the licensing of most university technologies, while embryonic compared to firm-based technologies, is not likely until at least the proof of concept stage (Thursby et al., 2001). If it is disclosed, the UTTO administration may be included in the list of potential actors involved in managing part of the stage. Also, if the technological potential of the early stage invention is prognosticated at this point, it may be possible to bring other developers into the process of technological development. Here, collaboration with other departments within the university or external ‘intermediate’ organizations like a research collaborative, particularly for technological developments requiring multi-disciplinary knowledge, is often started.

However, the still embryonic nature of this stage means that the relative task programmability and performance ambiguity is only slightly different from the scientific discovery stage. Goal incongruence is low due to the focus of most actors on finding ways that the new invention might be reduced to practice or on just learning more about it. Output measurability is also relatively low due to the nascent development of the technology. The risk of control displacement will exist with a potential for too much focus on research papers as an output. For example, publications continue as the main output measure and are particularly strong for tenure track faculty (Siegel et al., 2003a &b; Markman et al., 2004, 2005; Phan & Siegel, 2006). Potential disclosures also constitute output controls utilized at this stage with control displacement becoming a greater issue when high standards and protocols to vet quality disclosures do not exist. Input controls may change slightly but not significantly to include more multi-disciplinary inputs especially as the complexity of the early stage invention and its relation to more than one disciplinary knowledgebase increases. Funding for more development may also be solicited from these external intermediate organizations (Howells, 2006). In order to obtain funding for further development overall behavioral controls such as university rules for funding increase in importance. Depending on the external stakeholder activity at the particular time, contractual agreements will also
provide some behavioral control exercised by external providers of funds for further technology development. The organizational control framework suggests that at the early stage invention stage, behavior controls become increasingly important to the continued development of the technology.

**Proof of concept**

This stage of the UITT process is where the new invention or idea is shown to have some real application associated with it “but the mechanism by which they act may not have been discovered yet” (Markman *et al.*, 2005: 250). As such, the relative performance ambiguity with regard to the technology decreases from the early stages. While still nascent in development, the tasks associated with testing and experimenting with the new technology become clearer and thus relative task programmability compared with earlier stages becomes greater. The potential for goal incongruence and more ‘agency problem’ issues increases as the number of potential actors involved in the technology development increases. For example, even at this earlier stage where only internal university actors may be involved, empirical findings suggest that UTTOs prefer licensing while faculty members prefer ownership, which creates conflict with the organizational objectives of the UTTO in general (Thursby *et al.*, 2001; Thursby & Thursby, 2002).

Any increase in the number of actors involved provides a double-edged sword to the development process. On one hand, the increasing number of actors involved increases the chance of new findings and ideas being raised due to collaboration (i.e., more minds on the project). On the other hand, it also raises the potential for disconnection among the actors with regard to their final goals for the technology, leading to an increase in goal incongruence, conflict and administrative inefficiencies (Ensley, *et al.* 2002). Input controls may become increasingly important in order to control for this potential split in goal orientation. At this point, for example, the scientist faculty member may still be more interested in the scientific value of the concept than the commercialization and, if so, disclosure to the UTTO will be low. If the UTTO is brought into the process to start scoping out potential commercial opportunities, their protocols become important and may increase the formalization aspect of the behavior controls. Thus, while the behavioral controls become less centralized, they become more formalized in various contractual arrangements as disclosure takes place.

At this stage, output controls may begin to match the ultimate goal of the UITT process (i.e. commercialization and revenues based on the new technology) as some licensing can take place albeit still early in the technology’s development (Thursby *et al.*, 2001). Companies closely watching development in the scientific area may also become involved by making inquiries into the technology. These are likely to be small innovative companies (ibid: 62). This suggests that at the proof of concept stage, organizational controls introduced by the UTTO become more salient. The UTTO is most likely to be brought into the process at this stage of a technology’s development and its formal behavior controls utilized.

**Reduction to practice**

Similar to the proof of concept stage, this stage has moderate task programmability and performance ambiguity relative to the previous stages but performance ambiguity is slightly less given the more concrete understanding of the technology. Here the potential for goal incongruence is high due to the conflicting objectives of scientists, on one hand, the UTTO office, on another hand, and commercial interests, on still another. Ownership issues will be predominant.

