Knowledge spillovers, collective entrepreneurship, and economic growth: the role of universities

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Leyden, D. P., & Link, A. N. (2013). Knowledge spillovers, collective entrepreneurship, and economic growth: The role of universities. *Small Business Economics: An Entrepreneurship Journal*, 41(3), 797-817. DOI: 10.1007/s11187-013-9507-7

The final publication is available at Springer via http://dx.doi.org/10.1007/s11187-013-9507-7

Abstract:

To improve our understanding of the role that universities play in facilitating the transmission of knowledge to private-sector business enterprises so as to generate economic growth, this article builds on the Knowledge Spillover Theory of Entrepreneurship to develop a formal model of university-with-business enterprise collaborative research partnerships in which the outcome is both mutually desirable and feasible. This model shows that if a university seeks to act as a complement to private-sector collaborative R&D so that it will be attractive to both incumbent firms and startup entrepreneurs, it needs to structure its program so that business enterprise revenues increase and business enterprise R&D costs rise by a smaller proportion than revenues increase, if they rise at all (and a fall would be better). Such a structure is consistent with both business enterprise and university interests, but is only likely to be feasible if the university is subsidized to cover the cost of such public-private collaborative research partnerships. In the absence of such support, the university will have to cover its costs through a fee charged to participating business enterprises and that will result in the university being seen as a substitute rather than a complement to private-sector collaborative R&D, and thus the university will be seen as an unattractive partner for many business enterprises.

Keywords: Collective entrepreneurship | Knowledge spillovers | University collaboration

Article:

1 Introduction

Endogenous growth models have long recognized the connection between knowledge spillovers and growth. However, as Acs et al. (*2009*) and Braunerhjelm et al. (*2010*) note in their Knowledge Spillover Theory of Entrepreneurship (KSTE), such spillovers do not generate growth of their own accord. Rather, such spillovers must be transmitted through entrepreneurial actions. Thus, economic growth requires a balance between research and entrepreneurial activity (Michelacci *2003*) that is actuated by a matching process similar to that observed in labor markets (Pissarides *1990*).[1]

This article investigates the role that a university plays in determining that balance through such arrangements as research joint ventures, consortia, and research parks.[2] Empirical evidence, both anecdotal (Babbage *2011*) and more formally derived (Audretsch and Lehmann *2005*; Tassey *2008*; Link and Welsh *2013*), suggests that universities may play a significant role in the process by which knowledge is transformed into economic knowledge and that this process takes place at a local or regional level.[3] And, certainly in the USA, industry/university relationships, either formal as a research joint venture[4] or informal as a member of a consortium or a resident of a university research park,[5] have been increasing since the early 1980s. This trend is likely a result of both a university response to incentives established through, for example, the Bayh-Dole Act of 1980 and a response by industry to the productivity slowdown during the late 1970s and the realization that technology life cycles are shortening.[6]

Nearly a decade ago, Hall et al. (*2000*, *2003*) wrote that little is known about the types of roles that universities play in general in such research partnerships or about the economic consequences associated with those roles, and little has changed since then.[7] What research there is on the topic of universities as research partners focuses solely on industry motivations or on university motivations for engaging in an industry/university research relationship, but not on how the two sides interact. We know that industry has many motivations for partnering with universities, only one of which is to gain first access to complementary research activity and research results,[8] and that universities' motivation is to relieve administration-based financial pressures by incentivizing faculty to engage in applied commercial research with industry.[9] To our knowledge, no previous studies have attempted to formalize, mathematically, the relationship between the two parties.[10]

Intriguingly, however, the KSTE (see, for example, Audretsch and Lehmann *2005*) characterization of business enterprises firms or startup entrepreneurs suggests that how firms interact with universities may be at least in part dependent on whether the business enterprise is a firm or an entrepreneur.

There is thus a need for a broader framework that jointly accounts for the motivations of both universities and the two types of business enterprises when assessing the benefits and costs to collaboration and predicting the situations under which collaboration will be mutually beneficial. Absent this broader framework, responses to naïve policy prescriptions might be costly and unproductive. Acs et al. (*2009*, p. 28), for example, note the "need to explain where [entrepreneurial] opportunities come from, [and] how intra-temporal knowledge spillovers occur," and the State Science and Technology Institute (SSTI) recently proclaimed (*2008*, p. 13):

Innovation, in and of itself, will not necessarily translate into economic activity. Rather, it is the application of that technology and its introduction into the marketplace that results in economic growth. Having a strong R&D base is necessary but not sufficient to grow a technology-based economy. *An effective means of moving technology into the commercial marketplace is to encourage relationships between the researchers who are making the discoveries and the entrepreneurs and companies that have the ability to commercialize them* [emphasis added].

As we demonstrate in this article, it is only under a specific set of cost and profit conditions based on the interplay of university and business enterprise behaviors, which we refer to as collective entrepreneurship, that university-with-business enterprise partnerships are beneficial to both parties and therefore likely to occur.[11], [12]

The remainder of this article is outlined as follows. In Sect. 2 we examine the decision by private-sector business enterprises (that is, both KSTE firms and entrepreneurs)[13] to collaborate with other private-sector business enterprises. In that decision-making process, business enterprises have to balance the increased potential for revenues that comes with greater collaboration with both the decreased ability to appropriate those potential revenues and the increased cost of engaging in R&D that also come with greater collaboration. Then, in Sect. 3, we turn to the possibility that a business enterprise could engage in collaborative R&D with a university, and if it does, whether it will view the university as a complement to private-sector collaborative R&D, in which case it will increase that activity, or as a substitute, in which case it will reduce that private-sector collaborative activity. With Sect. 3 as background, Sect. 4 examines the policy alternatives for the university and the implications of its choices for the level and type of collaborative R&D that occurs as a result and the dependency of that choice on its own motivations and constraints. Being an initial theoretical exploration of what we refer to as collective entrepreneurship, we have relied on a number of simplifying assumptions, such as only focusing on cost and profit conditions. As we note below, we are aware of these modeling simplifications, and we expect that others will build upon our effort to address them in future analyses. Section 5 considers the normative implications of the model. Finally, Sect.6 concludes the article with a brief summary and discussion of the implications of this work for future research.

2 Private-sector collaboration

Consider a geographic region in which N heterogeneous profit-maximizing, private-sector business enterprises engage in R&D in collaboration with other business enterprises and use the results of that R&D to produce and sell product. Assume that each business enterprise in the region seeks to maximize its profitπ associated with R&D,[14] and, following the KSTE, let the impact of that R&D be the result of the business enterprise's status as an incumbent firm or startup entrepreneur, its ability σ to efficiently transform knowledge into economic (that is, commercially viable) knowledge, and the synergies it experiences that are associated with interacting with some n number of other business enterprises ($n < N$) in the region.

The revenue *r* associated with conducting such R&D will depend on the amount of the R&D, on its ability $\sigma$to transform the results of that R&D into economic knowledge, and on the degree to which the business enterprise can appropriate the value of the economic knowledge that it generates. Let *p* represent the potential revenue that could be earned by the firm were it not subject to competition from any other business enterprise in the region, and assume that *p* is an increasing function of σ (which lies between 0 and 1) and an increasing, concave function of *n* [15]:

$$p = p(\sigma, n) \ni \frac{dp}{d\sigma} > 0, \quad \frac{dp}{dn} > 0, \quad \frac{d^2 p}{dn^2} < 0 \qquad (1)$$

p is an increasing function of σ because a higher σ indicates that the enterprise has generated a greater level of economically usable knowledge.[16] *p* is an increasing function of *n* because of the economies of technological scope that come from interacting with a larger number of business enterprises and a concave function of *n* because the business enterprise faces downward sloping demand curves in its product markets that results in revenues rising at a diminishing rate as the number of firms it collaborates with, and hence the research output of the business enterprise, increases.

The actual revenue *r* that a firm can earn is typically less than its potential revenue *p* because the business enterprise is unlikely to be able to appropriate the full amount of *p* in the marketplace. While a number of factors affect the ability of a business enterprise to appropriate *p*, an increase in *n* will in general reduce the ability of the business enterprise to appropriate *p* because (1) an increase in *n* increases the probability that among the business enterprise's collaborators will be some of the business enterprises with which it competes, and (2) an increase in *n* reduces the time it takes before the knowledge spreads to non-collaborating, competitor business enterprises that are located in the region.[17] Thus, letting *a* be the proportion of *p* that the business enterprise can actually appropriate, we can describe the determination of *a* as:

$$a = a(n) \ni 0 < a < 1, \quad \frac{da}{dn} < 0, \quad \text{and} \quad \frac{d^2 a}{dn^2} > 0. \qquad (2)$$

Hence, the actual revenues *r* of the business enterprise can be defined as:

$r=r(\sigma,n)=a(n)\cdot p(\sigma,n)$. (3)

Finally, there are the costs *c* that the business enterprise incurs when it engages in R&D. We assume that such costs increase at an increasing rate with *n* for two reasons. First, with an increase in *n*, we would expect to see an increase in the scale of R&D activity. While there may be some scale economies at first, ultimately, diminishing returns are likely to be present. Second, as *n* increases, so will the likelihood that some of those *n* partners may attempt to manipulate the activities of the group for their own private benefit or even to free ride, and that will drive up the business enterprise's cost of maintaining and monitoring its partnerships in order to protect itself against such activities. Thus:

$$c = c(n) \ni \frac{\mathrm{d}c}{\mathrm{d}n} > 0, \quad \frac{\mathrm{d}^2 c}{\mathrm{d}n^2} > 0. \qquad (4)$$

The profits of the business enterprise will therefore be the difference between the actual revenue *r*associated with the appropriable amount of the business enterprise's research and the cost *c* of that business enterprise engaging in the R&D process:

$\pi=\pi(\sigma,n)=r(\sigma,n)-c(n)$. (5)

The optimal number n^* of collaborators for the business enterprise will then be that number of business enterprises that sets marginal profits to zero:

$$\frac{\partial \pi(\sigma, n^*)}{\partial n} = \frac{\partial r(\sigma, n^*)}{\partial n} - \frac{\mathrm{d}c(n^*)}{\mathrm{d}n} = 0 \qquad (6)$$

such that:

$\pi*=\pi(\sigma,n*)\geq 0$ (7)

Note that the business enterprise's marginal revenue, $\partial r(\sigma,n*)\partial n$, is the result of changes in both potential revenue $p(\sigma, n)$ and the level of appropriability $a(n)$:

$$\frac{\partial r(\sigma, n^*)}{\partial n} = \frac{\mathrm{d}a(n^*)}{\mathrm{d}n} \cdot p(\sigma, n^*) + a(n^*) \cdot \frac{\partial p(\sigma, n^*)}{\partial n}, \qquad (8)$$

and the business enterprise's marginal cost is $\mathrm{d}c(n*)\mathrm{d}n$. Figure 1 illustrates the partnership problem for a given business enterprise with a given σ. In the top diagram, the problem is illustrated in terms of total values with the profit-maximizing number of R&D partners n^* being where total profits are greatest. Total profits $\pi(\sigma, n)$are maximized where the slopes of the revenue curve $r(\sigma, n)$ and the cost curve $c(n)$ are the same. In the bottom diagram, the same problem is illustrated in terms of marginal values. Thus, the profit-maximizing number of R&D partners $n\,^*$ is located where the marginal revenue (mr) intersects the marginal cost (mc) curve, and the greater σ is, *ceteris paribus*, the greater will be n^*.

