Research Risk and Public Policy in a Knowledge-Based Economy: the Relative Research Efficiency of Government Versus University Labs

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Leyden, D. P., & Link, A. N. (2014). Research risk and public policy in a knowledge-based economy: the relative research efficiency of government versus university labs. *Journal of the Knowledge Economy,* 5(2):294-304. DOI: 10.1007/s13132-012-0145-0

The final publication is available at Springer via http://dx.doi.org/10.1007/s13132-012-0145-0

Abstract:

This paper contributes to the burgeoning literature about the knowledge economy by addressing the question of which intellectual-based institutions in an economy contribute the greatest amount to economic growth. In particular, we posit a theoretical model that compares the research efficiency of government research labs to university research labs. We conclude that there is merit in shifting public moneys from government research labs to university research labs from an efficiency perspective. This result opens the door for empirical research on relative research efficiencies and the implications for efficiency gains on economic growth.

Keywords: Research and Development (R&D) | Knowledge-based economy | Risk | Public policy

Article:

Introduction

The public reaction to the 2008–2009 economic slowdown in the USA signaled a renewed era of both public accountability for government policies and demands for innovative means to stimulate economic growth and development. A primary US policy response with regard to growth and development was to focus on job creation and investments in innovation.

The American Recovery and Reinvestment Act (ARRA) of 2009 (Public Law 111-5), also known as The Recovery Act, was signed by newly inaugurated President Barack Obama in February 2009. The premise of this fiscal stimulus was that government spending would quickly lead to business investments and subsequent consumer spending, thus mitigating the current recession. One of the stated purposes of ARRA is to "preserve and create jobs and promote economic recovery." Another stated purpose of the Act is to "provide investments needed to increase economic efficiency by spurring technological advances…"[1]

In September 2009, the National Economic Council (*2009*) released *A Strategy for American Innovation: Driving Towards Sustainable Growth and Quality Jobs*. This Executive Office of the President report lays "the foundation for the innovation economy of the future." The initiative "seeks to harness the inherent ingenuity of the American people and a dynamic private sector to ensure that the next [economic] expansion is more solid, broad-based, and beneficial than previous ones" (p. i). Under the heading "A Vision for Innovation, Growth, and Jobs," the report stated (p. 4):

Innovation is essential for creating new jobs in both high-tech and traditional sectors. … A more innovative economy is a more productive and faster growing economy, with higher returns to workers and increases in living standards. … Innovation is the key to global competitiveness, new and better jobs, a resilient economy, and the attainment of essential national goals.

To accomplish this, *A Strategy for American Innovation* emphasized that the economy must invest in the building blocks of American innovation by, among other things, restoring American leadership in fundamental research. Such building blocks will promote competitive markets that spur productive entrepreneurship, and that in turn will catalyze breakthroughs for national priorities. This theme was reemphasized in February 2011 with an updated version of this report. In *A Strategy for American Innovation: Securing Our Economic Growth and Prosperity* (National Economic Council *2011*), the Administration argued that through innovation we will "ensure that our economic growth is rapid, broad-based, and sustained" (p. 1).

While a near-term focus on job creation is understandable, the Administration's emphasis on innovation is also important if we are to sustain longer term growth. Indeed, Powell and Snellman's (*2004*, p. 199) definition of a knowledge economy as one "based on knowledge-intensive activities that contribute to an accelerated pace of technical and scientific advance" suggests that this issue is at the core of what it means to be a knowledge economy. But if longer term growth is crucial to a knowledge economy, the question is which institutions within our, or any nation's, national innovation system will leverage economic growth in the greatest amount for a given investment in innovation (e.g., in R&D), that is, how do we make efficient use of the economy's intellectual capabilities?[2]

In this paper, we compare and contrast the behavior of two types of research institutions: government research laboratories (hereafter, labs) and university research labs. Because of a unique blend of institutional structures and rewards, we argue that universities are in a better position than government labs to provide the research necessary to stimulate economic growth.

