"R&D: WHO DOES THE R, WHO DOES THE D?"

by

Olivier CADOT*
and
Dominique DESRUELLE**

N° 92/45/EP

* Assistant Professor of Economics, at INSEAD, Boulevard de Constance, Fontainebleau 77305 Cedex, France.

** Assistant Professor of Economics, at Montreal University, CP 6128, succ. A, Montreal, PQ H3C 3J7, Canada.

Printed at INSEAD,
Fontainebleau, France

August 1992

R&D: WHO DOES THE R, WHO DOES THE D?

Olivier Cadot and Dominique Desruelle*

Abstract

The paper considers the relationship between country size and the relative importance of research vs development activities. We first consider the allocation of scientists between research and development in a two-country, two-sector model where the research sector is characterized by a race. We show that an increase in country size in the sense of a proportional increase in the number of domestically available scientists and in the number of opportunities for development leads to a higher *proportion* of scientists being in the development sector. We also show that if the "final prizes" of a two-stage R&D race are positively related to country size, the conditional probability of success in the development stage given success in the research stage is higher for a large country than for a small country.

---

* Respectively INSEAD, bd de Constance, 77305 Fontainebleau, France, and Department of Economics, Université de Montréal, CP 6128, succ. A, Montréal, PQ H3C 3J7, Canada. We gratefully acknowledge INSEAD financial assistance under grant 2166R.

1. **Introduction**

In "small" industrial countries such as the U.K. or France, policymakers and the press regularly lament that these countries, while contributing substantially to fundamental research and thus to the advancement of knowledge, fail to transform this expertise into successful product development. Similarly, Hendry (1989) argues that there is a "British problem: the chronic inability of British industry to convert exceptionally high levels of technological expertise into commercial success in an international marketplace. [...] Britain is good at research and bad at (implicitely commercial) development[1]." The question of who does research and who does development is not only a positive one, it is also an important policy one. With international restrictions on the use of traditional industrial policy instruments, the capture of emerging product markets by domestic producers tends to become the hidden agenda behind many science and technology policies. Governments are thus naturally interested in the question of how a successful science and technology policy translates into a successful industrial policy.

Unfortunately, the economics literature treats the distinction between research and development activities only tengentially. Fudenberg, Gilbert, Stiglitz and Tirole (1983) show that the presence of several distinct stages in the R&D process matters in

---

[1] John Hendry, *Innovating For Failure: the Early History of the British Computer Industry*, Cambridge, MA: MIT press, p. 1.

that it introduces the possibility of leapfrogging in a model where success is a stochastic function of effort. Grossman and Shapiro (1987) consider a two-stage race, stage one being research and stage two development. They show that a country being outdistanced by its rival in the sense of being stuck in stage R while the rival has reached stage D will reduce its effort intensity. More recently, Choi (1991) suggested that research could be distinguished from development by assuming that in the research phase, the hazard rate - the instantaneous probability of discovery - is initially unknown. It may, for instance, be either some positive number, in which case the problem can be solved, or zero, in which case the problem cannot be solved. This assumption fundamentally changes the nature of a race, as discovery in the research phase now exerts an informational externality by enabling *all* participants to update their beliefs about the difficulty of the research problem. A breakthrough by one participant may then trigger a rush - an increase in the research intensity of every other participant. We will use this framework to tackle the question raised by Hendry. Is there any natural link between country size and the relative importance of research *vs* development activities? We approach the problem from two different and complementary perspectives.

The first explanation focuses on the allocation of resources between the research and the development sectors, and is based on the following view of research. Opportunities for research depend on the state of human knowledge, which is universal. Their abundance is thus not related to country size, because research networks transcend national boundaries[2]. On the other hand, opportunities for product development depend positively on the size of a country's manufacturing sector[3]. The question is then: if a large country has both more researchers and more opportunities for product development, how will it allocate its researchers compared to a small one? We show how an increase in country size tilts the proportion in favor of development by calculating the elasticity of the share of researchers employed in the development sector to a proportional increase in researcher and development-project endowments.

The second explanation considers research and development as successive stages in a sequential R&D process. We show that if imperfect integration of world markets makes the final prize of the R&D race dependent on country size, a small country can be "preempted" by a larger one. In particular, for some projects, the small country will give up if outdistanced, i.e. if stuck in stage R while the larger country makes it to stage D. By contrast, the large country will keep on racing even if outdistanced. Then, ex post, it will seem as if, on average, the smaller country was less successful than the larger one in transforming research expertise

---

[2] On the extent to which research networks do transcend national borders, one should consult bibliometric data published by the OECD in its 1991 science and technology policy review.