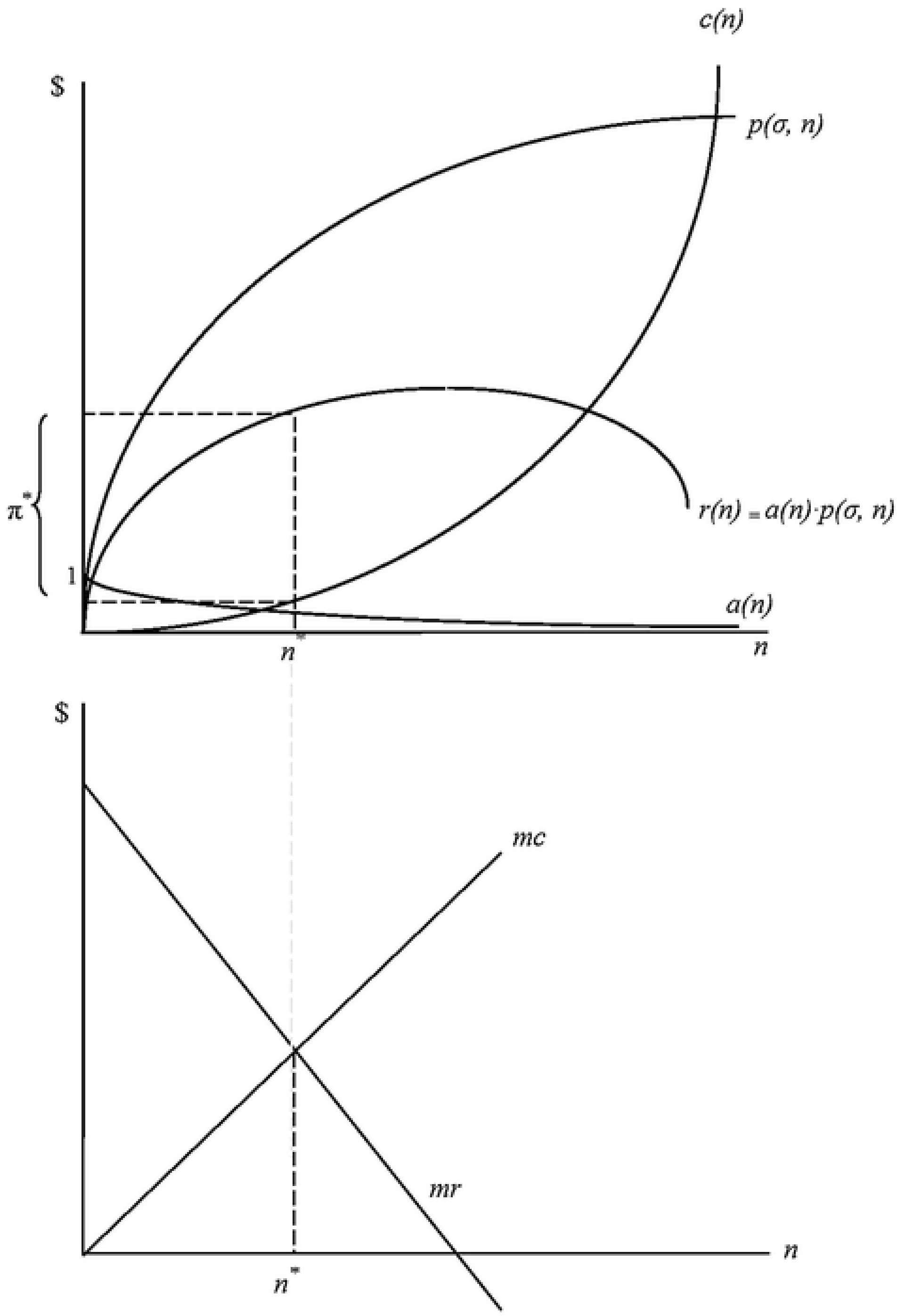

Fig. 1 Private-sector business enterprise collaboration

The logic of this problem is the same for all business enterprises. However, as the KSTE notes, there is a significant difference between incumbent firms and startup entrepreneurs, and this difference results in incumbent firms generally preferring a higher number of R&D partners than will startup entrepreneurs. Incumbent firms engage in R&D to generate marginal improvements in knowledge that they can exploit; startup entrepreneurs are typically individuals who only recently exited from an incumbent firm and whose focus is on the exploitation of the total knowledge set that they have taken from incumbent firms. Collaborative R&D among business enterprises focuses on marginal increases in knowledge that is not likely to significantly change the total store of knowledge. As a result, incumbent firms are more likely to have the institutional infrastructure and the volume of trade to exploit such marginal increases in knowledge, while startup entrepreneurs are not. Moreover, startup entrepreneurs are more likely to perceive the loss of appropriation associated with having R&D partners to be a greater threat than will incumbent firms both because the entrepreneurs are more susceptible to such risks and because they are unlikely to have the infrastructure and negotiating leverage to protect themselves from such loss of appropriation. Thus, despite the fact that startup entrepreneurs generally have greater σ than incumbent firms, they will have lower revenue functions $r(\sigma. n)$ that decline more quickly as the number of R&D partners increases. Hence, their marginal revenue curves will be lower, and they will prefer a smaller number of private-sector R&D partners.

3 Business enterprise demand for university collaboration

For the private-sector business enterprise, whether incumbent firm or startup entrepreneur, the decision to collaborate with a university ultimately depends on whether profits are higher or lower as a result of that collaboration. However, whether the business enterprise collaborates, and if so whether it views such collaboration as a substitute or a complement for private-sector collaboration, will depend not only on whether profits increase, but also on the relative change in the business enterprise's R&D costs and revenues that come about as a result of collaborating with a university.

3.1 Which business enterprises will collaborate with the university?

A university as a research partner can affect a business enterprise's profits in three ways: It can (1) increase the business enterprise's economies of technological scope, (2) reduce the business enterprise's ability to appropriate potential revenues, and (3) change the business enterprise's cost of engaging in R&D.

Collaboration with a university creates economies of technological scope. At a minimum, the university may be thought of as simply another collaborating business enterprise in the region. Thus, the university, like any business enterprise, creates the possibility of more interactions and more access to research capital and other knowledge spillovers, and this, in turn, gives the business enterprise in general the opportunity to increase its revenue stream. Interestingly, however, the startup entrepreneur in this regard will view the university as a somewhat safer partner to the extent the university is perceived as less of a competitive threat.

But of course, the university is more than just another collaborating business enterprise; it also embodies unique human and technical capital that might not be available in the private sector or, if available, for which the acquisition cost might be higher.[18] The university makes such unique capital available to the business enterprises with which it collaborates, thereby increasing for those business enterprises the research synergies that come from being able to explore a broader spectrum of research issues and from being able to view research questions from a different perspective. Particularly for startup entrepreneurs whose stock of human and especially physical capital is likely to be low compared to incumbent firms, this benefit is potentially of great significance. The university also may act as a facilitator of (potential or additional) synergies among the business enterprises themselves. By providing physical facilities for collaborations (e.g., meetings) and joint research, by sponsoring seminars, conferences, workshops, receptions, and by generally acting as matchmaker and objective chaperone, the university can thereby increase the quality of interactions among those business enterprises.[19] But as noted in the previous section, while this may be of benefit to startup entrepreneurs, particularly if it provides those enterprises with a safer environment in which to develop trust with other private-sector enterprises, it nonetheless also contains the potential risk of an increased loss of appropriation. On the whole, then, the university affords business enterprises with some ability to earn greater revenue from both their direct interaction with the university and the increased value of their collaboration with other business enterprises. In terms of our model, these effects increase the marginal value of potential revenue, $\frac{\partial p(\sigma,n)}{\partial n}$, for each participating business enterprise. Assume, then, that potential revenue $p(\sigma, n)$ and its marginal value $\frac{\partial p(\sigma,n)}{\partial n}$ both change by the parameter $\omega \geq 1$ (shown below) as a result of these economies of technological scope.

The presence of the university also reduces the ability of collaborating business enterprises to appropriate the output of their shared research for private gain. The reward structure for researchers in a university is primarily based on publications (Link *1996*). As a result, there will be limited interest on the part of university researchers to collaborate with business enterprises if they cannot use such collaboration to generate publications. Moreover, because university missions typically include providing general benefits to society in the form of increased knowledge, they tend to focus more on basic research than do business enterprises, and the commercial value of basic research is by its nature more difficult to appropriate. For these reasons, the presence of the university reduces the ability of business enterprises to appropriate the increased potential revenue that those business enterprises get from collaborating with the university and with other business enterprises. In terms of our model, these effects decrease the marginal degree of appropriability, $\frac{\mathrm{d}a(n)}{\mathrm{d}n}$, for each participating business enterprise. Assume, then, that the degree of appropriability $a(n)$ and its marginal value $\frac{\mathrm{d}a(n)}{\mathrm{d}n}$ both change by the parameter $\alpha \leq 1$ as a result of these effects. As suggested above, this is more likely to be a significant issue for the startup entrepreneur.

Finally, collaboration with a university will affect a business enterprise's cost of undertaking R&D, although the direction of change is not clear. On the one hand, the presence of the university might be expected to reduce the business enterprise's R&D costs because (1) the university may not require full compensation for the R&D production costs it incurs as a collaborator owing to the infrastructural nature of university research, (2) the university in its role as an "honest broker" can reduce various monitoring and transaction costs incurred by the business enterprises with whom it collaborates and thereby reduce the chance of the R&D process being manipulated to the benefit of a subset of collaborating business enterprises, and (3) the university may cover the cost of interactions among business enterprises by providing physical facilities for meetings and joint research as well as sponsoring seminars, conferences, workshops, and receptions. On the other hand, a business enterprise's R&D cost may rise as a result of collaborating with the university because of the additional costs associated with university requirements (including a possible fee) or with added lobbying and reporting costs associated with participating in a bureaucratic or political process.[20] Assume, then, that as a result of these factors, the business enterprise's R&D costs $c(n)$ and its marginal value $\mathrm{d}c(n)\mathrm{d}n$ both change by the parameter $\kappa>0$ (shown below). Because of the smaller typical size of a startup entrepreneur, these factors, whether positive or negative, are likely to weigh more heavily with the entrepreneur.

Given the above changes associated with university collaboration, the profits to the collaborating business enterprise in interacting with a university can be represented by:

$\pi U=\pi U(\sigma,n)=\alpha\cdot a(n)\cdot\omega\cdot p(\sigma,n)-\kappa\cdot c(n)\ni 0<\alpha\leq 1,\omega\geq 1,\text{and}\kappa>0.$ (9)

The optimal number $nU*$ of collaborators for the business enterprise will then be that number of business enterprises that sets marginal profits to zero:

$$\frac{\partial\pi^U(\sigma,n^{U*})}{\partial n}=\frac{\partial r^U(\sigma,n^{U*})}{\partial n}-\frac{\mathrm{d}c^U(n^{U*})}{\mathrm{d}n}=0, \quad (10)$$

where the business enterprise's marginal revenue $\partial rU(\sigma,n)\partial n$ is $\alpha\omega$ times the business enterprise's marginal revenue in the absence of university collaboration (see Eq. (8)):

$$\frac{\partial r^U(\sigma,n^{U*})}{\partial n}=\alpha\omega\cdot\frac{\partial r(\sigma,n^{U*})}{\partial n} \quad (11)$$

and the business enterprise's marginal R&D cost $\mathrm{d}cU(nU*)\mathrm{d}n$ is κ times the business enterprise's marginal R&D cost in the absence of university collaboration:

$$\frac{\mathrm{d}c^U(n^{U*})}{\mathrm{d}n}=\kappa\cdot\frac{\mathrm{d}c(n^{U*})}{\mathrm{d}n} \quad (12)$$

The question of whether a business enterprise chooses to collaborate with the university hinges on whether its profits in the absence of the university $\pi*$ are greater or less than the business enterprise's profits with the university $\pi U*$. Using Eqs. (5) and (9), that condition can be describe as:

$\pi U* \gtreqless \pi * \text{if} (\delta r \alpha \omega - 1) \cdot a(n*) \cdot p(\sigma, n*) \gtreqless (\delta c \kappa - 1) \cdot c(n*)$ (13)

where δr indicates the ratio of revenue in the absence of university collaboration with $nU*$ versus the revenue associated with the number of collaborators $n*$ in the absence of university collaboration, and δc indicates the same ratio with respect to the business enterprise's costs:

$$\delta_r = \frac{a(n^{U*}) \cdot p(\sigma, n^{U*})}{a(n^*) \cdot p(\sigma, n^*)} > 0 \quad (14)$$

$$\delta_c = \frac{c(n^{U*})}{c(n^*)} > 0 \quad (15)$$

The values of δr and δc indicate the impact on revenues and costs of the business enterprise choosing to change the number of private-sector collaborators as a result of the collaboration with the university. If $nU* > n*$, then $\delta r > \delta c > 1$. If $nU* < n*$, then $\delta c < \delta r < 1$. And if $nU* = n*$, then $\delta r = \delta c = 1$.