The essential reason for this argument is that the institutional structures of government labs and university labs differ. For government labs, this structure results in risk-averse behavior that increases the cost of conducting research and slows the research process down. By contrast, university research takes place in a highly competitive environment that results in risk-neutral (or even risk-taking) behavior that therefore avoids the inefficiencies associated with government labs and results in more efficient research that is more responsive to broad national, as well as more targeted (e.g., regional), needs.

In “A Model of Risky Research in Government Versus University Labs” section, we set forth a model of research activity in which the risk of engaging in research, and the associated reward structure for engaging in such research, is the essential element, and we examine the implications of our model for government labs and university labs. In “Summary and Implications” section, we summarize our findings and discuss the implications of our paper for future research.

A Model of Risky Research in Government Versus University Labs

Consider a research lab that produces some knowledge K through a risky production process:

$$K = K(E, \theta) \quad (1)$$

where E represents the lab's effort such that:

$$\frac{\partial K}{\partial E} > 0 \quad (2)$$

$$\frac{\partial^2 K}{\partial E^2} < 0 \quad (3)$$

and θ is an index variable representing the presence of production risk. θ is assumed to be a random draw from a set of possible states-of-nature with a known distribution function, $f(\theta)$, with greater values of θresulting in higher levels of K:

$$\frac{\partial K}{\partial \theta} > 0. \quad (4)$$

Assume for expositional convenience that the expected value of K is associated with $\theta = 0$:

$$\int_{\infty-}^{\infty} K(E,\theta) f(\theta) d\theta = K(E,0) \quad (5)$$

so that negative values of θ are associated with levels of K that are less than its expected value and positive values of θ are associated with levels of K that are greater than expected. Finally, assume that the total cost C of producing K is a strictly convex, positive function of the lab's effort E:

$$C = C(E) \quad \ni \quad \frac{dC}{dE} > 0 \ \text{ and } \ \frac{d^2C}{dE^2} > 0. \quad (6)$$

The value that the lab places on K, and hence the amount of effort E that the lab will expend, depends on whether the lab operates within a governmental or a university institutional structure.

Government Labs

Many studies, in keeping with popular belief, assume that government enterprises are more risk averse than their private sector counterparts (Mueller *1989*). However, a review of the literature over the past several decades reveals that little work, theoretical or empirical, has focused directly on this issue. The extant literature is dominated by empirical analyses that suggest that government enterprises may be risk averse because people who are more risk averse reveal a preference for employment in the public sector (Bellante and Link *1981*; Blank *1985*; Katz and Ziderman *1986*; MacCrimmon and Wehrung *1986*; Wilson *1989*). However, and the literature has ignored this point, it is not clear to what extent having risk-averse employees makes an enterprise act in a more risk-averse manner. Moreover, studies have found that the desire for greater job security is only a minor factor in the decision where to work (Baldwin *1987*) and that, when other factors are controlled for, there is no observable (in a statistical sense) difference in the risk aversion of government versus private sector enterprise behavior (Tucker *1988*; Bozeman and Kingsley *1998*).

This extant literature is indeed ambiguous on whether those who work in government are more risk averse than those who do not. However, implicit in most of these studies is that the source of risk aversion is the personal preferences of those who work in government, that is, that risk aversion is intrinsic to the individual. But risk aversion may also be induced in otherwise risk-neutral individuals by the reward structures that they confront, that is, be extrinsic. Indeed, given the ambiguous literature, we assume that those who work in government labs (from their top administrators on down) are intrinsically no more or less risk averse than those who work in university labs (from governing boards and top administrators on down), and for that reason, we assume for expositional simplicity that both types of labs are intrinsically risk neutral.[3] What we do argue is that government institutions, such as government labs, do exhibit greater extrinsic risk-averse behavior that is due to the presence of reward structures that elected officials impose in their attempts to solve the principal-agent problems between themselves and those government enterprises and that are not present to the same degree for university labs.[4]

