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Governments and the Decentralization of R & D

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RÉSUMÉ

Le but du présent article est de montrer comment les coûts et les bénéfices d'une décentralisation géographique des activités de R-D peuvent être identifiés et comparés. Les bénéfices pour la région qui reçoit les activités de R-D sont étudiés à la section 1. Ils découlent de l'effet multiplicateur de courte période, de l'amélioration du capital humain et de la modernisation éventuelle de la structure industrielle locale. Du côté des coûts, étudiés à la section 2, les effets observables de la décentralisation des activités de R-D proviendront essentiellement de la perte d'économies d'échelle et d'économies urbaines dans la production de l'output découlant de l'activité de R-D. Nous montrons à la section 3 que le flux des coûts et celui des bénéfices doivent être escomptés par le coût social du capital. La principale conclusion de cette recherche est que la décentralisation des activités de R-D dans un grand pays peu peuplé comme le Canada entraîne des coûts sociaux et réduit la position concurrentielle du pays au niveau international. Par ailleurs, le problème de la décentralisation de la R-D est nettement plus pertinent pour les petits pays (en termes de population et de dimension économique) que pour les grand pays, comme les États-Unis, où les masses critiques d'efforts de recherche peuvent être simultanément atteintes dans plusieurs secteurs et de nombreuses localisations.

Mots clés: Analyse coûts/bénéfices, économies d'échelle, économies urbaines, multiplicateurs, région, R-D.

* * * ABSTRACT * * *

The purpose of this article is to show how costs and benefits of geographical decentralization of R&D can be identified and compared. The benefits for the region that receives R&D activities are studied in section 1. They stem from the short-run multiplier effect, the amelioration of human capital and the possible modernization of the local industrial structure. On the cost side examined in section 2, the observable impacts of the decentralization of R&D concern the loss of returns to scale and of urban economies of the production of the R&D output. It is shown, in section 3, that the flows of costs and benefits must be discounted by the social cost of capital. The main conclusion of this article is that the decentralization of R&D in a large sparsely populated country entails social cost and would weaken its competitive position in world commerce. On the other hand, the issue of decentralization is more crucial for small countries (in terms of population and economic size) than for large ones, like the U.S., where critical masses of research efforts can be simultaneously attained in many fields and in many places.

Key words: cost/benefit analysis, economies of scale, multiplier, region, R&D, urban economies.

The current geographical distribution of R&D is the result of past decisions, both private and public. Barring government interference, one may presume that the workings of the competitive price system bring about a satisfactory if not an optimal spatial distribution of R&D in the private sector. In the public sector,[1] by contrast, the market discipline being less severe, the location decisions concerning R&D are open to many forms of political interference, among them, the decentralization to peripheral regions. Such decentralization can be carried out either by discriminating in favor of laboratories in the periphery (granting them more government funds than their researchers would have obtained in free competition with those of the metropolis) or by political decisions to build government laboratories in particular regions even though these regions are not optimal locations for such activities.[2]

A justification for such market interference is that government and university laboratories act as catalysts in peripheral regions not yet industrialized or that it may stop a process of desindustrialization. Because of these expected social benefits, the simple finding of inefficiency resulting from R&D decentralization is insufficent to brand such interference non-optimal. Thus, two questions are often asked: "Where should the expansion of science take place?" (Inhaber, 1974) and "What is its effect upon regional economic development?" (Clark, 1971). Furthermore, Malecki (1981, p. 326) said that "the effects of regional concentration of R&D remain poorly understood".

The purpose of this article is to answer these questions by showing how these costs and benefits can be identified and compared. The

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1 The public and/or non-profit sector comprises government laboratories and facilities, universities and colleges' R&D, and the R&D performed by private enterprises under government subsidies distributed in part on a geographical basis.