Input controls become more important as diversity increases. Behavioral controls continue to be more decentralized and more formalized into various contractual arrangements. Output controls, particularly from the UTTO perspective, shift to successful licenses and, if feasible, patents. Although
some have argued that obtaining equity is potentially more lucrative, UTTOs have identified that their most important objective is obtaining royalties and licensing fees (Thursby et al., 2001). This is the stage in which the UTTO will most actively seek out licensing opportunities (Markman et al., 2005). The organizational control framework suggests that at the reduction to practice stage, input control in managing the diversity of resources are important such that selection of the proper entrepreneur to commercialize the technology is key. Here selecting the correct inputs with commercialization issues in mind is essential. Part of this process involves developing effective contractual arrangements and determination of ownership rights that may later make or break a technology’s commercialization. For example, licensing a technology allows the university to maintain ownership but at the expense of control over the commercialization process and will also place burdens on the control possible by the licensees, as discussed below.

**Prototyping, formulation, compound**

In this stage the technology has proven a ‘reliable method of producing a given result’ “with a relatively clearer market application and more robust legal protection (e.g. stronger patents)” (Markman et al., 2005: 250). While market success may not be guaranteed, the knowledge of what actions lead to what technical performance is clearer at this stage than at previous stages, so relative performance ambiguity is lessened. The potential for goal incongruence will be high relative to earlier stages because of the introduction of numerous stakeholders and actors in the process as the technology moves towards a commercial, market-oriented perspective. This increase in stakeholders (some of whom will become owners of the technology via purchasing the patent rights or securing exclusive licenses) leads to the possibility of ‘principal-principal’ agency problems (Morck & Yeung, 2003; Phan et al., 2005). That is, more than one entity may have claims to owning the technology and thus goal congruence among the parties becomes of paramount importance. The greater the goal incongruence among principals the greater the chance of out of control technology projects with unsuccessful results.

Therefore, input controls become of paramount importance at this point although the path dependent choices made in previous stages will frame these issues. Inputs consist primarily of bringing in important market-based resources to help the commercialization effort succeed. These include human resources in the form of entrepreneurs whom have the necessary expertise in marketing for this stage as well as the corporate venture financing resources needed to fund commercial ventures. Due to the high potential for goal incongruence, behavioral-based controls are most likely to be contractual in nature-stipulating what each partner is to bring to the venture- and thus less formal and centralized. This is likely to manifest itself as a startup firm, although it may consist of a program to launch the technology within an existing firm.

Evidence for an increase in the diversity of inputs is demonstrated in a study by Franklin et al. (2001) that suggested the best approach for successful spinouts was a combination of academic and surrogate entrepreneurship and that universities with more favorable attitudes towards surrogate entrepreneurs generated the most startups. On the other hand, Clarysse and Moray (2004) found, in the Belgium University they studied, that it was better for the university to coach the startup team on business issues than hire a professional manager as a CEO. This supports the importance of input controls, which is one important factor explaining the difference in success achieved across different types of startups. It may be that in the Belgium University’s case the wrong CEO was chosen for the job! More evidence of the importance of input controls comes from differences found between ‘university founded’ and independent startup new technology business firms (NTBFs). University-based startups are more homogenous, have less developed dynamics and lower performance in terms of revenue growth and net cash flow than independent high-tech startups (Ensley & Hmieleski, 2005). Thus, the importance of diversity of inputs seems clear from the literature as long as the importance of choosing the right inputs via input controls is not ignored but actively managed.
For successful UITT, behavior-based controls based on traditional university policies will decline at this stage in order to support successful entrepreneurial activities. For example, the significant barriers to the commercialization of university technologies within Irish NTBFs were found to be largely behavior-based: with inadequate infrastructure and support, distribution of the university budget and the absence of a holistic approach to the process of entrepreneurial activities (Kinsella & McBrierty, 1997). Also, university-based nonprofit research foundations and private venture extensions leading to a startup enjoy separate budgets and greater autonomy than tradition UTTO structures (Markman et al., 2005), suggesting a decrease in centralization and formalization of bureaucratic policies for successful technological development.