To determine which business enterprises will choose to collaborate with the university, consider the four ways (summarized in Fig. 2) in which the business enterprise's R&D costs and revenues can change as a result of such collaboration:[21]

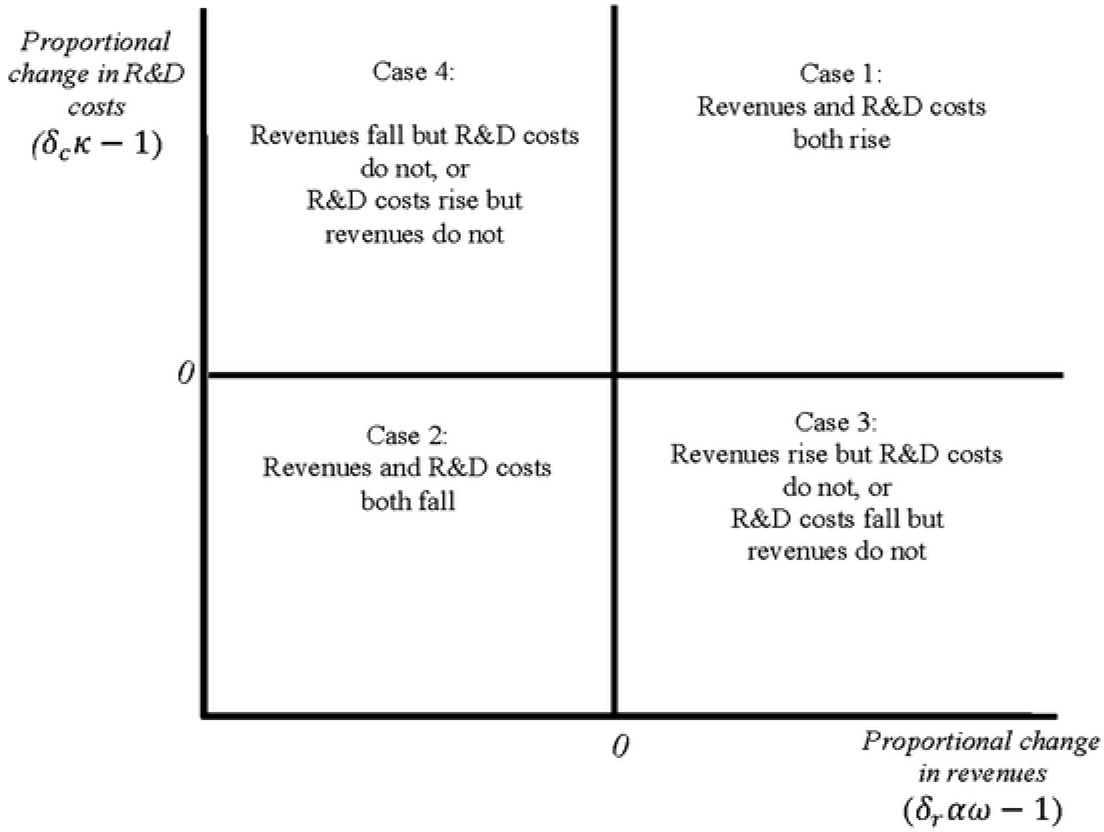

Fig. 2 Effect of university collaboration on revenues and R&D costs

Case 1—revenues and R&D costs both rise

Revenues and R&D costs will both rise if $\delta_r\alpha\omega>1$ and $\delta_c\kappa>1$. Because of that, we can rewrite Eq. (13) as:

$$\pi^{U*} \gtreqless \pi^* \quad \text{if} \quad \frac{a(n^*)\cdot p(\sigma,n^*)}{c(n^*)} \gtreqless \frac{\delta_c\kappa-1}{\delta_r\alpha\omega-1}, \quad (16)$$

and note that the final ratio is the elasticity of the business enterprise's R&D costs with respect to revenues associated with collaborating with the university:[22]

$$E_{c,r} = \frac{\delta_c\kappa-1}{\delta_r\alpha\omega-1} \quad (17)$$

Because the firm's revenue-cost ratio $\frac{a(n^*)\cdot p(\sigma,n^*)}{c(n^*)}$ ≥1, all business enterprises will choose to collaborate with the university if $E_{c,r} < 1$, that is, if the proportional increase in revenues exceeds the proportional increase in R&D costs. However, if $E_{c,r} \geq 1$, the decision to collaborate with the university will depend on whether the business enterprise's revenue-cost ratio $\frac{a(n^*)\cdot p(\sigma,n^*)}{c(n^*)}$ exceeds $E\ c,r$. The convexity assumptions of our model imply that the revenue-cost ratio is a declining function of n. Hence, if n is sufficiently small, the revenue-cost ratio will be greater than Ec,r, and the business enterprise will choose to collaborate with the university; if n is sufficiently large, the revenue-cost ratio will be less than Ec,r, and the business enterprise will choose not to collaborate with the university. Thus, startup entrepreneurs, who are relatively inactive in collaborating with other business enterprises, are more likely to find university collaboration attractive in this case than will incumbent firms. Figure 3 illustrates this conclusion with $n*\hat{}$indicating the level of n * at which a business enterprise would be indifferent between collaborating and not collaborating with the university.

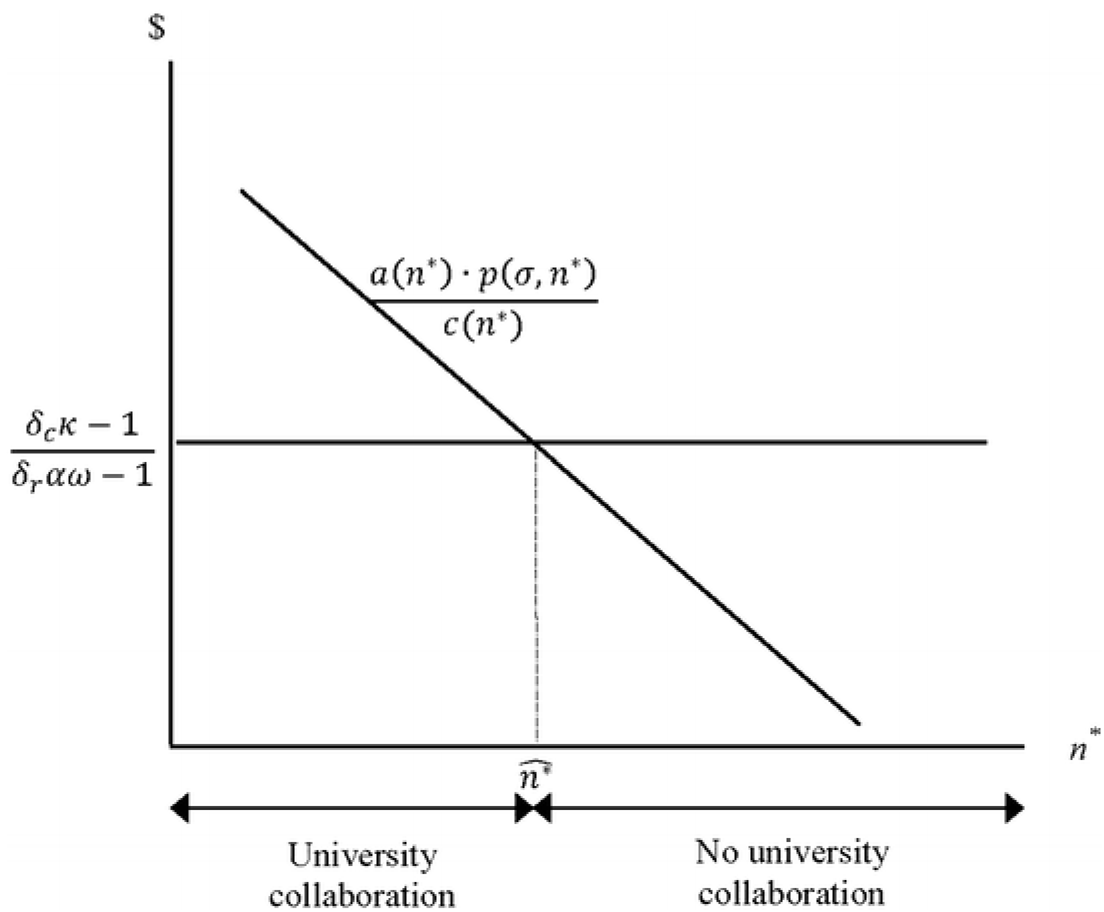

Fig. 3 R&D collaboration with the university when revenues rise proportionately less than R&D costs rise

Case 2—revenues and R&D costs both fall

Because revenues and R&D costs will both fall if $\delta r\alpha\omega<1$ and $\delta c\kappa<1$, we can rewrite equation (13) as (note the reversal of the inequality sign in the conditional inequality due to $\delta r\alpha\omega-1$ being negative):

$$\pi^{U*} \gtreqless \pi^* \quad \text{if} \quad \frac{a(n^*)\cdot p(\sigma, n^*)}{c(n^*)} \lesseqgtr \frac{\delta_c \kappa - 1}{\delta_r \alpha\omega - 1} \quad (18)$$

Because the business enterprise's revenue-cost ratio $\frac{a(n^*)\cdot p(\sigma,n^*)}{c(n^*)}$ ≥1, no business enterprise will choose to collaborate with the university if $E_{c,r} < 1$, that is, if the proportional fall in revenues exceeds the proportional fall in R&D costs. However, if $E_{c,r} \geq 1$, the decision to collaborate with the university will depend on whether the business enterprise's revenue-cost ratio $\frac{a(n^*)\cdot p(\sigma,n^*)}{c(n^*)}$ exceeds $E_{c,r}$. Because revenue-cost ratio is a declining function of *n*, if *n* is sufficiently small, the revenue-cost ratio will be greater than $E_{c,r}$, and the business enterprise will choose not to collaborate with the university. Likewise, if *n* is sufficiently large, the revenue-cost ratio will be less than $E_{c,r}$, and the business enterprise will choose to collaborate with the university. Thus, incumbent firms, which are relatively active in collaborating with other business enterprises, are more likely to find university collaboration attractive in this case than will startup entrepreneurs.

Figure 4 illustrates this conclusion with $\hat{n^*}$ indicating the level of n^* at which a business enterprise would be indifferent between collaborating and not collaborating with the university.

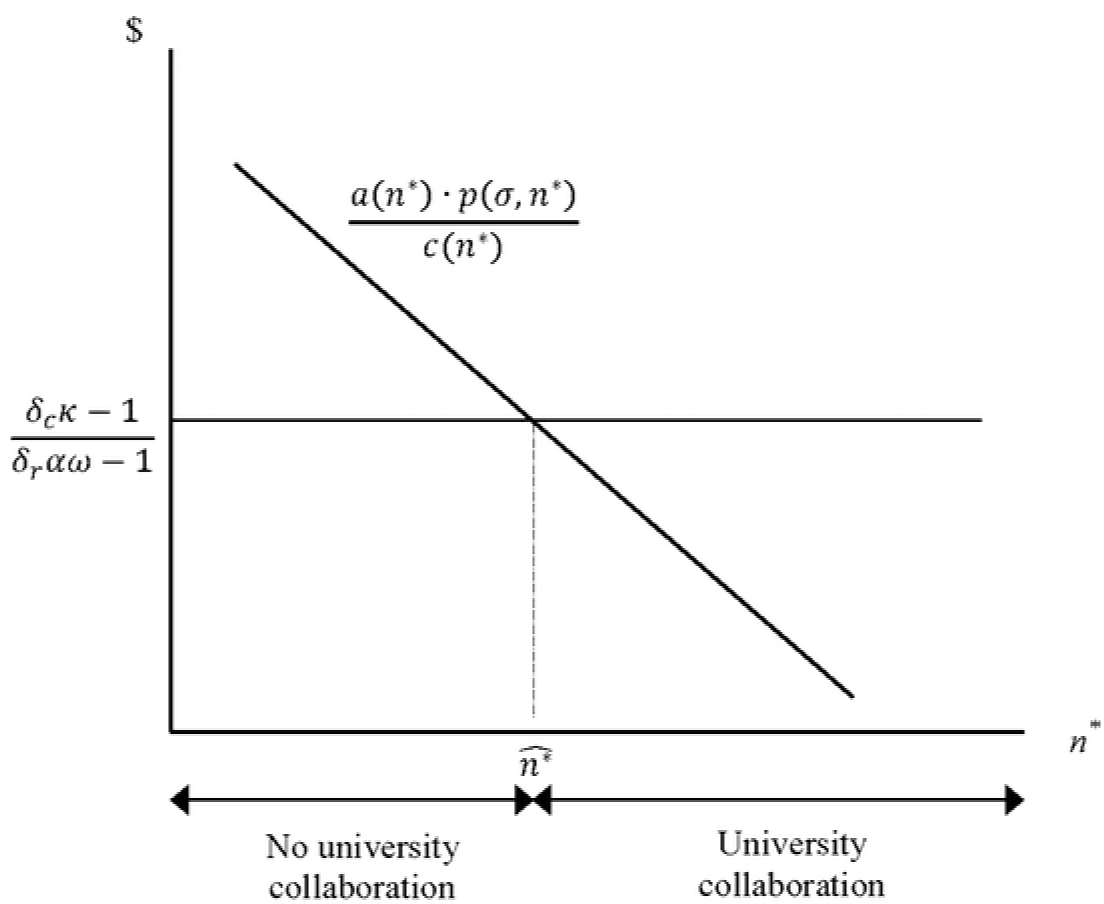

Fig. 4 R&D collaboration with the university when revenues fall proportionately less than R&D costs fall

Case 3—revenues rise but R&D costs do not, or R&D costs fall but revenues do not

Revenues and R&D costs will change in opposite directions with revenues rising but R&D costs not rising (or with R&D costs falling but revenues not falling) if $\delta r \alpha \omega \geq 1$, $\delta c \kappa \leq 1$, and one of these conditions holds as a strict inequality. If the first inequality holds as a strict inequality, the effect of increased economies of scope will outweigh the effect of a loss in appropriability. As a result, revenues will rise, and all business enterprises regardless of the degree to which they collaborate with other firms will choose to collaborate with the university. Similarly, if the second inequality holds as a strict inequality, then R&D costs will fall, revenues will not, and all business enterprises will choose to collaborate with the university.