2 For instance, France and the U.S. have been disseminating public R&D activities to peripheral regions for a long time on the basis of political criteria. (Brocard, 1981; Malecki, 1982). In Canada, there is a ministry that subsidises regional development activities (DRIE).

benefits for the region that is the recipient of R&D activities are studied in section 1. They stem from the multiplier effect, the improvement of human capital and the modernization of the local industrial structure. On the cost side which is examined in section 2, the observable impacts of the decentralization of R&D are found in the loss of returns to scale and urban economies in the production of the R&D output. Since the analysis of decentralization of an activity involves the comparison of costs and benefits between hypothetical locations (e.g. metropolis vs periphery), the computations will be made in differential benefits and costs. Finally, section 3 will show that both costs and benefits must be discounted by the social cost of capital.

Thus, a clear judgment can be made only by means of a social cost-benefit analysis (SCBA) (i.e., after having translated the advantages and costs of the decentralization policy into shadow prices and after having somehow incorporated the externalities.) One must recognize that not everybody considers it appropriate to apply SCBA to government policies. Richardson (forthcoming) for instance, is preoccupied with SCBA that do not use shadow pricing and migration possibilities, that study "broad" policies such as "the Regional Policy", or rely largely upon "soft" or qualitative data. That will not be the case for a SCBA applied to decisions of decentralization of R&D activities because this policy is well identified, limited in scope and its main costs and benefits are measurable.

1. THE BENEFITS

In this section, the three benefits (multiplier, human capital and industrial structure) for a region receiving new R&D activities will be evaluated. To properly conduct this evaluation, we must make sure that the different effects do not overlap. Otherwise there will be double counting. In order to eliminate any overlap between multiplier effects and the other two, only the <u>short-run</u> multiplier effect is added to human capital and industrial structure effects. The short-run multiplier holds the capacity of the region constant (changes in the productive capacity

of a region by induced investments and migrations are captured by the long-term multiplier (see Schwartz, 1982, pp. 8-23 and Nourse, 1968, p. 162). Thus, in our perspective there is nothing outside the long-term g multiplier since it includes the impact of the short-term multiplier, plus the impact of the changes brought about by the improvement of the human capital and the structural effects in the form of new investments (e.g. spinoffs).

1.1 The short-run multiplier effects

All projects, R&D projects included, have short-run multiplier effects. However, this fact alone cannot justify decentralization because the country's multiplier is the same,[3] wherever the project is undertaken, and the impact of the multiplier should not be confused with an increase in welfare. For instance, there can be no social gain stemming from the multiplier in conditions of full employment and fixed technology because by definition, the production (i.e., the factor remunerations) cannot be increased. However, in condition of less than full employment coupled with different regional unemployment rates and some interregional immobility of labour (all realistic assumptions), there is room for an increase in the country's welfare through the workings of differences between the country's overall multiplier and the local multipliers. The metropolis' local multiplier is larger than the multiplier of a peripheral region because of smaller leakages and because unemployment rates are higher in the periphery than in the metropolis. Thus, the social opportunity cost of the (immobile) labour is smaller in the periphery than in the metropolis. This is what provides room for a social gain in decentralization.

If only the indirect effects of the multiplier are taken into account,[4] the social gain (measured by the social value of the employment involved) for the country of decentralizing R&D activities is equal to

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3 It would be more appropriate to say almost the same. Indeed, in a region of a country (or a province) the leakage to other countries (or provinces) could be greater than the mean leakage so that the country's multiplier would be marginally lower for any project located in this region and vice versa.

4 By definition, the direct effect is equal to one. For instance, if the multiplier is 1,8, the direct effect is 1 and the indirect effect is 0,8.

(1) $$M_{mp} = k\{[m_1(1 - c_m) + Q_{rm}(1 - c_p)] - [p_1(1 - c_p) + Q_{rp}(1 - C_m)]\}$$

where

M_{mp} = the social gain linked to indirect effects generated by the differential multiplier measured in jobs. A monetary measure is possible by multiplying the jobs by the average salary of indirect labourers. This number can be negative if the effects are greater in the periphery than in the metropolis.

k = the direct R&D jobs of the project.

m_1 = the indirect effect of the metropolis multiplier. $m_1 = m - 1$, where m is the local multiplier in the metropolis.

p_1 = the indirect effects of the multiplier in the periphery. $p_1 = p - 1$, where p is the local multiplier in the periphery.