To formalize this argument, and following Leyden and Link (*1993*), assume a government lab is a Niskanen bureaucracy and that it seeks to maximize the budget B that it receives from elected officials.[5] These elected officials cannot directly observe the effort of the lab. As a result, they rely on the observation of actual production K in determining how much support to provide the lab. Thus:

$B=B(K)$. (7)

In determining the structure of $B(K)$, the elected officials have in mind a target output K_0. However, they recognize that the production of K is risky, and therefore, there may be times when they would like to encourage the lab to make additional effort (particularly when θ is negative). However, because they cannot observe the lab's effort, E, these elected officials also recognize that there may be times when the lab can reduce its effort (particularly when θ is positive). As a result, they will structure $B(K)$ so as to reward to some degree output above K_0 but to penalize to a greater degree output that falls below K_0. Thus, we model the budget function $B(K)$ as a strictly concave function of K:

$$B = B(K) \quad \ni \quad \frac{dB}{dK} > 0 \ \text{ and } \ \frac{d^2 B}{dK^2} < 0. \tag{8}$$

Finally, to force fiscal discipline on the lab, the elected officials insist that the lab balances its budget. The lab's problem then is to choose that level of effort, E, that maximizes the expected size of its budget subject to the constraint that the budget balances in expectation:

$$\max_E \int_{-\infty}^{\infty} B[K(E,\theta)]\, f(\theta)\, d\theta \quad \ni \quad \int_{-\infty}^{\infty} B[K(E,\theta)]\, f(\theta)\, d\theta = C(E). \tag{9}$$

The solution to this maximization problem is characterized by the first-order condition that marginal benefit (in this case in expectation) be equal to marginal cost:

$$\frac{1+\lambda}{\lambda} \int_{-\infty}^{\infty} \frac{dB}{dK} \frac{\partial K}{\partial E} f(\theta) d\theta = \frac{dC}{dE} \tag{10}$$

with $\lambda > 0$ being the Lagrangian multiplier associated with the constraint. Of course, while the budget may balance in expectation, it may not balance after any particular realization of θ. Following Leyden and Link (*1993*), we assume that there is sufficient slack in the lab's budget to allow for any end of year deficits or surpluses to be resolved.

Given the above reward structure, the decision to engage in risk-averse behavior depends on whether that behavior allows the lab to increase its budget. We define risk-averse behavior to be a costly act that reduces the enterprise's exposure to future uncertainty in order to better achieve its objective.[6] Within the structure of our model, such behavior will allow the government lab to produce the expected quantity:

$K\text{e}=\int_{-\infty}^{\infty} K(E,\theta) f(\theta) d\theta$ (11)

with certainty, and thereby increase its expected revenues:

$B(K\text{e})>B\text{e}$ (12)

where:

$B(K\text{e})=B[\int_{-\infty}^{\infty} K(E,\theta) f(\theta) d\theta]$ (13)

$B\text{e}=\int_{-\infty}^{\infty} B[K(E,\theta)] f(\theta) d\theta$ (14)

and where the inequality follows from the concavity of the $B(K)$ function.

This reduction in risk can be achieved through a variety of methods: insurance (Leyden and Link *1993*), privatization of the production process with performance guarantees (Leyden and Link *1993*), or increased emphasis on hierarchy, internal control, and formalism (Bozeman and Kingsley *1998*). Regardless of the method, the result is a slower production process and greater costs of production. Thus, the cost of production under risk-averse behavior can be modeled as:

$\hat{C}=\rho C(E)$ (15)

where $\rho > 1$ indicates both the degree of risk-averse behavior and the degree to which costs are higher under such behavior.