Case 4—Revenues fall but R&D costs do not, or R&D costs rise but revenues do not

The final possible case is that revenues fall but R&D costs do not (or R&D costs rise but revenues do not), which will occur if $\delta r \alpha \omega \leq 1$, $\delta c \kappa \geq 1$, and one of these conditions holds as a strict inequality. If the first inequality holds as a strict inequality, the effect of a loss in appropriability will outweigh the effect of increased economies of scope. As a result, revenues will fall, R&D costs will at best stay the same, and hence no business enterprise regardless of the degree to which they collaborate with other business enterprises will choose to collaborate with the university. Similarly, if the second inequality holds as a strict inequality, then R&D costs will rise, revenues at best will stay the same, and once again no business enterprise will choose to collaborate with the university.

Summarizing these four cases, then, no business enterprise will collaborate with the university if its revenues fall and R&D costs rise, or if its revenues fall but its R&D costs fall by a smaller proportion. If revenues and R&D costs rise, but R&D costs rise by a greater proportion, only business enterprises that have relatively few private-sector collaborators (particularly startup entrepreneurs) will choose to engage in university collaboration. And if R&D costs fall but revenues fall by a smaller proportion, only business enterprises that have a relatively large number of private-sector collaborators (particularly incumbent firms) will choose to engage in university collaboration. Finally, if revenues increase and R&D costs decrease, all business enterprises will choose to collaborate with the university. Figure 5 provides a summary of these results.

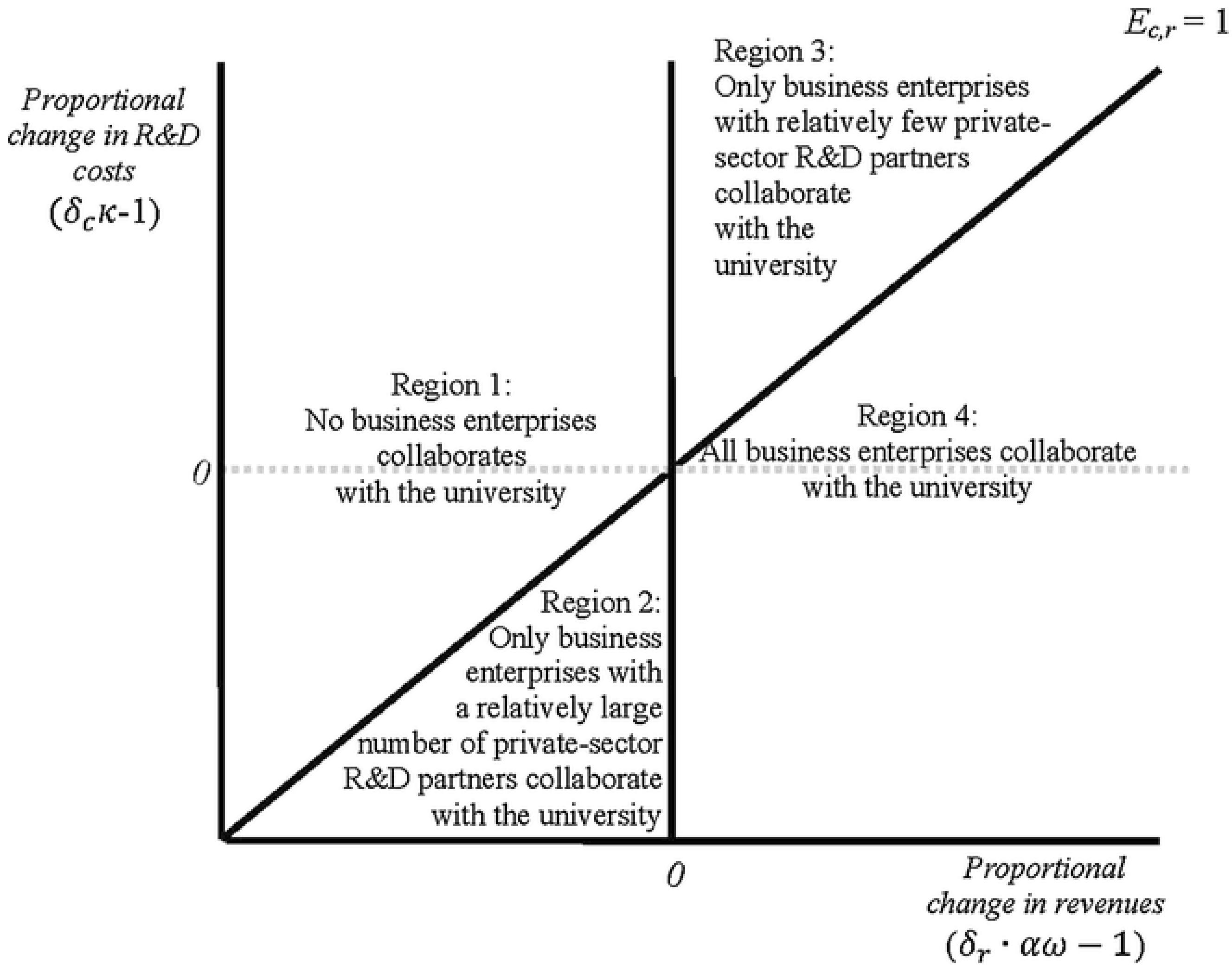

Fig. 5 Which business enterprises collaborate with university?

3.2 Is university collaboration a complement or substitute for private-sector business enterprise collaboration?

The presumed purpose of universities engaging in R&D with private-sector business enterprises is not simply to assist those firms with current R&D projects but to increase the level of collaborative R&D among private-sector business enterprises more generally so as to create a more active R&D culture in the regional economy that results in greater regional economic growth through the appropriation and transformation of knowledge into economic knowledge. Thus, the presumed purpose of universities is to increase the efficiency with which business enterprises convert knowledge to economic knowledge.

An important question, therefore, is whether the firms that choose to engage in collaborate R&D with the university treat that collaboration as a substitute or as a complement to private-sector collaborative R&D. In terms of our model, this question turns on whether the firms that engage in collaborative R&D with the university increase or decrease as a result the number of private-sector R&D partners, that is, whether n^{U*} is greater or smaller than n^*.

To answer that question, recall the first-order conditions [Eq. (10)] for the business enterprise that collaborates with the university. That first-order condition states that the business enterprise's marginal revenue with n^{U*} private-sector R&D partners should be equal to the business enterprise's marginal R&D cost associated with n^{U*}. Using Eqs. (11) and (12), we can express this requirement as:

$$\alpha\sigma \cdot \frac{\partial r(\sigma, n^{U*})}{\partial n} = \kappa \frac{\mathrm{d}c(n^{U*})}{\mathrm{d}n} \quad (19)$$

To understand the implications of Eq. (19), recall the first-order conditions [Eq. (6)] for private-sector business enterprise collaboration:

$$\frac{\partial r(\sigma, n^*)}{\partial n} = \frac{\mathrm{d}c(n^*)}{\mathrm{d}n} \quad (20)$$

If as a result of university collaboration the business enterprise's marginal revenue and marginal R&D cost functions change by the same proportion (that is, if $\alpha\omega=\kappa$), then Eq. (20) tells us that Eq. (19) will be satisfied with $n^{U*}=n^*$. However, if the marginal revenue function rises by a greater proportion than the marginal R&D cost function or falls by a smaller proportion (that is, $\alpha\omega>\kappa$), Eq. (19) requires a lower value for $\frac{\partial r(\sigma,n^*)}{\partial n}$ and/or a higher value for $\frac{dc(n^{U*})}{dn}$, and given the concavity of the revenue function and the convexity of the R&D cost function, this will occur with a value of n^{U*} that is greater than n^*. Finally, if the marginal revenue function rises by a smaller proportion as the R&D cost function or falls by a greater proportion (that is, $\kappa>\alpha\omega$), then Eq. (19) requires that $n^{U*}<n^*$. Thus, university collaboration can be either a substitute or a complement to private-sector collaboration, depending on whether the revenues of the business enterprise change proportionately more or less than does that same business enterprise's R&D costs. Figures 6, 7, and 8 illustrate the dynamics that generate these outcomes, and Fig. 9 summarizes these results in the same *change in revenues* × *change in R&D costs* policy space that we used to summarize whether a firm will choose to collaborate with the university.[23]

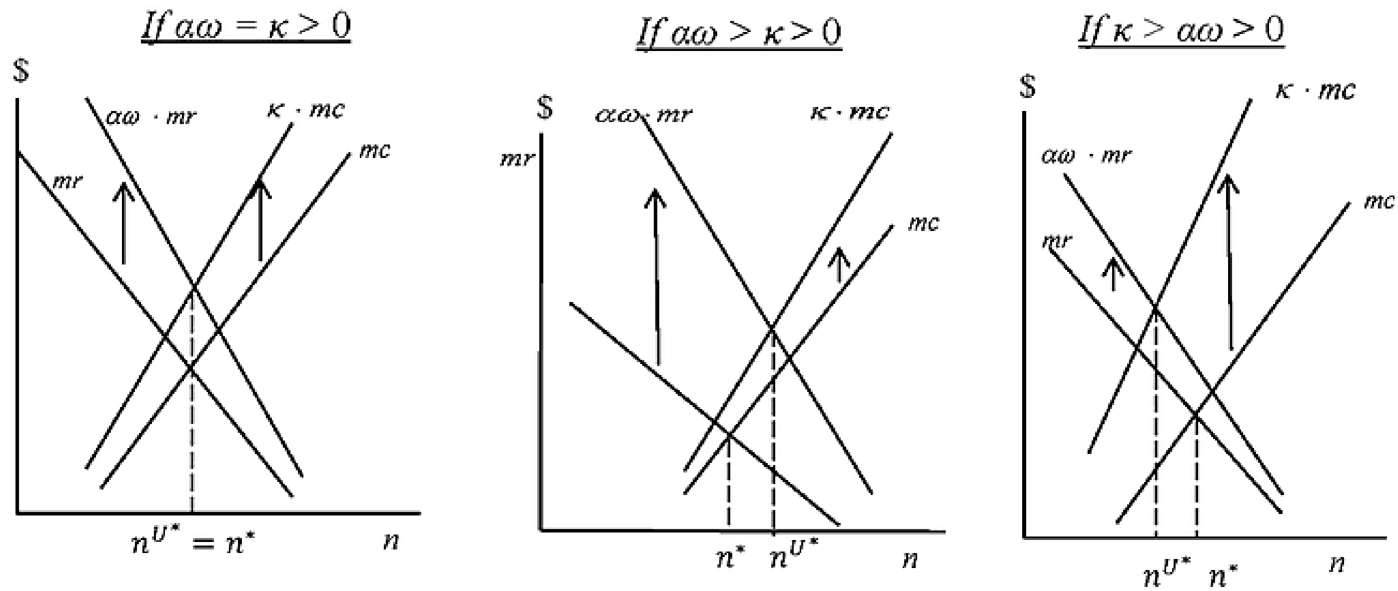

Fig. 6 Changes in the ideal number of private-sector R&D partners when university collaboration results in a rise in marginal revenue and marginal R&D cost