Q_{rm} = multiplier effect in the rest of the country if the project is located in the metropolis. $Q_{rm} = Q - m$, where Q is the country's multiplier.

Q_{rp} = multiplier effect in the rest of the country if the project is located in the periphery. $Q_{rp} = Q - p$, where Q is the country's multiplier and p the local multiplier in the periphery.

c_m = ratio of social cost of indirect labour over its nominal cost in the metropolis.

c_p = ratio of social cost of indirect labour over its nominal cost in the periphery.

The question whether decentralization yields social gains depends on the values of the parameters of equation (1). Moreover, two additional components must be taken into account: first, the difference in the social cost of direct labour according to the location of the project; and secondly, the transport costs of bringing material inputs to the periphery and the costs of communications. The above applies to the project itself, to the suppliers of the project and to the population linked directly and indirectly to the project.

The case of direct labour can be handled as follows. The direct labour in R&D projects is made up of researchers and of support personnel. For various reasons ranging from inferior professional working conditions to an increased difficulty of finding jobs for spouses, most researchers who are metropolitan oriented persons require a premium to work in the periphery. The premium either takes the form of higher salary or researchers of lower caliber. In both cases, research is more costly in the periphery. Support personnel are usually indigenous and may not require a premium.

Similarly, laboratories in the periphery as well as their local suppliers must incur additional costs to transport the material inputs originating in the metropolis and to communicate with the head office or with other scientists working in the metropolis.[5] These additional expenses as we shall see are due to the absence of urban economies and of metropolitan amenities. The population linked to the project (this includes the local services sector of the peripheral region) incurs similar costs.

Table 1 gives the results of a simulation of the social cost of a given R&D project in the metropolis compared with the same project in the periphery, taking into account the direct and indirect short-run multiplier effects. Conclusions can be inferred from such a simulation if and

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[5] Transport and communication costs have been recognized as far back as Clark (1971), pp. 308-309.

only if all parameters used come from good empirical studies. These parameters will vary from one situation to the other (different countries, different period... etc.) so that the results of the following simulation can only be considered as a realistic illustration.

To make this simulation, the following values have been given to the parameters of equation (1). k = 100 direct R&D jobs a year (40 researchers and 60 support personnel); m_1 (the indirect effect of the metropolis multiplier) = 0,8; p_1 (the indirect effects of the periphery multiplier) = 0,3; Q_{rm} (multiplier effect in the rest of the country if the project is in the metropolis) = 0,2; Q_{rp} (multiplier effect in the rest of the country if the project is in the periphery) = 0,7; Q (country multiplier) = 2,0;[6] c_m (ratio of social cost of indirect labour over its nominal cost in the metropolis) = 0,8; c_p (ratio of social cost of indirect labour cost over its nominal cost in the periphery) = 0,7.[7]

Moreover, the premium of the researchers to locate in the periphery has been arbitrarily set at $2,000 a year. It is obvious that for star researchers that amount could be much higher. However, we do not want to overstate the case. There would be no difference in the premium even if researchers were recruited locally as long as they would be of a caliber qualifying them for similar jobs in the metropolis. In other words, there is a social cost in retaining in the periphery "would be migrants" (see Jenkins and Kuo, 1978, p. 24). It is also hypothesized that the material inputs represent 50 % of the operating costs of the laboratories, and that one half of these inputs are only available in the metropolis area. Transport and communication costs that must be incurred by the enterprises of the periphery that supply inputs to the laboratory and to the population linked to the project, amount to 5 % of the wage bill of the laboratory. This is an arbitrary but plausible figure derived from previous empirical studies.