If for a given level of risk-averse activity, ρ, the increase in the size of the budget is no less than the rise in costs, it will be beneficial to engage in the risk-averse activity. Figure 1 illustrates this situation with a simple example in which the uncertain production process is one in which θ has the distribution function:

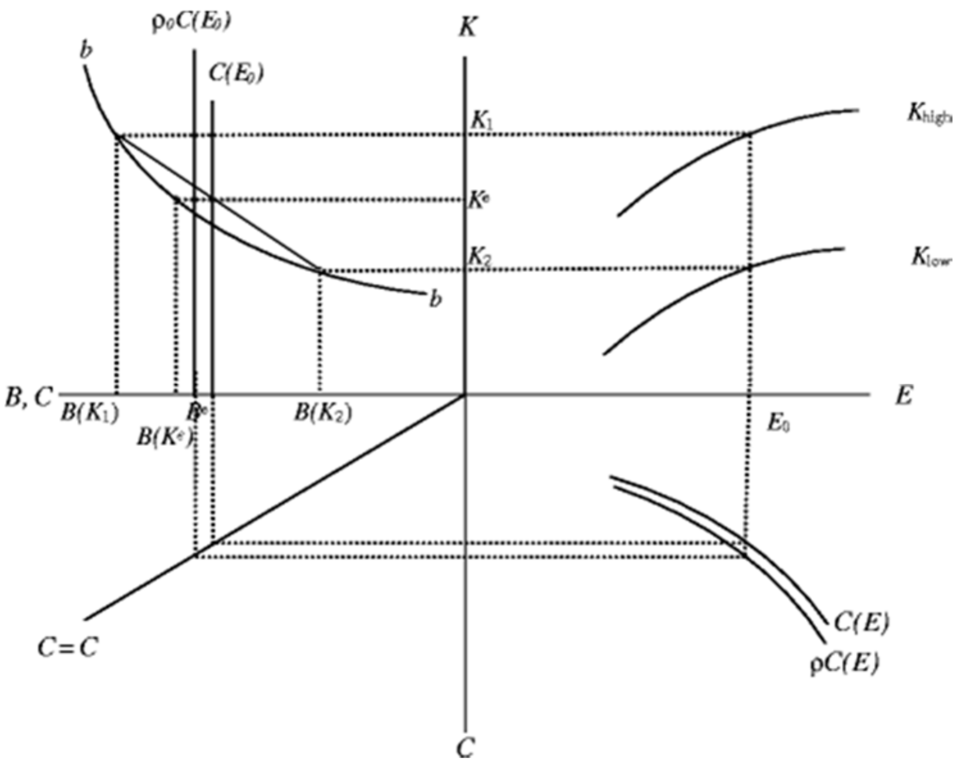

Fig. 1 The advantage of risk-averse behavior for a government lab

$$\theta \sim \begin{cases} \theta_{high}>0 \text{ with probability } p \\ \theta_{low}<0 \text{ with probability } 1-p \end{cases} \quad (16)$$

If the lab does not engage in risk-averse activity, this will result in output K_1 with probability p and output K_2 with probability $1-p$, for some level of effort, E_0. Assuming that E_0 is the solution to the lab's problem in the absence of risk-averse behavior, expected output will be:

$$K^e = pK_1 + (1-p)K_2. \quad (17)$$

The expected budget in this case will be B^e:

$$B^e = pB[K_1] + (1-p)B[K_2], \quad (18)$$

with the balanced budget constraint being:

$$B^e = C(E_0). \quad (19)$$

Figure 1 also illustrates what happens if it benefits the lab to engage in risk-averse activity. Assume that the lab engages in ρ_0 level of risk-averse activity and that as a result it can produce the expected output K^e with certainty. Because the budget function bb is a concave function of output, the budget associated with this certain output will be $B(K^e)$, and this budget is greater than the expected budget B^e associated with producing K with risk. Because $B(K^e)$ exceeds the cost, $\rho C(E_0)$, of engaging in risk-averse research production, it pays to act in a risk-averse manner. And in this particular case, because the budget rises by more than the cost associated with the risk-averse behavior, there will be an expected surplus. Because the balanced budget requirement requires that this surplus be eliminated, the lab will find it in its interest to increase its effort which in turn will increase output and hence increase the lab's budget even more.