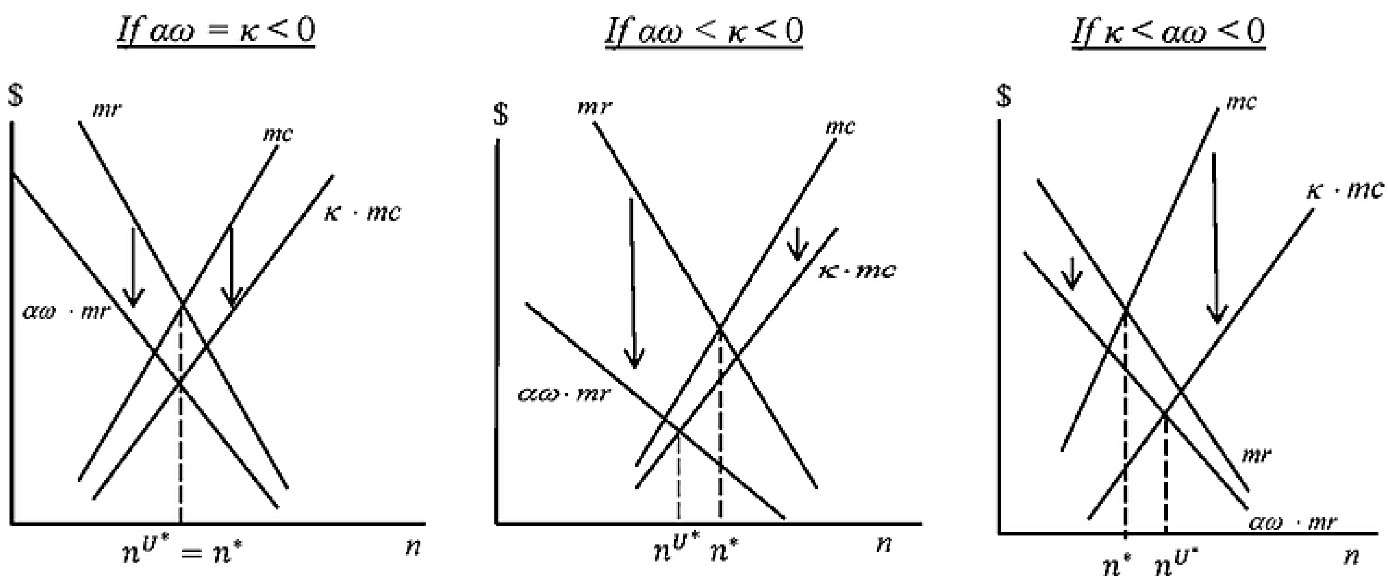

Fig. 7 Changes in the ideal number of private-sector R&D partners when university collaboration results in a fall in marginal revenue and marginal R&D cost

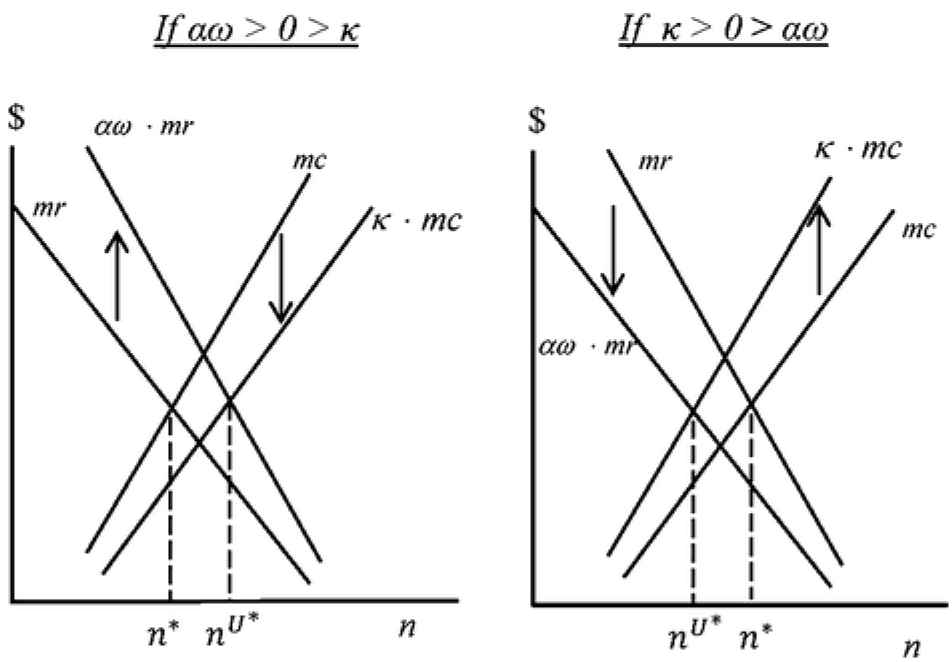

Fig. 8 Changes in the ideal number of private-sector R&D partners when university collaboration results in marginal revenue and marginal R&D cost changing in opposite directions

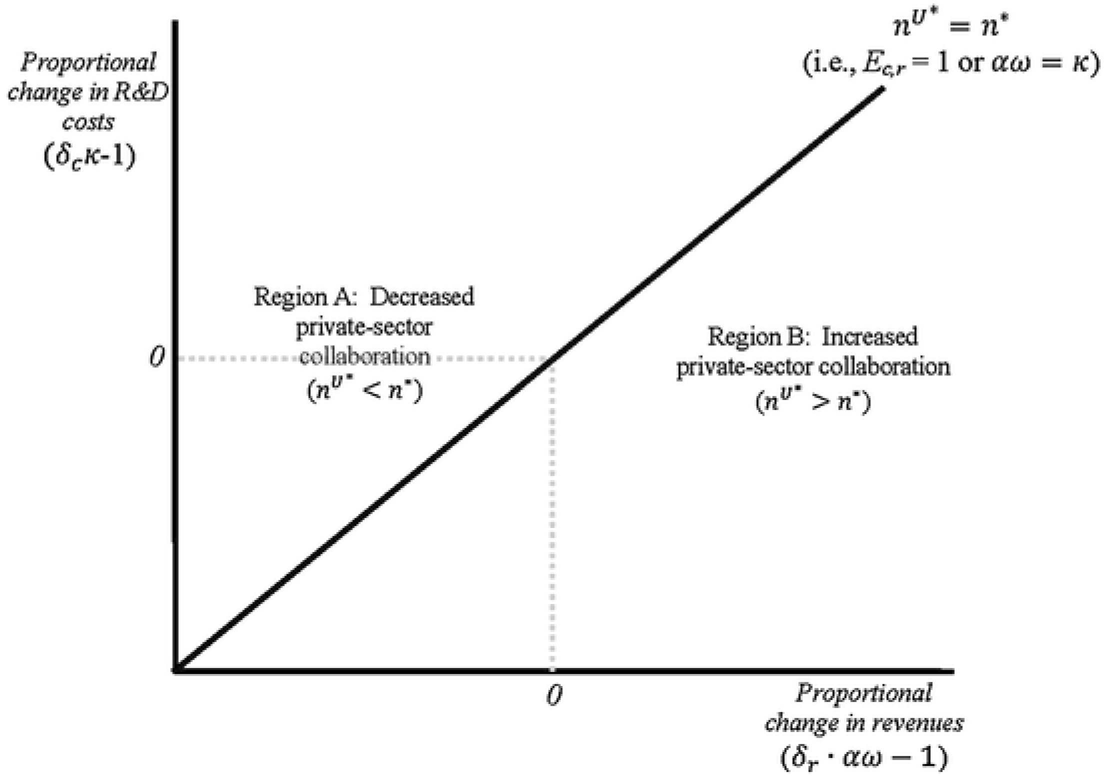

Fig. 9 Effects of university R&D collaboration on private-sector R&D collaboration

3.3 Overall results

Figure 10 provides an overall summary of the results of the behavior of business enterprises that are offered the opportunity to collaborate with the university. The incentive to collaborate with the university depends on how R&D costs and revenues change:

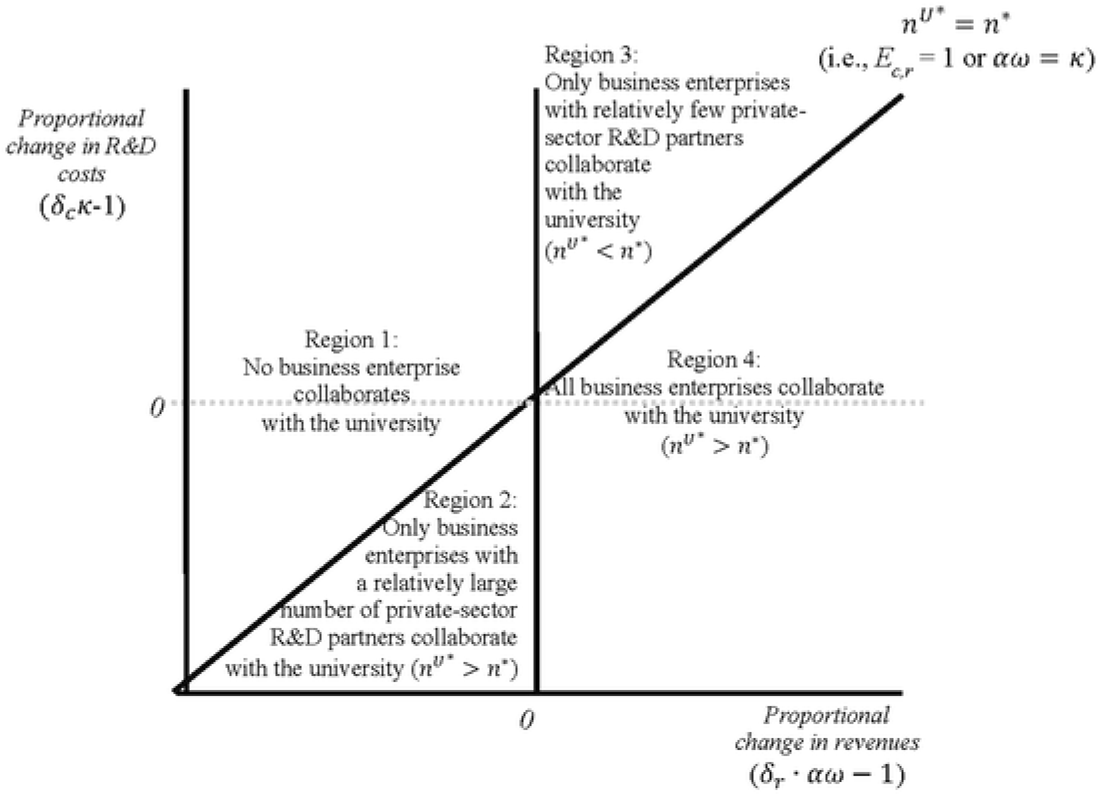

Fig. 10 Business enterprise demand for university collaboration-summary

- If collaboration with the university results in revenues rising and R&D costs falling, revenues rising proportionately more than R&D costs rise, or revenues falling proportionately less than R&D costs fall, then business enterprises that are relatively more active in private-sector R&D collaborative activity (particularly incumbent firms) will choose to collaborate with the university.

- If collaboration with the university results in higher revenues, then firms that are relatively less active in private-sector R&D collaborative activity (particularly startup entrepreneurs) will choose to collaborate with the university.

For those business enterprises that choose to collaborate with the university, whether those business enterprises treat the university as a substitute or complement to private-sector collaboration will depend on the relative change in R&D costs versus revenues:

- If R&D costs rise proportionately more than revenues rise, university collaboration will be a substitute for private-sector R&D collaboration and the number of private-sector R&D collaborators will fall.
- If revenues rise and R&D costs fall, or rise proportionately more than R&D costs rise, or fall proportionately less than R&D costs do, university collaboration will be a complement for private-sector R&D collaboration and the number of private-sector R&D collaborators will rise.

4 University supply of collaboration

The degree to which business enterprises collaborate with the university and the effect of that collaboration on the level of private-sector collaboration will depend not just on the business enterprises but on the choices that the university makes regarding the collaborative R&D program it establishes. And those choices depend in turn on the objectives of the university, the cost of delivering that program, and how that program is paid for.