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6 The values of the parameters have been derived from numerous empirical studies done in Quebec from 1979 to 1983 by one of the authors.

7 The computation of the social cost of labour in the periphery (or elsewhere) is explained in Jenkins and Kuo (1978). Since we suppose that the researchers are never unemployed, the ratio of their social opportunity cost to their nominal wage is one. Thus 0,8 and 0,7 apply only to support personnel.

TABLE 1

Social costs of an R&D project in the metropolis compared to its costs when decentralized to the periphery, including the effects of the multipliers

	Nominal wage rate/year	Wage bill	Conversion factor: social cost/ nominal cost	Social costs	Total social costs
Metropolis location					
Direct labour					
40 researchers	28 000	1 120 000	1,0	1 120 000	
60 support personnel	15 000	900 000	0,8	720 000	
		2 020 000		1 840 000	
Multiplier effects					
Indirect labour					
$100 \times 0,8 = 80$ jobs	15 000	1 200 000	0,8	960 000	
$100 \times \frac{0,2}{1,0} = 20$ jobs	15 000	300 000	0,7	210 000	
		1 500 000		1 170 000	
TOTAL					3 010 000
Location in periphery					
Direct labour					
40 researchers	30 000	1 200 000	1,0	1 200 000	
60 support personnel	15 000	900 000	0,7	630 000	
		2 100 000		1 830 000	
Multiplier effects					
Indirect labour					
$100 \times 0,3 = 30$ jobs	15 000	450 000	0,7	315 000	
$100 \times \frac{0,7}{1,0} = 70$ jobs	15 000	1 050 000	0,8	840 000	
		1 500 000		1 155 000	
Transport and communication costs					
• On inputs other than Direct Labour [2,100,000x(0,5)(0,05)]				52 500	
• On account of Local Multiplier [450 000 × (0,05)]				22 500	
				75 000	
TOTAL					3 060 000

The last column of Table 1 shows that there is practically no difference between the total social costs of an R&D project in the metropolis and those of the same project located in the periphery. The reason of this result is that the lower social cost of indigenous labour of the periphery is counterbalanced by the wage premium given to researchers (or lower productivity) and by additional transport and communication costs. Thus, using very conservative values for all parameters of equation (1), it seems difficult to justify a policy of regional decentralization of R&D activities on the ground of the multiplier effect.

1.2 The impact on human capital

It has been argued that the coming of university and government researchers into a peripheral region engenders a multiplier effect qualitatively different from the multiplier effect we discussed in section 1.1. These researchers, (with their high degree of academic knowledge) presumably improve community organizations, increase the local demand for cultural goods and services and encourage entrepreneurship. Thus they become the leaven of the region. That perspective is long term. Furthermore, the project which may look marginal to this type of labour force in the metropolis may not be so when added to the much smaller numbers of the periphery. A priori then the impact (benefit) of the project looks much more important in the periphery. In practice, the contribution of the new arrivals, though positive, is likely to be small. Indeed, in countries like Canada, the small peripheral cities already have a relative endowment of natural scientists, mathematicians and engineers similar to the one of large metropolises.[8]

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8 This surprising result is based on data from the 1981 Census covering 23 Canadian cities of all sizes accounting for 73 % of Canadian R&D. A regression analysis shows that there is no positive relationship between the size of each city's total labour force and the percentage (around 4 %) of each city's total labour force accounted for by natural scientists, mathematicians and engineers (see Lacroix and Martin (1987)).

Moreover, experience shows that the passage of professionals in peripheral regions is short-lived,[9] and they do not involve themselves in the local social and political life. The competent ones hope that their competence will soon be recognized and allow them to return to the metropolis. Yet the passing through of these people, albeit brief, does somehow improve the image of the region. But, "such benefits are likely to be limited and, if the supporting infrastructures do not exist or are altered in some way, short-lived" (Buswell, 1983, p. 17).