Finally, before turning to the case of university labs, it is important to make note of the dynamic process that often occurs in the funding of government labs from 1 year to the next. While this process depends on the budgetary processes used by elected officials, and while these processes can change as a result of shifts in political attitudes toward spending, it is common for officials, either explicitly or implicitly, to use an incremental budgetary process. Thus, the budget function offered each year depends on the actual budget from the previous year. If these officials view budgetary surpluses as evidence of less need for future funds and view budgetary deficits as evidence of inefficient production that should not be rewarded, then the lab has a strong incentive to come in at budget and to try to maintain as close to a steady budget from year to year. Particularly for labs that anticipate greater than expected output, there is an incentive to slow down the research process or attempt to spread that process out over more than 1 year to maintain a steady budget.

University Labs

While university labs must also balance their budgets and also seek to maximize the size of their budgets, they are not subject to the same political influences that give rise to the concave budget function that government labs see. The reasons for this are several. First, not all universities are publicly owned entities. Second, regardless of whether they are public or not, the social role that universities are expected to play leads to them being insulated to a greater or lesser extent from the political pressures that government labs are subject to. Third, a relatively large part of university research funding comes from sources outside the annual public sector budgetary process.

Add to that the fact that university research is highly competitive both within the individual institution and between institutions, the fact that the benefits of university research include the ability to attract higher quality students (particular graduate students) and faculty, and the fact that greater research results in generally higher prestige for the institution, and it is clear that the benefit function for the university of research lab activity will be at least linear if not convex with respect to research output.[7]

To formalize these observations and explore their implications, we can (as with the government lab) model the university lab as a Niskanen bureaucracy that seeks to maximize its budget *B* subject to a budget constraint. In the case of the university, the budget may come from a variety of sources: public sector allocations to be sure, but also private grants, tuition, and income from other enterprises whose success is directly or indirectly affected by the activities of the university lab. Thus, the budget will be a function of the level of output *K* of the lab and, following on the observations above, we can model this as a linear function:

$$B = B(K) \quad \ni \quad \frac{dB}{dK} > 0 \ \text{ and } \ \frac{d^2 B}{dK^2} = 0, \quad (20)$$

and thus, the lab's problem, like that of the government lab, is to choose that level of effort *E* that maximizes the expected size of its budget subject to the constraint that the budget balances in expectation:

$$\max_E \int_{-\infty}^{\infty} B[K(E,\theta)]\, f(\theta)\, d\theta \quad \ni \quad \int_{-\infty}^{\infty} B[K(E,\theta)]\, f(\theta)\, d\theta = C(E). \quad (21)$$

The solution to this problem is characterized by the first-order condition that expected marginal benefit be equal to marginal cost:

$$\frac{1+\lambda}{\lambda} \int_{-\infty}^{\infty} \frac{dB}{dK} \frac{\partial K}{\partial E} f(\theta) d\theta = \frac{dC}{dE} \quad (22)$$

Finally, as with the government lab, while the budget may balance in expectation, it may not balance after any particular realization of θ. We assume that there is sufficient slack within the lab's budget to allow for any problem with year-end deficits or surpluses to be resolved.