4.1 The university's cost function

Consider first the R&D cost function for the university. As noted above, the university increases the profits of a collaborating business enterprise by providing some combination of enhanced economies of technological scope and possible reduced costs that is sufficient to overcome any loss in appropriability and possible increased costs. If we assume that the cost of providing enhanced economies of technological scope rises at an increasing rate, and that the cost of providing reduced R&D costs to a collaborating business enterprise rises in the same manner, then the university's cost function can be characterized as:

$$c_U = c_U(\omega, \kappa) \ni \frac{\partial c_U}{\partial \sigma} > 0, \quad \frac{\partial^2 c_U}{\partial \sigma^2} > 0, \quad \frac{\partial c_U}{\partial \kappa} < 0, \quad \frac{\partial^2 c_U}{\partial \kappa^2} > 0 \qquad (21)$$

such that:

$cU(1,1)=0$. (22)

Note that implicit in Eqs. (21) and (22) is the assumption that the level of diminished appropriability, that is, the value of α, is exogenous at some value $\alpha\ 0 < 1$ and imposes no cost on the university. We will examine this assumption later.

The university's policy options implied by this university cost function can be described using a set of iso-cost curves, beginning with the iso-cost curve associated with a minimal program characterized by Eq. (22), that is, a program of no net cost to the university and in which there are no enhanced economies of scope and no change in the R&D cost function for participating business enterprises. That program is illustrated in Fig. 11 by the point *A* and is associated with the iso-cost curve *B 0* .[24] Note that because of the convexity of the university's cost function *c U* , this zero-cost iso-cost line will cross the $\delta r\alpha\omega-1=0$ line at some point*D* where $\delta c\kappa-1>0$. Whether it comes in contact with the $nU*=n*$ line (where $\alpha\ \omega = \kappa$) is an empirical question. If it does, it will be at a value of $\omega > \frac{1}{\alpha_0}$ and a value of $\kappa>1$, thus requiring (in a loose sense) that the cost to the university of increasing the firm's economies of scope rises more slowly than does the cost to the university of reducing the firm's R&D cost function. Figure 11 is drawn assuming that this latter condition is not the case.

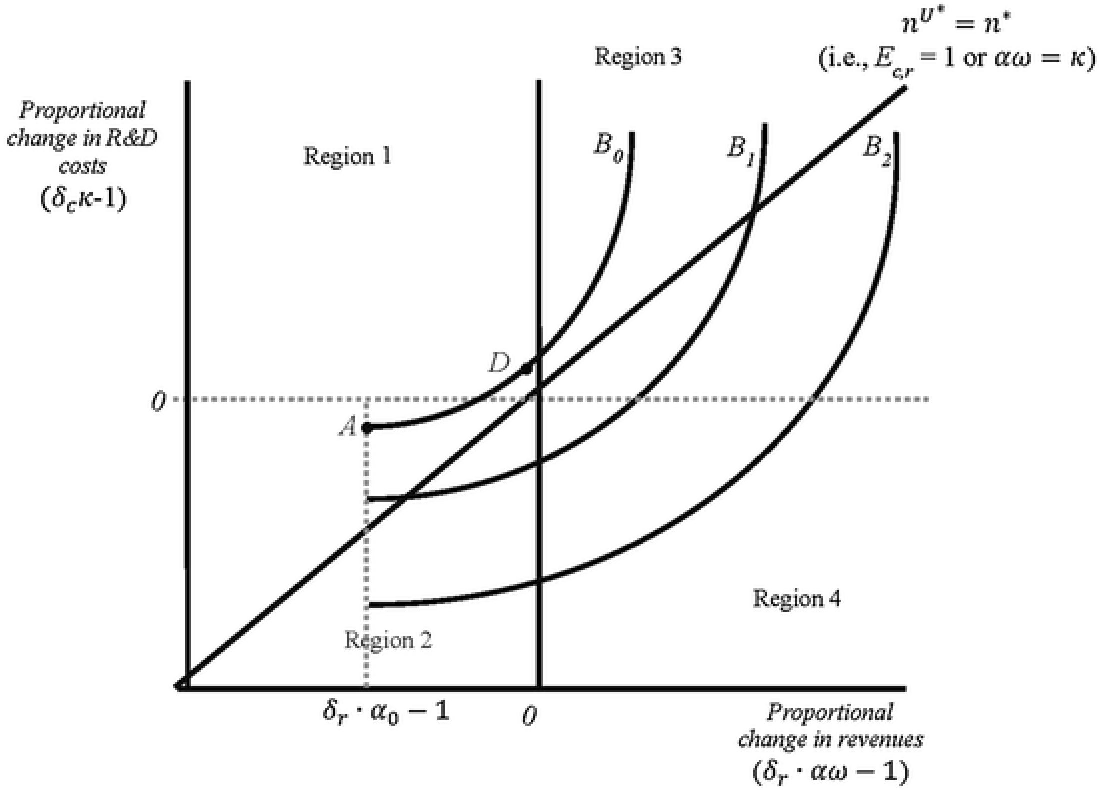

Fig. 11 University supply of collaboration

The iso-cost curve for a university program that reduces a participating business enterprise's R&D cost function (that is, $\kappa < 1$) and/or increases expected revenue (that is, $\omega > 1$) will lie to the southeast of the iso-cost curve $B\ 0$. Thus, the iso-budget curves $B\ 1$ and $B\ 2$ in Fig. 11 represent programs that result in positive net costs to the university with the cost associated with $B\ 2$ being greater than the cost associated with $B\ 1$.

4.2 The university's objective

What option the university chooses will depend on the university's objective and what funding arrangements exist. Coates and Humphreys (*2002*) and Coates et al. (*2004*) argue that university motivations are bureaucratic with the essential question being whether they are slack-maximizing (which is akin to profit-maximizing) versus budget maximizing.

If universities are slack-maximizing, they would prefer programs to the northwest of the iso-cost curve B_0 in Fig. 11, that is, programs located in Region 3 that involve firms that are relatively inactive in private-sector collaborative R&D with other business enterprises. In such a case, while the program would enhance the revenue potential for participating business enterprises, it also would essentially charge participating business enterprises a price (that is, κ would be >1). While some business enterprises would choose to participate in such a program, because the program lies in Region 3, it would be limited to business enterprises that have relatively few private-sector R&D partners (particularly startup entrepreneurs), and those business enterprises that would participate would treat the program as a substitute for private-sector collaboration and therefore reduce the number of their private-sector R&D collaborators.[25]

By contrast, if universities are budget-maximizing, they would prefer programs to the southeast of the iso-cost curve B_0, that is, programs located in Region 2 (where business enterprises that are already relatively active participants in private-sector collaborative R&D (particularly incumbent firms) would choose to participate) or in Region 4 (where a wide variety of business enterprises, both incumbent firms and startup entrepreneurs, would choose to participate). In either case, the university in this case would act as a complement to private-sector collaborative R&D.

As Coates and Humphreys (*2002*) and Coates et al. (*2004*) demonstrate, one can distinguish a slack-maximizing bureaucrat from a budget-maximizing bureaucrat by its reaction to grants. In the case of a slack-maximizing bureaucrat, a lump-sum grant would not alter its behavior, while in the case of a budget-maximizing bureaucrat, such a grant would result in an expansion of its program. Although more formal empirical analysis is required, it is our experience that universities typically expand their programs when provided with lump-sum grants, thus implying that the budget-maximizing model is the more accurate one.[26]

Of course, the ability of a budget-maximizing university to offer a program on a iso-cost curve such as B_1 or B_2, and thereby stimulate increased private-sector collaborative R&D among a wide array of business enterprises, will depend on the university's ability to garner grants: the larger the grant, the greater ability to offer a program that stimulates private-sector collaborative R&D.[27] And that ultimately depends on the interests of sponsors, governmental or otherwise.,[28], [29]

Finally, before turning to normative issues, consider the role that α plays. The value of α may in part be exogenously determined by the academic culture within which the program operates. But to the extent that α can be controlled, an α that is closer to one (that is, one in which there is less loss of appropriability) will mean that a lower subsidy is required to make a program viable and potentially make the program more attractive to a wider range of business enterprises.[30] Thus, in Fig. 11, a higher α would shift all the iso-cost curves to the right (though the B_0 iso-budget line would still cross the $\delta r \alpha \sigma - 1 = 0$ line at some point where $\delta c \kappa - 1 > 0$), thereby reducing the grant that the university would have to receive in order to be attractive to business enterprises and to act as a complement for private-sector R&D collaboration.[31]. However, there may be limits to the ability to increase α due to constraints imposed by the university's academic culture and to interactions between α and ω. Indeed, to the extent that increased economies of technological scope can only come about through increased sharing, this would result in the iso-cost curves being steeper. And this would result in it being more costly to attract firms to the program for any given ω and κ, and thereby make it more difficult for the university to serve as a complement to private-sector R&D collaboration rather than as a substitute for such activity.

5 Normative considerations

It is well known that in general the lack of complete appropriability results in business enterprises engaging in an inefficiently low level of R&D. Likewise, a well-established finding in the bureaucracy literature is that budget-maximizing bureaucrats typically overproduce. Together these observations suggest that the two inefficient behaviors would to some extent counteract each other so that the participation of universities in the collaborative R&D process might result in an improvement in the overall efficiency in the level of R&D reminiscent (this time in a public context) of Smith's invisible hand.

The creative destruction literature provides some reason to believe that this argument may be true.[32] Of particular interest is work by Aghion and Howitt (*1992*) and Howitt and Aghion (*1998*), which argues that creative destruction is likely to result in an inefficiently low level of innovation due to a lack of appropriability, intertemporal spillovers, and business-stealing effects, but that R&D subsidies can counteract such inefficiencies, particularly those that target capital and thereby avoid the agency problems associated with direct R&D subsidies.[33] Within the context of this article, this argument suggests that university programs properly structured to avoid agency problems would indeed improve efficiency.

6 Conclusions

To improve our understanding of the role that universities play in facilitating the transmission of knowledge to private-sector business enterprises and its conversions to economic, that is, commercially viable, knowledge so as to generate economic growth, this article developed a formal model of university-with-business enterprise collaborative research partnerships in which the outcome was both mutually desirable and feasible, and concluded that if a university seeks to act as a complement to private-sector collaborative R&D, it needs to structure its program so that business enterprise revenues increase and business enterprise R&D costs rise by a smaller proportion than revenues increase, if they rise at all (and a fall would be better). Such a structure is consistent with both business enterprise and university interests, but is only likely to be feasible if the university is subsidized. In the absence of such support, the university will have to cover its costs through a fee charged to participating business enterprises, and this will result in the university being seen as a substitute rather than a complement to private-sector collaborative R&D and thus as an unattractive partner for many business enterprises.

A number of additional issues concerning university collaborative research programs remain. Perhaps most important is the need to explore the mechanism by which firms choose collaborative research partners. As suggested by an anonymous referee, two options are possible here. The first option would be to formally model the partnering process using Pissarides's (*1990*) work on matching in labor markets. The second option would be to characterize business enterprises by overlapping knowledge bases with the choice of partners being the result of a tension between a desire for greater knowledge spillovers between partners (which would argue for less overlap) and a desire for reduced coordination costs between partners (which would argue for greater overlap). With either approach, the university would then be characterized by its own (perhaps unique) characteristics, and the implications of this for business enterprise partnering choice explored.

A second issue concerns the market environment of business enterprises. This article assumes that individual business enterprises act in isolation when deciding whether to participate in university programs. However, as Åstebro and Bazzazian (*2011*) argue, local and regional conditions almost surely play a role in the effectiveness of university efforts. To the extent that is true, the success of university collaborative research programs may depend on understanding that role.

Finally, several issues remain concerning the university's funding process. Given the current political pressure to reduce governmental deficits in both the USA and Europe, there is reason to believe that external public funding is not likely to be forthcoming in the near future. The question is whether this conclusion is unique to current circumstances or is a more general phenomenon connected to macroeconomic fluctuations. In the absence of Keynesian fiscal policies (which seems to be increasingly the case), governments are most likely to support university collaborative research programs at the peak of a macroeconomic expansion and least likely to support such programs at the bottom of a contraction, thus giving rise to a dynamic funding problem for universities. Moreover, as shown in this article, business enterprises are attracted to university collaborative research programs to the degree those programs increase expected revenues and reduce expected R&D costs for the business enterprise. But it is also true that interest rates (which provide the foundation for calculating present values) typically rise as the macroeconomy expands and fall as the economy contracts.[34] Thus, for a given university collaborative research program, and because future revenues associated with collaborative research are likely to be more distant than future R&D costs, business enterprises would likely be least interested in collaborating with universities at the height of an expansion and most interested in collaborating in the depth of a contraction. This then would result in business enterprise behavior exacerbating the problem of fluctuating support for university collaborative research programs. To the extent this argument is correct (more research would be useful in this regard), universities that wish to offer collaborative research programs face a complicated dynamic funding and participation problem.[35] Of course, one possible solution to the external funding problem is for universities to look internally for funds. As noted above in footnote 25, universities are complex organizations with a large number of programs and multiple objectives. The issue arises, therefore, whether that complexity affects the choices universities make with regard to collaborative research program design and support. If the boundaries between various university programs are impermeable, there may be little effect of such complexity on the design and funding of collaborative research programs. But to the extent there are synergies between university programs and fungibility in the funding of those programs, it may be that universities may be able to direct support to collaborative research programs internally and therefore may not need to depend on external funding as much.