1.3 The modernization of the local industrial structure

The governments that have tried, through the decentralization of R&D, to induce or preserve industrialization in remote regions have implicitly assumed that R&D activities change the "milieu". The "milieu" being the key variable for regional development, they have bet that its change will stimulate local economic activities in the form of spin-offs and cross effects for other industries. Obviously, we are no longer stipulating ceteris paribus conditions. Ideally the government should not only intervene with R&D but through an "integrated" approach dealing not only with physical infrastructure, as in the past, but also with the introduction of institutional and sociological changes (Gaffard, 1986; Stöhr, 1986). The problem is that in practice, no government is prepared to intervene in such a massive scale to deal with regional disparities since it does not have to do so in the metropolis which already has all the characteristics of the "integrated approach".

Can the decentralization of some R&D plus a few institutional changes make up for the lack of large urbanisation? In this section, we shall argue that when R&D decentralization is envisaged almost as a separate policy, compared to the metropolis, it is unnecessary and

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9 The government of Quebec has compiled statistics on the average stay of transient doctors in the periphery: 3 years! The turnover of personnel is consequently large. Excluded from our analysis are mining and forest engineers that have freely chosen that way of life.

unlikely to launch a development process, and in some cases not even desirable.

The decentralization of R&D is unnecessary

The decentralization of R&D is unnessary for different reasons. First, synergy is available at no cost in the metropolis even though metropolises are not equally successful in harnessing this force. Second, except for the case of a need for a technology which is of no interest to those outside the region,[10] what matters is access to technology, not the local generation of technology. Even if the problem is specific to a region, it does not mean that local R&D is the solution, because the problem might be so complex that only a distinguished laboratory of the metropolis might be able to solve it (Martin, 1982). In this respect, access to technology can be provided more cheaply by all sorts of means: systems of scientific diffusion, technical schools, subsidiaries of national and international firms etc. (Maillat and Vasserot, 1986b). Third, the importance of small and medium size businesses (SMBs) as initiators of high-tech development in the periphery is overrated. SMBs are usually not the initial investors in new fields (Planque, 1985). Pioneering research and development in a particular region must be done by large firms (Dorfman, 1983) so that "growth in high-tech activities in less industrialized regions is mainly due to the location of large plants" (Pottier, 1985), p. 67).[11] Of course, because of the complementary role played by SMBs with large plants, if the development process continues, they eventually become numerically important. But here, we are dealing with an effect, not with a primary cause.

Finally, generation of simple innovations does not require university level R&D. For instance, in the case of industrial reconversion of the Jura region (Switzerland) from manufacturing of mechanical

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10 Being banned almost all over the world because of its harmfulness, the case of asbestos abundant in Quebec is a good example.

11 Rees (1986) found the same kind of results.

watches to digital watches and other products, Maillat and Vasserot (1986a) found that 75 % of innovations were imitations, 15 % were cases of diversification, and only 10 % were cases of bifurcations. Only the last type requires high-tech research.

Decentralization of R&D is unlikely to start an industrialization process

It is difficult, if not impossible, for scientific complexes, high-tech growth poles or "technopôles" to survive in the periphery. Numerous studies show that the periphery cannot satisfy the minimum conditions for the survival of scientific complexes. The main reasons given by different authors, are the lack of distinguished universities and urban amenities which both attract and retain the specialised labour; the inability to rapidly constitute a critical mass of researchers in a small region, to maintain a "pressure cooker" atmosphere among scientists and to provide risk capital. Consequently, the successful scientific complexes are only found within or near large urban areas (Planque, 1985; Dorfman, 1983; Malecki, 1986). The other scientific complexes - e.g., Sophia - Antipolis in France - only survive through heavy subsidies or government interventions (Miller and Côté, 1985; Savy, 1986). The ultimate test of any decentralization policy is the ability to generate spontaneous spin-offs, because it is always possible for a government to subsidize successive rounds of decentralization to cover up past mistakes. It seems that this is the most important drawback of a decentralization policy.