[3] Rosen (1991) argues that large firms tend to invest more in R&D than smaller ones and choose safer projects. While drawing on different arguments, we show a - loosely - comparable result relating to country size.

into successful product development. In other words, the ratio of successes in stage R over successes in stage D will be higher for the small country than for the big one, the phenomenon noted by Hendry.

The paper is organized as follows. Section 2 considers a two-sector model of the allocation of effort between research and development and solves it. Section 3 considers a two-stage race between two countries. Section 4 concludes.

2. **Research vs development in a two-sector model**

We consider here a simple two-country, two-sector model where "research" and "development" are distinct activities drawing from the same pool of resources - researchers - but with otherwise no special link, and where every research project may be undertaken by researchers of any country while development projects are country-specific. A model where research and development are sequentially linked activities is presented in section 3.

2.1 *The model*

The world is composed of country 1 and country 2. Country i ($i = 1,2$) is endowed with N^i identical researchers who can work on either research or development projects. Researchers are perfectly mobile between the research and development sectors of one country and totally immobile between countries. Country i is also endowed with a portfolio of K^i_D development projects. The development projects are country-specific: a development project of country 1 is not available to country 2, and vice-versa. Each such project employs one researcher and is characterized by a constant hazard rate, μ. In both countries, μ is distributed across projects on the interval $[0,\bar{\mu}]$ according to a common distribution $F(\mu)$, of density $f(\mu)$. This distribution and the number of development projects in each country are assumed constant through time; this means that a development project that is successfully completed is immediately replaced by a project with identical characteristics. If successful, a development project yields a prize normalized to 1.

The world is endowed with a number of identical research projects. In contrast to development projects, these projects can be undertaken in both countries. In country i, the hazard rate of a research project that employs n^i researchers is the time-independent function $\lambda(n^i)$. The function $\lambda(n^i)$ is strictly increasing and concave in n^i, and asymptotically approaches 1 as n^i tends to infinity. If successful, the project yields a prize Z, whether the discovery takes place in country 1 or country 2. This prize can be thought of as the present expected value of royalties from a patent.

Research projects are randomly generated by nature. Their number can therefore fluctuate through time depending upon the success of existing projects and the arrival of new projects. Initially, there are K_R research projects in the world.

Development and research projects are undertaken by private firms or by governments. Firms are risk neutral and maximize payoffs discounted at a rate r. Governments maximize the expected value of the domestic R&D sector's output, also discounted at rate r. In country i, the market for researchers clears at time t at a wage $w^i{}_t$, and firms take this wage as given[4].

2.2 *Solution*

We describe here the equilibrium of the two countries' markets for researchers. Given that the prize of a successful development project equals 1, a development project is active at time t if and only if its hazard rate μ exceeds the current wage $w^i{}_t$.[5] Thus the total labor demand from the development sector is

$$N_D^i = K_D^i \int_{w_t^i}^{\bar{\mu}} f(\mu)\, d\mu = K_D^i \left[1-F(w_t^i)\right] \tag{1}$$

Inverting this equation, the wage of researchers can be expressed as the following function of N_D:

$$w_t^i = F^{-1}\left(1-\frac{N_D^i}{K_D^i}\right) \equiv g\left(\frac{N_D^i}{K_D^i}\right) \tag{2}$$

where g is a monotonically decreasing function.

Research projects are all identical ex ante. Since the hazard

[4] These hypotheses imply that governments and firms behave identically in the research sector.