At this stage the ultimate objective of the UITT process - the revenue created from the commercialization of the technology - is utilized as the output measure of success. However, the creation of a startup firm or project could also be seen as an output. Di Gregorio and Shane (2003) showed that university policies of making equity investments, a low inventor share of royalties and the university’s intellectual eminence increased the creation of startups. It is important to keep in mind the extensive risks involved in staking out equity claims in startup NTBFs, however. The act is risky in terms of investments necessary for further development and commercialization as well as enforcing and/or settling on intellectual property rights and other legal issues. In university equity arrangements, the university essentially ‘loosens its control of the technology in exchange for future cash flow rights’ (Markman et al., 2005: 252). Thus, the formal university bureaucracy transforms into more arm’s length contractual arrangements in the startup phase based on the technology’s prototype. As such, the organizational control framework suggests that at the prototyping, formulation, compound stage, input and outcome controls increase in importance while behavior controls decrease.

Figure 1

Performance contingency model for organizational control mechanisms

<table>
<thead>
<tr>
<th>Process Choice (Type of Control Mechanism)</th>
<th>Context (Stage of Technological Development)</th>
</tr>
</thead>
<tbody>
<tr>
<td>* Input</td>
<td>* Task Programmability</td>
</tr>
<tr>
<td></td>
<td>* Performance Ambiguity</td>
</tr>
<tr>
<td></td>
<td>* Goal Incongruence</td>
</tr>
<tr>
<td>* Behavioral</td>
<td>* Output Measurability</td>
</tr>
<tr>
<td></td>
<td>* Formalization</td>
</tr>
<tr>
<td></td>
<td>* Centralization</td>
</tr>
<tr>
<td></td>
<td>* Bureaucratic vs. contractual</td>
</tr>
<tr>
<td>* Output</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Type (Monetary vs. Achievement Items)</td>
</tr>
</tbody>
</table>

We now come to the end of the UITT process from the perspective of the technological development. The analysis suggests that the various stages have unique characteristics and that effective
organizational controls vary across those stages. This is encapsulated in the model provided in Figure 1 that illustrates that the types of organizational controls and their effects on performance of the technology change over time. Each stage is examined with regard to the types of organizational controls associated with it and the effects on performance, specifically the effectiveness of achieving a positive outcome for that stage. Namely, this would mean the successful advancement to the next stage. Ultimately, the overall objective (from a larger perspective) is technology transfer and not just licensing or patenting of the technology at any one stage (though this may be the specific objective of some organizations such as the UTTO). Thus, the entire UITT process is successful when the technology is incorporated in a successful commercialization that results in revenues from the utilization of the technology. Of course, it is possible that an actor within the UITT process may have their own non-monetary objectives such as using the process as a gateway for developing relationships with companies in general or having non-commercial impacts on society based on the technology, but that is outside the focus of the objective of commercialization.

Table 3 depicts the five technology stages categorized according to aspects of the task environment and the types of organizational controls utilized at each stage developed from this theory.

Discussion

Implications for Management

Organizational controls are important because their use or non-use during particular stages of the UITT process can effectively drive the overall performance of the UITT endeavor. Organizational control mechanisms via output and behavioral controls determine the incentives and reward schemes of the organizations involved and hence the direction of effort taken in any technology commercialization process. Input controls determine who is involved in the UITT project and what these actors might desire as their own outputs for the project. Ultimately, the types of organizational controls utilized will have a material effect on the performance of the UITT process.

One implication for those managing such endeavors from the university perspective (i.e. the UTTO) is to inventory the types of inputs, rules and output controls utilized to help manage the process. This is important to make visible the organizational controls being used and their effects on the process. Often actors in the UITT process will know intuitively that they have an inappropriate incentive structure but not necessarily map out a plan to change, let alone implement any changes. An example is seen in Siegel et al. (2003a) where a university department chair laments that his university does not value the UITT process because it does not reward technology transfer in the promotion and tenure process. Documenting and explicating the role of organizational controls via control audits helps to focus attention on the issue and, as argued in this paper, leads to more productive UITT commercialization.