Empirical studies in many countries show that it is unlikely that R&D will have a noticable impact on the local level of economic activity. Studies examining the local impact of research institutes in Germany, Holland and France found no appreciable effects (Maillat and Vasserot, 1986b; Brocard, 1981). The conclusion is that "decentralization of large research and production plants has not led to the formation of a genuinely diversified industrial fabric" (Pottier, 1985, p. 68).

Finally, there are not enough high-tech activities to go around to satisfy all regions that may want it (Wachter, 1986). Indeed the

importance of the high-tech sector has been exaggerated (Rees, 1986).

High technology may not even be desirable

Regions should implement policies that will increase their potential for development. It is the economic value of a project that counts, not its technological status. Nothing proves that a high-tech project is preferable to a project in a low-tech sector. Consider for example the case of Lowell (Massachusetts) where the new high-tech plants pay lower wages than textile factories (Rees, 1986, p. 292).

In conclusion of this section, we may say that the argument of section 1 has been that outside the "integrated approach" (an unlikely possibility), the decentralization of R&D in a country (or part of a large country) with a metropolis surrounded by a distanced, sparsely populated periphery is not likely to produce social gains because it is unnecessary, often undesirable, and cannot generate spin-offs in the periphery in a scale comparable to the metropolis. Moreover, the multiplier and human capital effects of such a policy are, overall, very small or nil.

2. THE COSTS OF THE DECENTRALIZATION OF R&D

In section 1, some minor costs were introduced to compute the social gain. However, these costs pertained exclusively to the generation within the regions of the benefits (externalities) of decentralization. It is now time to investigate the cost of producing the R&D output. Two features of the R&D activity are used to examine its production function: 1) its footlooseness (among medium and large cities) and, at the same time, 2) its high agglomeration into large cities. The explanation of this peculiar spatial distribution, in spite of its footlooseness, lies in the role of agglomeration economies in the production function (see Labbé, 1980, p. 399; Carlino, 1982, p. 99 ff).

These agglomeration economies can be of three types: scale economies in the size of the laboratories; localization economies, i.e. economies that benefit laboratories when their number increases in a particular location; and finally urban economies. All three increase the tendency of laboratories not to locate on a random basis or simply according to the population.

We consequently suppose that the output of the laboratories (N) in city i is a function of:

$$N_i = \lambda_i \, c_i^{\alpha} \, t_i^{\gamma} \, E_i^{\sigma}$$

where λ_i is a factor that shifts the production function (in each laboratory) according to the presence of urban economies[12] and where $\alpha + \gamma + \sigma$ can be > 1 i.e., a situation of increasing returns to scale, independent of the laboratory's location; c_i is the number of researchers of a given quality, t_i the number of support personnel and E_i the equipment used by the laboratory.

The urban economies depend on the characteristics of the city: proximity to transport nodes as well as to other cities, variety and quantity of other economic activities, urban infrastructures, land topography, institutional factors, etc. (Carlino, 1982, p. 99). The impacts of these characteristics can furthermore be enhanced by returns to scale with respect to the size of the cities i.e., λ_i would increase with the size of the city. This factor influences the productivity of the inputs.

If we accept the preceding relation between inputs and outputs, the implications are straightforward: if scale and urban economies play

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12 The authors [Carlino (1979, 1982), Labbé (1980) and Shefer (1973)], who attempted to measure the urban economies applicable to the manufacturing activity, postulated that the production function of each manufacturing unit is homogenous of degree one: i.e., $\sigma + \alpha + \gamma = 1$. Our approach is consequently a bit different from them because we suppose that in our sectors, $\sigma + \alpha + \gamma$ can be greater than one. Therefore, we cannot use all their technology to directly measure agglomeration economies.

a role in the production of R&D, and if the periphery cannot provide them, there will be a social cost attached to the decentralization of R&D activities.