Acknowledgments

This article was presented at the Workshop on Academic Policy and the Knowledge Spillover Theory of Entrepreneurship, sponsored by the Competence Center for Global Business Management and the CisAlpino Institute for Comparative Studies in Europe, and held 20–21 August 2012 at the University of Augsburg, Augsburg, Germany. Special thanks to Zoltan Acs, Maksim Belitski, David B. Audretsch, Christopher Hayter, Marcel Hülsbeck, Mirjam Knockaert, Erik E. Lehmann, and two anonymous referees for their helpful comments and suggestions.

References

Acs, Z. J., Braunerhjelm, P., Audretsch, D. B., & Carlsson, B. (2009). The knowledge spillover theory of entrepreneurship. *Small Business Economics, 32*(1), 15–30.

Adams, J. D. (1990). Fundamental stocks of knowledge and productivity growth. *Journal of Political Economy, 98*(4), 673–702.

Aghion, P., & Howitt, P. (1992). A model of growth through creative destruction. *Econometrica, 60*(2), 323–351.

Alexopoulos, M. (2011). Read all about it!! What happens following a technology shock? *American Economic Review, 101*(4), 1144–1179.

Alvarez, S. A., & Barney, J. B. (2007). Discovery and creation: Alternative theories of entrepreneurial action. *Strategic Entrepreneurship Journal,1*(1–2), 11–26.

Anand, B. N., & Khanna, T. (1996). *Intellectual property rights and contract structure (Working Paper #3, Working Paper Series H)*. New Haven: Yale School of Management.

Åstebro, T. B., & Bazzazian, N. (2011). Universities, entrepreneurship and local economic development. In M. Fritsch (Ed.), *Handbook of Research on Entrepreneurship and Regional Development*. New York: Edward Elgar.

Audretsch, D. B., & Lehmann, E. E. (2005). Does the knowledge spillover theory of entrepreneurship hold for regions? *Research Policy, 34*(8), 1191–1202.

Audretsch, D. B., Leyden, D. P., & Link, A. N. (2012). Universities as research partners in publicly supported entrepreneurial firms. *Economics of Innovation and New Technology, 21*(5–6), 529–545. doi:10.1080/10438599.2012.656523.

Babbage. (2011). MIT and the art of innovation. *The Economist.* Retrieved from http://www.economist.com/blogs/babbage/2011/01/mit_and_art_innovation.

Baldwin, W. L., & Link, A. N. (1998). Universities as research joint venture partners: Does size of venture matter? *International Journal of Technology Management, 15*(8), 895–913.

Berman, E. M. (1990). The economic impact of industry-funded university R&D. *Research Policy, 19*(4), 349–355.

Blumenthal, D., Gluck, M., Lewis, K. S., Stoto, M. A., & Wise, D. (1986). University-industry research relationships in biotechnology: Implications for the university. *Science, 232*(4756), 1361–1366.

Bonaccorsi, A., & Piccaluga, A. (1994). A theoretical framework for the evaluation of university-industry relationships. *R&D Management, 24*(3), 229–247.

Bozeman, B., Hardin, J., & Link, A. N. (2008). Barriers to the diffusion of nanotechnology. *Economics of Innovation and New Technology, 17*(7–8), 751–753.

Braunerhjelm, P., Acs, Z. J., Audretsch, D. B., & Carlsson, B. (2010). The missing link: Knowledge diffusion and entrepreneurship in endogenous growth. *Small Business Economics, 34*(2), 105–125.

Breton, A., & Wintrobe, R. (1982). *The logic of bureaucratic conduct: an economic analysis of competition, exchange, and efficiency in private and public organizations*. New York: Cambridge University Press.

Campbell, T. I. D. (1997). Public policy for the 21st century: Addressing potential conflicts in university-industry collaboration. *The Review of Higher Education, 20*(4), 357–379.

Coates, D., & Humphreys, B. R. (2002). The supply of university enrollments: University administrators as utility maximizing bureaucrats. *Public Choice, 110*(3–4), 365–392.

Coates, D., Humphreys, D. R., & Vachris, M. A. (2004). More evidence that university administrators are utility maximizing bureaucrats. *Economics of Governance, 5*(1), 77–101.

Cockburn, I., Henderson, R. (1997). *Public-private interaction and the productivity of pharmaceutical research* (NBER Working Paper 6018).

Cohen, L. (1994). When can government subsidize research joint ventures? Politics, economics, and limits to technology policy. *American Economic Review, 84*(2), 159–163.

Cohen, W. M., & Levinthal, D. A. (1989). Innovation and learning: The two faces of R&D. *The Economic Journal, 99*(397), 569–596.

Cohen, W. M., & Levinthal, D. A. (1990). The implications of spillovers for R&D and technology advance. In V. K. Smith & A. N. Link (Eds.),*Advances in applied micro-economics*. Greenwich, CT: JAI Press.

Cohen, W. M., Florida, R., Randazzese, L., & Walsh, J. (1997). Industry and the academy: Uneasy partners in the cause of technological advance. In R. Noll (Ed.), *Challenge to the university*. Washington, DC: Brookings Institution Press.

Cohn, E., Rhine, S. L., & Santos, M. C. (1989). Institutions of higher education as multi-product firms: Economies of scale and scope. *Review of Economics and Statistics, 71*(2), 284–290.

Council on Competitiveness. (1996). *Endless frontiers, limited resources: U.S. R&D policy for competitiveness.* Washington, DC: Council on Competitiveness.

Ehrenberg, R. G., Rees, D. I., & Brewer, D. J. (1993). How would universities respond to increased federal support for graduate students? In C. Clotfelter & M. Rothschild (Eds.), *Studies of supply and demand in higher education* (pp. 183–210). Chicago: University of Chicago Press.

Feller, I. (1990). Universities as engines of R&D-based economic growth: They think they can. *Research Policy, 19*(4), 335–348.

Fisher, I. (1932). *Booms and depressions: Some first principles*. New York: Adelphi.

Government-University-Industry Research Roundtable (GUIRR. (2006). *Guiding principles for university-industry endeavors*. Washington, DC: National Academy Press.

Hall, B. H. (2004). University-industry research partnerships in the United States. In J.-P. Contzen, D. Gibson, & M. V. Heitor (Eds.), *Rethinking science systems and innovation policies*. West Lafayette, IN: Purdue University Press.

Hall, B. H., Link, A. N., Scott, J. T. (2000). *Universities as research partners* (NBER Working Paper 7643).

Hall, B. H., Link, A. N., & Scott, J. T. (2003). Universities as research partners. *Review of Economics and Statistics, 85*(2), 485–491.

Hébert, R. F., & Link, A. N. (2009). *A history of entrepreneurship*. New York: Routledge.

Henderson, R., Jaffe, A. B., Trajtenberg, M. (1995). *Universities as a source of commercial technology: A detailed analysis of university patenting 1965-1988* (NBER Working Paper No. 5068).

Hertzfeld, H. R., Link, A. N., & Vonortas, N. S. (2006). Intellectual property protection mechanisms in research partnerships. *Research Policy, 35*(6), 825–838.

Howitt, P., & Aghion, Philippe. (1998). Capital accumulation and innovation as complementary factors in long-run growth. *Journal of Economic Growth*, *3*(2), 111–130.

Jaffe, A. (1989). Real effects of academic research. *American Economic Review*, *79*(5), 957–978.

Klevorick, A. K., Levin, R. C., Nelson, R. R., & Winter, S. G. (1995). On the sources and significance of interindustry differences in technological opportunities. *Research Policy, 24*(2), 185–205.

Knight, F. H. (1921). *Risk, uncertainty, and profit*. Boston, MA: Houghton Mifflin.

Layson, S. K., Leyden, D. P., & Neufeld, J. R. (2008). To admit or not to admit: The question of research park size. *Economics of Innovation and New Technology, 17*(7/8), 691–699.

Lee, Y. S. (2000). The sustainability of university-industry research collaboration: An empirical assessment. *Journal of Technology Transfer*, *25*(2), 111–133.

Leyden, D. P., & Link, A. N. (1999). Federal laboratories as research partners. *International Journal of Industrial Organization, 17*(4), 575–592.

Leyden, D. P., & Link, A. N. (2013). Collective entrepreneurship: The strategic management of Research Triangle Park. In D. P. Audretsch & M. L. Walshok (Eds.), *Creating competitiveness: Entrepreneurship and innovation policies for growth* (pp. 176–185). MA: Northampton.

Leyden, D. P., Link, A. N., & Siegel, D. S. (2008). A theoretical and empirical analysis of the decision to locate on a university research park". *IEEE Transactions on Engineering Management, 55*(1), 23–28.

Link, A. N. (1996). Research joint ventures: Patterns from *Federal Register* filings. *Review of Industrial Organization, 11*(5), 617–628.

Link, A. N., & Scott, J. T. (2005). Universities as partners in U.S. research joint ventures. *Research Policy, 34*(3), 385–393.

Link, A. N., & Scott, J. T. (2007). The economics of university research parks. *Oxford Review of Economic Policy, 23*(4), 661–674.

Link, A. N., & Welsh, D. H. B. (2013). From laboratory to market: On the propensity of young inventors to form a new business. *Small Business Economics, 40*(1), 1–7.

Lööf, H., & Broström, A. (2008). Does knowledge diffusion between university and industry increase innovativeness? *Journal of Technology Transfer*, *33*(1), 73–90.

Mansfield, E. (1991). Academic research and industrial innovation. *Research Policy, 20*(1), 1–12.

Mansfield, E. (1992). Academic research and industrial innovation: A further note. *Research Policy, 21*(3), 295–296.

Mansfield, E., & Lee, J.-Y. (1996). The modern university: Contributor to industrial innovation and recipient of industrial R&D support. *Research Policy, 25*(7), 1047–1058.

Michelacci, C. (2003). Low returns to R&D due to the lack of entrepreneurial skills. *Economic Journal, 113*(484), 207–225.

Morales, M. F. (2003). Financial intermediation in a model of growth through creative destruction. *Macroeconomic Dynamics, 7*(3), 363–393.

Morgan, R. P. (1998). University research contributions to industry: The faculty view. In P. D. Blair & R. A. Frosch (Eds.), *Trends in Industrial Innovation: Industry Perspectives & Policy Implications*. Research Triangle Park, NC: Sigma Xi, The Scientific Research Society.

Mowery, D. C., Teece, D. J. (1996). Strategic alliances and industrial research. In R. S. Rosenbloom, W. J. Spencer (Eds.), *Engines of innovation: U.S. industrial research at the end of an era.* Boston: Harvard Business School Publishing.

Niskanen, W. A. (1971). *Bureaucracy and Representative Government*. Chicago: Aldine-Atherton.

Pissarides, C. A. (1990). *Equilibrium unemployment theory*. Oxford: Basil Blackwell.

Schumpeter, J. A. (1934). *The theory of economic development* (R. Opie, Trans.). Cambridge: Harvard University Press (Original work published 1912).

Segerstrom, P. S., & Zolnierek, J. M. (1999). The R&D incentives of industry leaders. *International Economic Review, 40*(3), 745–766.

Siegel, D., Waldman, D., Link, A. N. (1999). *Assessing the impact of organizational practices on the productivity of university technology transfer offices: An exploratory study* (NBER Working Paper No. 7256).

State Science and Technology Institute (SSTI). (2008). *A resource guide for technology-based economic development*. Washington, DC: Economic Development Administration.

Tassey, G. (2008). Globalization of technology-based growth: The policy imperative. *Journal of Technology Transfer, 33*(6), 560–578.

Thesmar, D., & Thoenig, M. (2000). Creative destruction and firm organization choice. *Quarterly Journal of Economics, 115*(4), 1201–1237.

Van de Ven, A. H. (1993). A community perspective on the emergence of innovations. *Journal of Engineering and Technology Management*, *10*(1–2), 23–51.

Wyckoff, P. G. (1990). The simple analytics of slack-maximizing bureaucracy. *Public Choice*, *67*(1), 35–47.