Also, the analysis suggests that the most appropriate role of the UTTO may be in making the transition from the early stage invention towards the prototyping stage where other organizational entities and control structures take over. That is, the role of the UTTO is best suited for managing the licensing and selling of university technology and network facilitator of university researchers rather than the actual management of technological commercialization endeavors. This falls in line with recent empirical data showing that 72% of a near-census survey of 128 UTTOs utilized a cash royalty licensing scheme as opposed to sponsored research (11%) and equity (17%) (Markman et al., 2005). Furthermore, the same study reported that: “although two thirds of the universities … have invested significant resources in incubators and have expressed an interest in new business startups and economic development, most of them have not linked this to their technology transfer strategy choices or to the mission of their UTTOs. This disconnect may be one reason why university incubators tend to remain at the fringe of regional
economic development efforts…” (ibid: 258). Compare this with Colyvas et al.’s (2002) suggestion that the UTTO’s role is “not to develop links between the university and industry, but rather to monitor, facilitate, and regulate the transactions between parties” (: 65). Clearly, they refer to behavioral controls.

Table 3
Characteristics of each stage of technological development

<table>
<thead>
<tr>
<th>Stage of Technological Development</th>
<th>SCIENTIFIC DISCOVERY</th>
<th>EARLY STAGE INVENTION</th>
<th>PROOF OF CONCEPT</th>
<th>REDUCTION TO PRACTICE</th>
<th>PROTOTYPING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative Task Programmability</td>
<td>Lower</td>
<td>Low/Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Higher</td>
</tr>
<tr>
<td>Relative Performance Ambiguity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(in well managed project)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potential for Goal Incongruence</td>
<td>Depends on culture-</td>
<td>Lower</td>
<td>Moderate</td>
<td>Higher</td>
<td>Depends on situation- Potentially High</td>
</tr>
<tr>
<td></td>
<td>Relatively low</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potential for Output Measurability</td>
<td>Relatively low</td>
<td>Lower</td>
<td>Moderate</td>
<td>Higher</td>
<td>Relatively Higher</td>
</tr>
</tbody>
</table>

Potential Actors Involved

Scientist; University Administrator

Scientist; University Administrator, UTTO Administrator; Other Developers

Scientist; University Administrator; UTTO Administrator; UTTO Staff

Scientist; University Administrator; Utto Administrator; Firm Entrepreneurs; Other Developers

Potential Organizations Involved

University Department

University Department; UTTO; Intermediates

University Department; UTTO; Intermediates; Start-up Firm

University Department; UTTO; Intermediates; Start-up Firm

Inputs (Control Parameters)

Scientific discipline-based: Scientists, students; Asset-specific Technical Equipment

Scientific (multi)discipline-based: Scientists, students

Scientific (multi)discipline-based: Scientists, students; UTTO staff

Scientific (multi)discipline-based: Scientists, students; UTTO staff; External Stakeholders

Behavioral (Control Parameters)

University Rules/Regulations

University Rules/Regulations; UTTO rules; Contractual regulations

UTTO rules; Contractual regulations

Contractual regulations

Output (Control Parameters)

Publications; Potential Inventions

Publications; Inquiries on technology; Licenses

Licenses; Royalties; Patents; Equity placements

Successful Prototype; Patents; Licenses; Equity placements; Royalties; Sales/Revenues

Most Effective Controls

INPUT / BEHAVIORAL

BEHAVIORAL

BEHAVIORAL

OUTPUT / BEHAVIORAL

OUTPUT / INPUT

Others have already made the argument that the main strength of university research lies in basic research and that the division of labor between this and applied research needs to be enforced (Rosenberg & Nelson 1994). Indeed, the research quality of a university was negatively associated with its commercial activity in one study of AUTM licensing survey data (Thursby & Kemp, 2002). This seems to reiterate the problem of aligning the incentive and goals of faculty with those of the UTTO. For example, Markman et al. (2004) found that, while financial incentives seemed to drive the entrepreneurial activities of UTTO personnel, incentives to scientists and academic departments were negatively related to entrepreneurial activity. Academics may not value financial incentives (Colyvas et al., 2002) and the somewhat surprising negative relationship found is an indication of a UTTO struggling to ‘incentivize’ the process only to encourage the introduction of low quality inventions (e.g. Jensen et al., 2003). This is a form of control displacement. Faculty who disclose inventions may be seen as ‘selling out’ and therefore, as the financial incentives rise, a backlash to disclosure may be created. Thus, a negative effect occurs as the university increases its pay-off to potential inventors in order to drive entrepreneurial activity. Faculty inventors themselves might see this as selling out their notion of what it is to be an academic. The higher pay-off only emphasizes this difference. Furthermore, the continued focus on traditional tenure and promotion incentives at these same universities exacerbate the situation and may emphasize in the minds of some that those who accept the higher pay-offs are not ‘real academics’ (e.g.
trading tenure and/or academic reputation for dollars). Changing the output controls by accepting patents and technology platforms as items considered for tenure decisions would help to ameliorate this problem.