The tasks of this section are thus to firstly determine whether there are returns to scale and urban economies in the production of R&D outputs, and secondly, the implications of the existence of such economies for decentralization.

2.1 On the existence of returns to scale for R&D

Theoretically, it can be expected that the increase in the size of laboratories increases the productivity of the researchers through their cross-fertilization and through the use of indivisible equipment. However, the value of interpersonnel contacts may diminish rapidly and may even become negative if, having to reach too many people, communication channels become too complicated. Similarly, the miniaturization of research equipment (e.g., personal computers) dispense with large scale equipment. Moreover, long distance communications have become very cheap. All these things reduce the necessity of large laboratories. A clear answer on the existence of returns to scale in R&D is consequently not theoretically possible.

Empirically, one finds that in electronics, the efficiency of researchers increases with the increase in the size of teams and with the presence of a star researcher on the team (see Wallmark et al., pp. 83-84). In pharmacy proper, because the scientific possibilities have reached a plateau, the minimal size of a laboratory is now between 200 and 300 researchers (CDMA, 1983, p. 34). Economies of scale are present until personnel reaches 1000-1500 (Burstall et al., 1981, pp. 70-72 and United Nations, 1979, p. 35). In biotechnology, the field is ... through small firms. But their life-cycle is sh... survive become medium size (Eastman, 198... pulp and paper industry, the ... research in one lan...

small laboratories for special purposes. These fields, being quite representative of R&D, enable us to conclude that in general, there are important returns to scale in the activity of R&D.

2.2 On the existence of urban economies for R&D

Among agglomeration economies, the urban economies are reputed to be the most important (Labbé, 1980, p. 416). Since this fact has been established for manufacturing activities, a question remains concerning their role in the production function of the R&D output. As might be expected, the answer to the question will be empirical. The basic data will be those pertaining to industrial private reasearch in the U.S. The reason for restricting the analysis to this type of research is that this is the only case where we are quite sure that the actual spatial distribution aims at efficiency. Indeed, either because of the profit motive or the competition of other firms, private firms locate their laboratories so as to minimize costs or to maximize R&D output. It is also the case where rival explanations, e.g., inertia (past decisions), government interference, etc. have the smallest chance of materially influencing the pattern of location.

The answer to the question on the existence of urban economies for R&D is yes because the empirical results of numerous regression analyses show not only that private R&D is, in the U.S., concentrated in urban areas, but more importantly that this concentration increases with the size of the city.[13]

2.3 The cost implications of decentralizations of R&D

Decentralization of R&D concerns returns to scale (at the plant level) and urban economies that shift the production function.

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13 For a complete presentation and discussion of these empirical results and others, see Malecki (1980) and Lacroix and Martin (1987).

In a small country (or a region of a large country) that can afford only one large research facility, the availability of returns to scale might force a clear cut choice of location: either in the periphery or in the metropolis. However, a clear cut choice in favor of one region will rarely be made because of the political weight of different regions.

The usual solution is a distribution of R&D activities according to the importance of local population. In that case, the required large laboratory is broken into less efficient units, more costly to operate, and of lower performance. In practice then, although that need not be the case, decentralization may entail important costs on account of returns to scale.

Decentralization of public R&D will also produce even more important losses of urban economies.[14] Indeed private research, except for data collection or highly subsidized operations, is rarely found in the periphery. That means private spin-offs will not materialize in the periphery (see Brocard, 1980; Malecki, 1986; Perrin, 1986) except if its central city has at least 400 000 inhabitants (Planque, 1982, p. 293) and a surrounding population of at least one million (Stöhr, 1986).

The higher costs of R&D will, ceteris paribus, reduce the output of innovations and thus reduce the economic potential of the country (especially if it is a small country), jeopardizing the competitive position of its industries. That will bring in imports and loss of export markets. All this will bring unemployment to both the metropolis and the periphery.