[5] We assume that development projects can be stopped and restarted at no cost.

rate of a research project is $\lambda(n)$ if n researchers work on the project and since the cost of n researchers at time t in country i is nw^i_t, it is worthwile putting at least a few researchers on a project if $\lambda(n) - nw^i_t$ is positive for some n. Given that $\lambda(n)$ is a concave function of n, this occurs if $\lambda'(0)$ exceeds w^i_t. This last condition being the same for all research projects, either all projects will be undertaken or none will be. We rule out this second possibility by assuming that if all researchers worked in the development sector the wage would be low enough to make it worthwile to undertake a research project. That is to say, we assume

$$\lambda'(0) > g\left(\frac{N^i}{K_D^i}\right) \quad , \quad i=1,2 \qquad \textbf{(3)}$$

Therefore, all projects will be undertaken in both countries. In the research sector, the two countries are involved in K_R identical races. For the sake of simplicity, we assume that when firms or governments determine the number of researchers to employ in one race, they assume that the wage rate stays constant over time at its present value[6]. Then, the value of a research race for country i, v^i, is given by

[6]In fact, the wage rate fluctuates over time since the number of research projects changes. Our assumption is justified if the fluctuation in the number of research projects does not affect the wage too much or if the current wage is a good prediction of the wage in the future.

$$v^i = \frac{\lambda(n^i)Z - n^i w^i}{r + \lambda(n_i) + \lambda(n_j)} \tag{4}$$

where n^i and n^j are the numbers of researchers employed on that research race in country i and country j ($j \neq i$, $i=1,2$)[7]. The optimal n^i is the one that maximizes v^i. It is therefore obtained by setting $\partial v^i / \partial n^i$ equal to zero. After rearranging this first-order condition, one finds

$$\frac{\lambda'(n^i)\,[r + \lambda(n^j)]\,Z}{r + \lambda(n^i) + \lambda(n^j) - n^i \lambda'(n^i)} = w^i \tag{5}$$

The equality between demand and supply of researchers is given in each country by

$$N_D^i + K_R n^i = N^i \tag{6}$$

Putting together equations (2), (5) and (6), we find that the two countries' optimal number of researchers in each research race is given by the following set of equations:

$$\begin{aligned} \frac{\lambda'(n^1)\,[r + \lambda(n^2)]\,Z}{r + \lambda(n^1) + \lambda(n^2) - n^1 \lambda'(n^1)} &= g\left(\frac{N^1 - K_R\, n^1}{K_D^1}\right) \\ \frac{\lambda'(n^2)\,[r + \lambda(n^1)]\,Z}{r + \lambda(n^1) + \lambda(n^2) - n^2 \lambda'(n^2)} &= g\left(\frac{N^2 - K_R\, n^2}{K_D^2}\right) \end{aligned} \tag{7}$$

The allocation of researchers between the research and development sectors, $N_D{}^i$ and $N_R{}^i$, in both countries, then follows from the set of equations (7) and

---

[7]See Grossman and Shapiro (1987).

$$N_R^i = K_R n^i, \qquad i=1,2$$
$$N_D^i = N^i - K_R n^i, \qquad i=1,2 \tag{8}$$

2.3 *Comparative statics*

We are now ready to address the question of how country size affects the relative incentives to do research or development, i.e., in our two-sector model, the intersectoral allocation of researchers. Specifically, we consider how the allocation of researchers between the research and development sectors differs between the two countries in the following circumstance: Country 1 is larger than country 2 while both countries have the same relative abundance of researchers, which is to say that country 1 has more researchers and more development projects than country 2 and the ratio of development projects to researchers is identical in both countries. To do so, we totally differentiate the system of equations (7) with respect to country 1's endowment of researchers and of development projects. To make the computations easier to follow, we define the following function:

$$a^i(n^i,n^j) = \frac{\lambda'(n^i)\,[r+\lambda(n^j)]}{r+\lambda(n^i)+\lambda(n^j)-n^i\lambda'(n^i)} \tag{9}$$

Therefore, the system of equations (7) can be rewritten as

$$a^1(n^1,n^2) = g\left(\frac{N^1 - K_R\, n^1}{K_D^1}\right)$$
$$a^2(n^1,n^2) = g\left(\frac{N^2 - K_R\, n^2}{K_D^2}\right) \qquad (10)$$

Differentiating this system of equations and solving it for dn^1 and dn^2, one gets

$$dn^1 = \frac{1}{\Delta K_D^1}\, g'\left(\frac{N^1-K_R n^1}{K_D^1}\right)\left[a_2^2+\frac{K_R}{K_D^2}g'\left(\frac{N^2-K_R n^2}{K_D^2}\right)\right]\left[dN^1-\frac{N^1-K_R n^1}{K_D^1}dK_D^1\right]$$
$$dn^2 = -\frac{a_1^2}{\Delta K_D^1}\, g'\left(\frac{N^1-K_R n^1}{K_D^1}\right)\left[dN^1-\frac{N^1-K_R n^1}{K_D^1}dK_D^1\right] \qquad (11)$$

where $a^i{}_1$ and $a^i{}_2$ are the partial derivatives of a^i with respect to n^1 and n^2 and

$$\Delta = \left[a_1^1+\frac{K_R}{K_D^1}\, g'\left(\frac{N^1-K_R n^1}{K_D^1}\right)\right]\left[a_2^2+\frac{K_R}{K_D^2}\, g'\left(\frac{N^2-K_R n^2}{K_D^2}\right)\right] - a_1^2\, a_2^1 \qquad (12)$$