On the other hand, Markman et al. (2008) recently showed that gray market activities for new discoveries or ‘bypassing activity’ (in which faculty members bypassed the UTTO administration in commercializing their technological inventions because of the tedious, bureaucratic nature of the process) was reduced with autonomous technology licensing offices (TLOs) and when faculty departments received greater shares of the royalties from the licensing. Indeed, earlier Markman et al. (2005) stated that “the direct, and often strong, oversight by a university administration limits the autonomy of UTTO management in matters of decision making, licensing strategies, and incentive systems” (: 247). All of this suggests that tying the incentives of individual actors such as scientists with those of administration such as the department itself can help drive the UITT process. This phenomenon is explained by considering the effects of correct output controls (e.g., incentives based on the output for academics-better financial rewards as well as tenure/promotion rewards) and lessening behavior controls (e.g., effects of too stringent university administration oversight) on UITT success. Thus, taking into account the organizational control theory perspective developed in this paper helps to explain some of these anomalies from the empirical literature and ties together the findings from the largely inductive research stream.

The organizational control theory also helps explain what is found once a technology leaves the university and enters the commercialization space. Startups, for instance, are useful for technology commercialization endeavors in which the technological development stage is such that marketing efforts become imperative. Here the focus will be in the middle to later stages of the technology’s development when a utility and market for the technology needs to be found and cultivated for ultimate commercialization success. A potential major problem is that some university-based startups become too reliant on their relationship with the university. As far back as the late 1980’s, Doutriaux (1987) found a negative growth rate for manufacturing firms in Canada started by university entrepreneurs with continuing contracts with academia. Recently, research suggests that over dependency on university technologies still exists. Strong ties between the startup and the university can create dependency issues (Johansson et al. 2005). Therefore, both theoretical and empirical evidence (based on this organizational control perspective) suggests that breaking away from the formal, centralized bureaucracy of the university should be actively encouraged in the latter stages of the UITT process as well as a ‘decentralized management style’ for UTTOs (Link & Siegel, 2005; Markman et al., 2008).

Implications for Research

The theoretical framework described in this paper provides a potentially valuable roadmap for future research in the area. This is due to the fact that organizational controls are related to the major impediments of the UITT process identified in the literature- namely, cultural and incentive misalignments. The concept of the stages of technological development is also helpful because UITT manifests itself as a long, drawn-out process that requires different approaches and specifically, as shown in the analysis of this paper, different organizational controls during various stages.

The performance contingency model of Figure 1 illustrates that performance can be affected by the process choices made (in this case, the use of different organizational controls). Future research can use the conceptual framework of Figure 1 to develop and test more detailed hypotheses. The whole process provides many avenues for very detailed investigations. For example, this research could be accomplished using longitudinal data that follows the development of a technology across the stages or cross-sectional data that compares different project/programs at the same stage of development to measure different process choices and their effects on performance. The analysis in this paper shows that researchers could alternatively focus on a particular stage to examine effective controls within it or as a
pan-level study that examines changes across stages. For example, a longitudinal study could investigate the changes in organizational controls over the many stages in which the technology progresses. Use of a case study methodology might also provide for evidence of qualitative differences in the diversity of inputs characterized in the analysis here. For example, Parker and Zilberman (1993) showed that the emphasis on hiring lawyers versus entrepreneurs could make a difference to the way the UTTO is managed. Also, at the personal level the ‘professionalization’ of scientists may be affected by previous experiences with the UITT process, paralleling the finding at the organizational level that a university’s previous successful experience was a key determinant of startup formations (O'Shea et al., 2005). Case studies would allow for the study of more intricate nuances in the use of inputs into the UITT process as well as perhaps the other constructs of the theory presented here. One study that could be used as an example of how to pursue this type of longitudinal case study research (with regard to the use of organizational controls) was conducted by Cardinal et al. (2004). They provide a case example of a small entrepreneurial firm that looked at changes in the types of organizational controls and their emphasis over the lifecycle or evolution of the organization.