Zeckhauser, R. (1996). The challenge of contracting for technological information. *Proceedings of the National Academy of Science*, *93*(23), 12743–12748.

Zucker, L. G., Darby, M., Armstrong, J. (1994). *Intellectual capital and the firm: The technology of geographically localized knowledge spillovers*(NBER Working Paper 4946).

Footnotes

1 Thus, the debate over whether entrepreneurship is essentially a process of creation or discovery (Alvarez and Barney *2007*) misses the point. As Michelacci (*2003*) and Acs et al. (*2009*) argue, creation of knowledge by researchers and existing firms and the discovery of such knowledge by entrepreneurs are both required.

2 We abstract from the important impact that universities have through their role in educating and graduating students.

3 Åstebro and Bazzazian (*2011*), in their wide-ranging review of the empirical literature on the impact of universities on local entrepreneurship and economic development, rightly sound a cautionary note on our ability to make definitive claims about the causal impact of universities on economic development.

4 See Link and Scott (*2005*).

5 See Link and Scott (*2007*), Layson et al. (*2008*), Leyden et al. (*2008*), and Åstebro and Bazzazian (*2011*) for discussions of university research parks.

6 The Council on Competitiveness (*1996*, pp. 3–4) recently noted and emphasized this trend in the USA: “[P]articipants in the U.S. R&D enterprise will have to continue experimenting with different types of partnerships to respond to the economic constraints, competitive pressures and technological demands that are forcing adjustments across the board.…[and in response] industry is increasingly relying on partnerships with universities ….” Relatedly, Link (*1996*) showed that university participation in formal research joint ventures (RJVs) has increased steadily since the mid-1980s, Cohen et al. (*1997*) documented that the number of industry/university R&D centers increased by more than 60 % during the 1980s, and a recent survey of US science faculty by Morgan (*1998*) revealed that many desire even more partnership relationships with industry. Mowery and Teece (*1996*, p. 111) contend that such growth in strategic alliances in R&D is indicative of a “broad restructuring of the U.S. national R&D system.”

7 Hall's (*2004*) subsequent emphasis on industry/university research partnerships in the US is on intellectual property. See also the role of intellectual property protection mechanisms (Hertzfeldet al. *2006*).

8 Cohen et al. (*1997*) provide a selective review of this literature, emphasizing the studies that have documented that university research enhances firms' sales, R&D productivity, and patenting activity. See Blumenthal et al. (*1986*), Jaffe (*1989*), Adams (*1990*), Berman (*1990*), Feller (*1990*), Mansfield (*1991*, *1992*), Van de Ven (*1993*), Bonaccorsi and Piccaluga (*1994*), Klevorick et al. Winter (*1995*), Zucker et al. (*1994*), Henderson et al. (*1995*), Mansfield and Lee (*1996*), Zeckhauser (*1996*), Campbell (*1997*), Baldwin and Link (*1998*), Lee (*2000*) and Lööf and Broström (*2008*). Cockburn and Henderson (*1997*) show that it was important for innovative pharmaceutical firms to maintain ties to universities. Hall et al. (*2000*, *2003*) suggest that perhaps such research ties with universities increase the "absorptive capacity," in the sense of Cohen and Levinthal (*1989*, *1990*), of the innovative firms. This literature is reviewed by Audretsch et al. (*2012*).

9 See Berman (*1990*), Feller (*1990*), Henderson et al. (*1995*), Zeckhauser (*1996*), and Siegel et al. (*1999*).

10 GUIRR (*2006*, p. 8) point out that "Institutional practices and national resources should focus on fostering appropriate long-term partnerships between universities and industry." While we do not offer recommendations about such partnerships in this article, we do acknowledge the importance of the timing of such relationships and their longevity. However, our model (below) is static and does not taking timing into account. Clearly, that is an area for future research.

11 Leyden and Link (*2013*) discuss collective entrepreneurship in the context of the management of places. Therein they hypothesize that the strategic management of places is functionally related to the collective positive entrepreneurial effort of individuals, each exercising his/her perception and action at different time based on their personal preferences, expertise, and estimation of the best steps forward. Collectively, they engage in what might be called a process of social sequential learning that moves a place forward for the common weal.

12 We thank an anonymous referee for pointing out that in a knowledge spillover perspective costs and profits are certainly important, as are other intermediary inputs and long-term strategies (for example, those that affect regional R&D culture and economic knowledge) that may or may not be captured in a static model that focused on costs and profits. We fully agree with this point, and we are hopeful that our initial theoretical effort toward collective entrepreneurship will provide a foundation for later extensions in the literature to account for these subtleties.

13 For an interesting antecedent to the KSTE distinction between firms and entrepreneurs, see Hébert and Link's (*2009*) discussion of Adam Smith's and Jeremy Bentham's contrasting views of the entrepreneur.

14 For expository reasons, we reduce the dynamic, uncertain problem of maximizing expected profits to a static, deterministic one. See Knight's (*1921*) classic work on risk and uncertainty for a justification of this approach.

15 The assumption that potential revenue (and later appropriability and costs) is a function of n is a simplifying assumption intended to proxy for the complex matching process by which business enterprises identify and partner with other business enterprises in ways that are to the mutual advantage to those business enterprises.

16 Economically usable knowledge includes the results of the entrepreneurial discovery process that may result in novel applications of technology and forms of output.

17 Anand and Khanna (*1996*) argue that the inability to fully appropriate the value of an innovation is due to the presence of weak property rights that arise because of an inability to specify the context and boundaries of knowledge in a manner that makes violation of those property rights verifiable. Cohen (*1994*) notes that this inability to fully appropriate the value of the research may, if severe enough, lead to incentive problems in engaging in efficient private-sector collaboration, that is, collaboration that results in more research than would be generated in the absence of the collaboration.

18 There are, of course, markets for human and technical capital, but the nature of R&D in a business enterprise is likely to be more focused on the development side and therefore more applied and proprietary, while the nature of R&D in a university is likely to be more focused on the research side.

19 Bozeman et al. (*2008*) and Leyden et al. (*2008*) demonstrate this point.

20 See Baldwin and Link (*1998*) and Leyden and Link (*1999*) for empirical analyses based on the latter two effects—a reduction in appropriability and a (reduction) in business enterprise research costs. Clearly, we are only focusing on university-industry factors that affect costs and profits. We acknowledge, as urged by an anonymous referee, that there are other important rationales to consider. He/she is correct, but their inclusion is beyond the scope of our model.

21 The ensuing discussion assumes that α, ω, and κ are not functions of n. This assumption is made for the sake of model clarity. However, we recognize that these parameters may indeed vary to some degree with the number of private-sector collaborators. One possibility that is plausible and consistent with the conclusions of this article is that the loss in appropriability associated with the presence of a university is smaller for incumbent firms (i.e., those that have a larger number of private-sector collaborators) than for startup entrepreneurs (i.e., those that have a smaller number of private-sector collaborators) so that $\partial\alpha/\partial n > 0$. Likewise, the cost savings associated with collaborating with the university is relatively greater for startup entrepreneurs than for incumbent firms (i.e., $\partial\kappa/\partial n < 0$). Of course, the issue is an empirical one and deserving of future work.

22 This is an arc elasticity with the base equal to the level of revenues and costs associated with the absence of university collaboration.

23 Because $nU* = n*$ when $\alpha\sigma = \kappa$, and because the degree to which $nU*$ differs from $n*$ is a positive, continuous function of the degree to which $\alpha\sigma$ differs from κ, we can illustrate these results in the same *change in revenue* × *change in R&D costs* policy space used to summarize the conditions under which a business enterprise will choose to collaborate with the university.

24 Technically, point *A* lies in Region 1 below the $\delta c\kappa - 1 = 0$ line because $\alpha_0 \omega < \kappa$ (recall that ω and κ equal 1 and α_0 is less than 1), which implies $nU* < n*$ (see the discussion following Eq. (20)), and $nU* < n*$ implies that $\delta c\kappa - 1 < 0$ (see the discussion following Eq. 15). Intuitively, point *A* lies in Region 1 below the $\delta c\kappa - 1 = 0$ line because the increased loss of appropriability ($\alpha_0 < 1$) results (given no compensating gains in terms of a lower cost function or increase prospects for revenue) in participating firms reducing their level of collaboration with other business enterprises, and that results in a fall in costs and a (proportionately greater) fall in revenues.

25 If the iso-budget line B_0 were to cross the $\alpha\sigma = \kappa$ line, the university could design a balanced-budget program or even positive-profit program that lies in the upper part of Region 4 in Fig. 11. This would still result in a program that essentially charges a fee to participate ($\kappa > 1$), though all business enterprises would find the program attractive. Those that participated would have an incentive to increase the number of private-sector partners. However, because the program would be in the upper part of Region 4, this latter incentive would be weak.

26 See Wyckoff (*1990*) for a simple comparative static analysis of budget maximization versus slack maximization.

27 Our analysis assumes that the university program exists in isolation. However, we recognize that university objectives are likely more complex with multiple objectives and the possibility for fungibility in the funding of multiple programs. Åstebro and Bazzazian (*2011*), for example, note the potential conflict between university efforts to support local startups and university desire for licensing revenue, and Ehrenberg, Rees, and Brewer (*1993*) provide evidence of universities using revenues from one program to subsidize others. To the extent universities treat the revenues of various programs as fungible, a research program with somewhat higher costs (on the iso-cost curve B_1 for example) might be possible without a grant. Initial work on a more sophistical model of university objectives suggests that the relative salience to the university of its various programs determines the degree to which funding in one program is used to subsidize others.

28 Breton and Wintrobe (*1982*) take a more expansive view of bureaucracy by focusing broadly on policy decisions rather than technical production decisions. The Niskanen literature, which derives from Niskanen (*1971*) and within which our work fits, focuses on policy as well. However, that focus is primarily from a quantitative perspective (such as the quantity to produce)

and not from a qualitative one, such as what should be produced and what the qualities of that output should be. From the perspective of this article, Breton and Wintrobe's work is potentially of greater value for understanding the design of a research program, that is, whether it focuses on the goals of increasing revenues and reducing costs that are identified in this article and what mix (that is where on the iso-cost curve) the program would operate.

29 Business enterprise support for universities, to the extent it is motivated by profit considerations, is subsumed within the structure of this article’s model. However, as an anonymous referee rightly points out, business support for universities may also be motivated by more uncertain, dynamic, and longer term considerations such as the development and maintenance of relationships, access to future graduates, etc. Such motivations are clearly worthy of inquiry but are beyond the scope of this article.

30 Åstebro and Bazzazian (*2011*) in their discussion of university entrepreneurial activity suggest that while there are tensions within universities regarding the balance between traditional academic and entrepreneurial interests, the culture of some universities has adapted to entrepreneurial interests.

31 Baldwin and Link (*1998*) provide empirical evidence that research joint ventures with universities tend to be larger than those that do not involve universities and argue that the reason for this is that business enterprises in a large research joint venture (because they already have a large number of research partners) incur relatively little additional loss of appropriability if they also collaborate with a university. Leyden and Link (*1999*) provide similar evidence and argument for research joint ventures involving governmental labs. In terms of the model in this article, this suggests that university programs may empirically tend to be located in Region 2 and that α may be a positive function of the total number private-sector business enterprises (which in Region 2 would primarily be incumbent firms) that choose to collaborate with the university. See Cohn et al. (*1989*) for more general evidence of economies of scope in universities.

32 The creative destruction literature traces its origins to Schumpeter (*1934*). For a discussion of Schumpeter’s work on entrepreneurship, the context within which it was developed, and how it compares to other theories of entrepreneurship, see Hébert and Link (*2009*).

33 See also Segerstrom and Zolnierek (*1999*) for an alternative approach. There are two extensions of the Aghion and Hewitt argument worth noting. First, Morales (*2003*) extends that argument to the realm of financial capital, arguing that subsidies to financial capital are also growth enhancing, though this time because of improved monitoring. Second, Thesmar and Thoenig (*2000*) argue that recent decades (if not the past century) have seen an increase in product market volatility and creative destruction that has led to a shift away from fixed capital and unskilled labor and toward skilled labor, that is, higher levels of human capital. Such an argument suggests that universities, beyond their value in creating skilled workers, may provide an important role in acting as matchmaker between skilled workers and firms in the regional

economy. See Audretsch et al. (*2012*) for empirical evidence of this connection with respect to the use of graduate students.

34 A classic description of this pattern can be found in Fisher (*1932*).

35 For evidence of other links between R&D and macroeconomic fluctuations, see Alexopoulos (*2011*).