The thought experiment we consider is one where, starting with identical endowments for both countries, N^1 and $K^1{}_D$ increase in the same proportion ($dN^1/N^1 = dK_D{}^1/K_D{}^1$). Therefore,

$$dN^1 - \frac{N^1 - K_R n^1}{K_D^1}\, dK_D^1 = \frac{N_R^1}{N^1}\, dN^1 \qquad (13)$$

Differentiation of a^2 shows that $a^2{}_1$ is strictly positive and $a^2{}_2$ is strictly negative. Furthermore, Δ is strictly positive if the duopoly game played by the two countries for each research race is locally stable, which is what we assume. Putting these facts together, and given that

$$dN_R^i = K_R dn^i, \qquad i=1,2$$
$$dN_D^i = dN^i - K_R dn^i, \qquad i=1,2 \tag{14}$$

one finds after some straightforward algebraic manipulations that

$$0 < \frac{dN_R^1}{dN^1} < 1$$
$$\frac{d\left(\frac{N_R^1}{N^1}\right)}{dN^1} < 0 \tag{15}$$
$$\frac{dN_R^2}{dN^1} > 0$$

In words, as country 1 gets larger, it splits its additional researchers into the research and development sectors. However, since the elasticity of the number of researchers in the research sector with respect to the total number of researchers is less than 1, the percentage of researchers in the research sector goes down in country 1. On the other hand, country 2 reacts to the increase in the size of country 1 by putting in more researchers in the research sector. This is due to the fact that in research races of the type described here, efforts are strategic complements, i.e. each participant increases its effort when its competitor does so ($dn^2/dn^1 > 0$). Therefore, one finds that the larger country puts a higher percentage of its researchers in the development sector than the smaller country. This implies that when one compares the smaller and the larger countries, one finds that the smaller country is relatively less successful in the development sector than in the research sector.

3. <u>Research vs development in a sequential model</u>

We consider here a model where research and development are activities undertaken in sequence, in a race between two countries. The question is whether a small country has a bigger chance than a large one of losing out in the development stage.

3.1 *The model*

R&D is a two-stage process: a research stage (phase R) is conducted first, and then follows a development stage (phase D). Time is divided in discrete periods: one can move on to the development stage only if the research stage has been successfully completed in the previous period. Each R&D project has a fixed size, so that a country faces, in each period, a binary decision. If a new project is contemplated, the decision is whether to start phase R; if a project has been active for at least one period, the decision is whether to pursue it, in phase R or in phase D.

Phase R of a project is characterized by a random probability of success per period, $\tilde{\lambda}$, which can take on the values 0 or λ, with probability p on λ. Phase D of a project can be undertaken only upon successful completion of phase R. It is characterized by a known probability of success μ.

Two countries are working simultaneously on the same portfolio of R&D projects. When one country completes phase R, the other country learns that the project is feasible and accordingly revises p to 1. When country i completes phase D before country j, country i gets a monopoly payoff M_i, while country j gets nothing. M_1 and M_2 are not identical, reflecting differences in home market size and other country-specific demand factors. When both countries make the breakthrough in the same period, they get duopoly payoffs C_1 and C_2, which are, for similar reasons, not identical. We assume that country 2 is the larger country and, therefore, that $M_2 > M_1$ and $C_2 > C_1$. There is no interim reward for completion of phase R. Resources are country-specific and have a constant cost c_j. The larger country is assumed to have a cost of doing research lower than or equal to the small country's cost; that is to say, $c_2 < c_1$. In order to avoid cluttering the notation, no discounting is used; one may think of the terminal prizes being period-specific, each country obtaining after termination a payoff of zero.