The cross sectional type of study could employ more quantitative, perhaps econometric, data analysis such as those found in the survey studies of Markman et al. (2005); Siegel et al. (2003a,b) or Thursby and Kemp (2002), etc. Here surveys could be done to measure the use of various organizational controls across different UTTOs or UITT projects either within or across the stages of technological development. Within studies would show the differential effects on the use of organizational controls across organizations. Across studies would verify the changes necessary for effective UITT.

Choosing the most appropriate or ‘right’ dependent variable is a continuing research challenge in the field (Phan et al., 2005). The analysis provided in this paper suggests that the dependent variable will vary depending on the stage of technological development being studied. As seen in Figure 1, performance in the model here is measured as both the advancement to the next stage of development (i.e. progress in the technology) and the ultimate goal of revenues gained via commercialization of the technology (which is the raison d'être of commercialization endeavors). This last but important variable, however, may raise difficult empirical problems such as differences in accounting and declaration (or lack thereof) of income across different companies (private or public) and not-for-profit organizations. Perhaps a simple dichotomous variable (commercialized=1; not commercialized=0) would suffice. Regardless, the use of this as the ultimate performance measure, while theoretically ideal, will pose problems for empirical studies particularly those studying the stages before any actual commercialization is determinable.

Various control variables should be kept in mind, as well, when designing studies based on the analysis here. When comparing across organizations in charge of creating the controls used, the stage of organizational development or its lifecycle is likely to be important. This is due to the fact that, as argued here, organizational controls change across the evolution of an organization (Cardinal et al., 2004). This could be captured using the proxy of ‘Organizational Age’. Experience with cooperative partnerships (taking into account the role of learning over time) and the development of trust (Das & Teng, 1998) for the organizations in the UITT process also might be important control variables. Specifically, developing trust may decrease the propensity to utilize monitoring and behavior controls that otherwise might be present and be a proxy for input controls. Other potential controls, beyond trust, could come from factors found to be useful facilitators of knowledge transfer: e.g., social connectedness, IP policies, technical relatedness and capabilities (Santoro & Bierly, 2006).

While it is beyond the scope of this paper, which focuses on the university-based technology perspective, the essence of the process perspective could be continued using the process models of commercialization from the perspective of the entrepreneurial firm. For example, Vohora et al. (2004) describe the sub-processes involved specifically in startups that have four critical junctures of opportunity
recognition, entrepreneurial commitment, credibility and sustainability. In essence this is a feedback process (i.e. from the firm perspective) rather than feed-forward process (i.e. from the university technology perspective). Future research studies could utilize the organizational control theory illustrated here to examine these other processes specific to the company perspective or technology management in general. Furthermore, other organizational and strategic theoretical perspectives beyond TCE and agency theory (including, for example, the resource based view and resource dependency theory) could also shed light on the phenomenon by continuing to develop a better understanding of the processes at work. Hopefully, this will help move the field along the trajectory towards greater scientific knowledge and better management of what is an important and interesting field of research.

Indeed, some important groundbreaking technologies have stemmed from university-based work (including technologies that helped build the internet and search engines for navigating it) but evidence suggests that much of these have been the products of only a few large entrepreneurial universities with engineering schools such as at MIT and Stanford. Better ways of managing the UITT process would lead to greater probability of successful UITT at the other schools that have had excellent engineering and scientific technological developments but have been less successful in their transfer of those technologies. Recent work on regional innovation clusters suggests that schools in underdeveloped entrepreneurial environments may require ‘a more proactive role in providing incubation capabilities’ than in more developed entrepreneurial regions (Breznitz et al., 2008). This suggests the need for greater organizational controls of all types. The contingency model developed here can contribute towards that projection by providing an organizational control theory framework that: 1) integrates and explains the empirical findings in the area; 2) leads to future empirical research; and, 3) helps improve organizational functioning of the important UITT process. Ultimately, this would help to move potentially lucrative and frame-changing technologies from the relative controlled environment of the university laboratory to the commercial space where the probability of going ‘out-of-control’ without proper management practices increases dramatically.
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