Given these circumstances, it turns out that there is no incentive to engage in any level ρ of risk-averse behavior, that is, there is no extrinsic risk aversion, because such activity necessarily results in higher costs (recall that $\rho > 1$):

$\rho C(E) > C(E)$ (23)

but, such activity does not result in a greater budget due to the linear budget function:

$B(K^e)=B^e$ (24)

where:

$B(Ke)=B[\int^{\infty}_{-\infty}K(E,\theta)f(\theta)d\theta]$ (25)

$Be=\int^{\infty}_{-\infty}B[K(E,\theta)]f(\theta)d\theta$ (26)

Figure 2 illustrates this situation with the simple example of the θ distribution function:

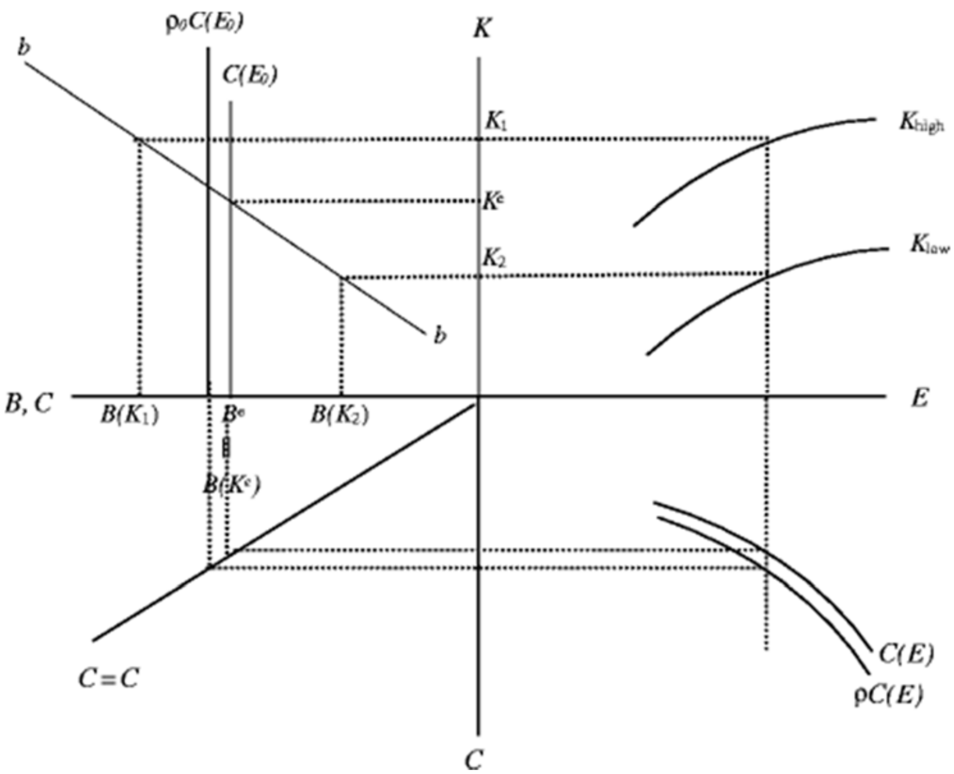

Fig. 2 The advantage of risk-neutral behavior for a university lab

$$\theta \sim \begin{cases} \theta_{\text{high}}>0 \text{ with probability } p \\ \theta_{\text{low}}<0 \text{ with probability } 1-p \end{cases}$$ (27)

If the lab does not engage in risk-averse activity, it will produce output K_1 with probability p and output $K_2$with probability $1-p$, given some level of effort E_0 which we assume is the solution to the lab's problem in the absence of risk-averse behavior. Expected output will hence be:

$K^e=pK1+(1-p)K_2$, (28)

and the expected budget B^e (read off of the budget curve bb) will be:

$B^e = pB[K1] + (1-p)B[K_2]$, (29)

with the balanced budget constraint being:

$B^e = C(E_0)$. (30)

As can be seen because of the linear budget curve bb, the expected budget with risky production B^e is no different than the budget with certain production of the level of expected output $B(K^e)$. Given that observation and given the fact that risk-averse activity is costly, any decision to engage in risk-averse activity will result in an expected deficit, and therefore, the university lab is always better off choosing to engage in research without such activity. Moreover, because much of the funding for university research is the result of a competitive, entrepreneurial process in which funding is project specific, there is no advantage to engaging in the inter-temporal risk-averse activity observed with government labs. Thus, university labs are more efficient than government labs both because they avoid incurring expenses associated with risk-averse activity (which are socially undesirable even if of benefit to the government lab) and because they avoid the slowdowns and pacing that government labs find of benefit to assure a steady stream of funding.