3.2 *Solution*

In order to assess each country's incentive to pursue the R&D effort, we calculate project-specific payoffs in each state of the game, denoted by a function $v(\omega)$. The state ω of the game is either (D,D), (D,R), (R,D) or (R,R,t), where t is the number of unsuccessful research periods[8]. The payoff obtained by a country upon abandonment of a project is zero, so that a project is started

[8] In every state except (R,R), all uncertainty about $\tilde{\lambda}$ is lifted, so that expected continuation payoffs are stationary. In stage (R,R), by contrast, each period elapsed without success is "bad news" about $\tilde{\lambda}$, thus depressing expected continuation payoffs.

or pursued as long as it offers a nonnegative payoff.

We now construct a "scenario" or candidate equilibrium for the race and show that it does not place inconsistent requirements on parameter values. The scenario is the following: Country 1 (the small one) and country 2 both start any new research project (a project in state (R,R,0)); Country 1 and country 2 abandon all old research projects (state (R,R,1)), that is to say all projects that have not moved past the research stage after one period in any of the two countries; country 2 (the large country) continues working on any project that is at the development stage in at least one country; country 1 continues working only on projects that are at the development stage in country 1 (it abandons projects where it is lagging behing country 2, that is to say project in stage (R,D)). We now compute the project's payoffs to both countries in the various stages of the game under this scenario. We will then check that there exists values of the race parameters (c_1, C_1, M_1, c_2, C_2, and M_2) under which the optimal decisions of country 1 and 2 conform to this scenario.

If both countries are in the development stage, the probability of success of each country is μ, and the payoff to country j (j=1,2) is

$$V_j(D,D) = -c_j + (1-\mu)^2 v_j(D,D) + \mu(1-\mu)M_j + \mu^2 C_j$$
$$= -\frac{c_j}{\mu(2-\mu)} + \frac{1}{2-\mu}[\mu C_j + (1-\mu)M_j] \tag{16}$$

If country 1 is in stage D while 2 is in stage R, the probability of success (meaning getting to stage D) of country 1 is λ and the probability of success (meaning winning the race) of country 2 is μ. Therefore, payoffs to country 1 and 2 in that stage are

$$v_1(D,R) = -c_1 + \mu M_1 + (1-\mu)\,[\lambda v_1(D,D) + (1-\lambda)\,v_1(D,R)]$$
$$= \frac{1}{\lambda+\mu-\lambda\mu}\left[-\left(1+\frac{\lambda(1-\mu)}{\mu(2-\mu)}\right)c_1 + \left(\mu+\frac{\lambda(1-\mu)^2}{2-\mu}\right)M_1 + \left(\frac{\lambda\mu(1-\mu)}{2-\mu}\right)c_1\right] \tag{17}$$
$$v_2(D,R) = -c_2+(1-\mu)\,[\lambda v_2(D,D)+(1-\lambda)\,v_2(D,R)]$$
$$= \frac{1}{\lambda+\mu-\lambda\mu}\left[-\left(1+\frac{\lambda(1-\mu)}{\mu(2-\mu)}\right)c_2 + \left(\frac{\lambda(1-\mu)^2}{2-\mu}\right)M_2 + \left(\frac{\lambda\mu(1-\mu)}{2-\mu}\right)c_2\right]$$

The payoffs to countries 1 and 2 when 1 is in stage R while 2 is in stage D are:

$$v_1(R,D) = -c_1 + (1-\mu)\,[\lambda v_1(D,D) + (1-\lambda)\,v_1(R,D)]$$
$$= \frac{1}{\lambda+\mu-\lambda\mu}\left[-\left(1+\frac{\lambda(1-\mu)}{\mu(2-\mu)}\right)c_1 + \left(\frac{\lambda(1-\mu)^2}{2-\mu}\right)M_1 + \left(\frac{\lambda\mu(1-\mu)}{2-\mu}\right)c_1\right]$$
$$= v_1(D,R) - \left(\frac{\mu}{\lambda+\mu-\lambda\mu}\right)M_1 \tag{18}$$
$$v_2(R,D) = -c_2+\mu M_2+(1-\mu)\,v_2(R,D)$$
$$= -\frac{c_2}{\mu}+M_2$$

The payoffs to both countries in state (R,R,0) (the research stage of a new project) are

$$v_1(R,R,0) = -c_1 + p\,[\lambda^2 v_1(D,D) + \lambda(1-\lambda)\,v_1(R,D)] \tag{19}$$
$$v_2(R,R,0) = -c_2 + p\,[\lambda^2 v_2(D,D) + \lambda(1-\lambda)\,(v_2(D,R) + v_2(R,D))]$$

The payoffs to both countries in the state (R,R,1) (the research stage of an old project), conditional on it being abandoned at stage (R,R,2), are the same as those given in equation (19) with p being updated in a Bayesian way to reflect the lack of success in the first period.

To be an equilibrium, our scenario imposes the following set of restrictions on payoffs:

$$\begin{aligned} v_1(R,R,0) &\geq 0 \\ v_2(R,R,0) &\geq 0 \\ v_1(R,R,1) &< 0 \\ v_2(R,R,1) &< 0 \\ v_2(D,R) \geq 0 &> v_1(R,D) \end{aligned} \tag{20}$$

Our final task is to check that these restrictions are not incompatible with one another. Abandonment of old projects can be justified if lack of success in the first period of a project is sufficiently informative as to its unfeasibility, i.e. if λ, the probability of success of a good project, is high enough. It can be seen by inspection of (17), (18) and (19) above that $v_j(D,R)$, $v_j(R,D)$ and $v_j(R,R,0)$ are all increasing in M_j and C_j and decreasing in c_j; and that $v_2(D,R)$ is of a form identical to $v_1(R,D)$ with M_1, C_1 and c_1 replaced by M_2, C_2 and c_2. If country 2's larger size is reflected, as we have postulated, in higher levels of M_2 and C_2 or in a lower level of c_2, everything else being equal, we have $v_2(D,R) > v_1(R,D)$ and $v_2(R,R,0) > v_1(R,R,0)$. Therefore, it is possible to satisfy all constraints in (20) simultaneously. The scenario we have considered can indeed occur for some range of the model's parameters.

It is easy to convince oneself that the reverse scenario (the large country giving up projects when it is lagging behind and the small country always staying in the race) cannot happpen. "Symmetric" scenarios (both countries never giving up in a race, or both countries always giving up if they fall behing) are of course possible. Therefore, if research projects are characterized by triplets (p,λ,μ) drawn by nature from some distribution, some projects and some histories of the game will be such that country 1 (the small one) gives up some races while country 2 always goes on. Provided that such histories occur with positive probability, it will be observed *ex post* that the large country is, on average, more often present in the development stage than the small country. Furthermore, it will be observed that the probability of success at the development stage conditional on early success at the research stage is higher for the large country than for the small country. The reason is that, on average, the large country catches up early advances of the small country more often than the small country catches up advances of the large country.

4. Concluding remarks

We have proposed two distinct explanations for the empirical observation that smaller countries seem both under-represented and less successfull in the product development stage than in the research stage. The first explanation is based on a "universal" view of research according to which opportunities for research projects depend on the state of scientific knowledge, which is common to all countries. By contrast, opportunities for product development are related to the size a country's economy. Country size can be understood, in this perspective, as a proportional increase in the number of available scientists and researchers and in the number of opportunities for product development. We show that an increase in country size defined in this way leads to a more than proportional increase in the number of researchers in the development sector. In other words, the elasticity of employment in the development sector to a proportional increase in researchers and development opportunities endowments is more than one.

The second explanation is based on the idea that large countries have more opportunities than smaller ones do to get value out of successful product development. It is then possible that, in a two-stage R&D process, smaller countries will be "preempted" when larger ones make a breakthrough from stage R to stage D, while larger ones will not. Ex post, it will seem that, on average, smaller countries make it less often to the development stage, and reap less reward for their successes in research.

References

Choi, J.P., 1991, Dynamic R&D competition under hazard-rate uncertainty, *Rand Journal of Economics* 22, 596-610.

Fudenberg, D., R. Gilbert, J. Stiglitz and J. Tirole, 1983, Preemtion, leapfrogging and competition in patent races, *European Economic Review* 22, 3-31.

Grossman, G. and C. Shapiro, 1987, Dynamic R&D competition, *Economic Journal* 97, 372-387.

Hendry, J., 1991, *Innovating for Failure: the Early History of the British Computer Industry*, Cambridge, MA: MIT press.

OECD, 1991, *Science and Technology Policy, Review and Outlook,* Paris: OECD publications.

Rosen, R.J., 1991, Research and development with asymmetric firm sizes, *Rand Journal of Economics* 22, 411-429.