Summary and Implications

From an efficiency perspective, our theoretical results suggest that shifting the research funding to university labs and away from government labs would result in greater output both statically and over time. Although not formally captured in the theoretical model above, universities, because of their greater entrepreneurial flexibility, are more adept at responding to changes in research needs, of being able to focus on specific needs be they regional or industry specific.[8] Because university research takes place within a broader educational structure (especially graduate education), research in universities not only results in greater knowledge for use in the economy; it also is more likely to increase human capital, both skill and intellectual, as well as increase the rate at which this capital is transferred. And this increase will further increase the ability of national, regional, and sectoral economies to sustain themselves and grow.[9]

These arguments, of course, are preliminary, and empirical evidence to support our findings is needed. Still, our theoretical model, which focuses on differences in the extrinsic risk aversion of government versus university labs, is an attempt to begin to understand why there might be differences in the research efficiency of university labs versus government labs.

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Footnotes

1 The policy emphasis in ARRA on jobs, especially innovation-based jobs, traces at least to the National Academy of Sciences (*2007*) report, *Rising Above the Gathering Storm: Energizing and Employing America for a Better Economic Future*. This was a foundation report for the America COMPETE Act of 2007 (P.L. 110-69), which was reauthorized as the America COMPETES Reauthorization Act of 2010 in January 2011.

2 Dubina et al. (*2012*) anticipate the importance of this question, but they emphasize that there is an optimal level of innovation to maximize economic growth.

3 In the model below, the extrinsic risk aversion of the government lab is attributed to a concave revenue function; in contrast, the extrinsic risk neutrality of university lab is attributed to a linear revenue function. If in fact both types of labs are also intrinsically risk neutral but the government lab being (weakly) more intrinsically risk averse than the university lab, this could be modeled by constructing a lab's objective function whose arguments are the lab's revenue function and its degree of intrinsic risk aversion. In this case, the objective function of the government lab would be more concave than the objective function of the university lab because of the concavity of the government's revenue function and its (weakly) greater intrinsic risk aversion. While the exposition of this model would be a bit more complicated mathematically, the conclusions would be the same as the model presented in this paper.

4 We are using the phrase elected officials to indicate legislators or individuals in elected executive positions.

5 Niskanen (*1971*) argues that public enterprises maximize budgets both because of a desire on the part of the manager of the public enterprise for such things as salary, power, and ease of managing the bureau and because it serves the interests of elected government officials who depend on the public enterprise to propose new and expanded programs among which the elected officials can choose to satisfy their constituencies.

6 Bozeman and Kingsley (*1998*, p. 110) define risk as “the exposure to the chance of loss from one's actions or decisions.” Within the context of our model, a lab's decision centers on the level of output to produce.

7 Indirect evidence that supports the idea that university research can attract better students and enhance university reputations can be found in O'Brien et al. (*2010*) that found that greater faculty research, in this case in business schools, was associated with higher salaries for their graduates. While the article argues that this is the result of differences in the quality of instruction, there may be a sample selection bias as well. To the extent there is a sample selection bias, it lends support for the idea that research attracts better students. And in either case, the higher salaries suggest that the general reputation of the university is higher as well.

8 This conclusion does not alter our prior that government, much like the private sector, can act in an entrepreneurial manner (see Link and Link *2009*).

9 Sauermann and Cohen (*2011*) provide evidence that researchers who seek intellectually challenging and independent work environments are more innovative than those who seek job security and control. To the extent university labs attract relatively more of those with intrinsic interest in intellectually challenging and independent work environments, the advantages of university labs are still higher.