3. THE TEMPORAL PERSPECTIVE

Some people hold that the reasoning of the previous sections is short-sighted because it neglects the possibility that if decentraliza-

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[14] Even if we exclude the small transportation and communication costs already accounted for in table 1.

tion is pursued long enough, thresholds will eventually be crossed such that the growth process will proceed in a self-sustaining manner. In disguise, this is the growth pole hypothesis that we have dismissed in section 1.3. But even accepting it for the sake of argument would not justify the policy because the temporal perspective also militates against it since the flows of benefits and costs must be discounted at the social rate (8 % to 10 % in many countries). This favors the metropolis because this is where the benefits appear the earliest.[15] Since the costs appear, relatively speaking, earlier than the benefits in the periphery, this further reduces the attractiveness of that solution.

4. CONCLUSION

In a cost benefit approach, it is the algebraic sum (in discounted terms) of the costs and of the advantages that provide the answer. Our previous examination of these costs and advantages can be summed up[16] this way:

TABLE 2
Social costs and advantages of decentralizing R&D to peripheral regions

	Impact in periphery minus impact in the metropolis	Magnitude of effect
Advantages		
Multiplier effects	0	0
Human capital effect	+Δ	small
Modernization of industrial structure	-Δ	important
Costs		
Loss of returns to scale	-Δ	important
Loss of urban economies	-Δ	important
Total net loss	-Δ	important

15 In learning, the more you already know, the faster you incorporate new knowledge. On the other hand, because the large metropolis is the incubator "par excellence" of small businesses (Lichtenberg, 1960), spin-offs appear more rapidly in the metropolis.

16 Because of the impressionistic nature of the data, only classes of magnitudes can be used. However, since all items (except one and it is reputable to be very small) are either 0 or negative, the overall result is clearly negative. That's why we can draw conclusions from such a table.

The conclusion is that the decentralization of R&D in a small but geographically large country entails social costs and would weaken its competitive position in world commerce. However, it is clear that the importance of the problem of decentralization of R&D is much greater in a large sparsely populated country (like Canada) than in a compact country such as U.K. or Germany. Similarly, the issue of decentralization is more crucial for small countries (in terms of population and economic size) than for large ones, like the U.S., where critical masses of research efforts can be simultaneously attained in many fields and in many places. Small countries cannot afford that, and must consequently be prudent in R&D decentralization.[17]

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17 This approach elucidates the apparent paradox noticed by Inhaber (1974, p. 199) when he discovered that Canada was highly centralized while the United States were not.

REFERENCES

Brocard, M. (1981), "Aménagement du territoire et développement régional: le cas de la recherche scientifique", L'espace géographique, no. 7, pp. 61-73.

Burstall, M.L., J.H. Dunning and A. Lake (1981), Multinational Enterprises, Governments and Technology: Pharmaceutical Industry, O.C.D.E., Paris.

Buswell, R.J. (1983), "Research and Development and Regional Development: A Review", Technological Change and Regional Development, London Papers in Regional Science, no. 12, ed. by A. Gillepsie, Pub. Pion Limited, London.

Canadian Drug Manufacturing Association (CDMA) (1983), A Case for the Retention of Section 41 (4) of the Patent Act, Toronto.

Carlino, G.A. (1979), "Increasing Returns to Scale in Metropolitan Manufacturing", Journal of Regional Science, vol. 19, no. 3, (August).

Carlino, G.A. (1982), "Manufacturing Agglomeration Economies as Returns to Scale: A Production Function Approach", Papers of the Regional Science Association, vol. 50, pp. 95-108.

Clark, N.G. (1971), "Science, Technology and Regional Economic Development", Research Policy, no. 1, pp. 296-319.

Dorfman, N.S. (1983), "Route 128: The Development of a Regional High Technology Economy", Research Policy, no. 12, pp. 299-316.

Eastman, H.D. (1985), Le rapport de la Commission d'enquête sur l'industrie pharmaceutique, Ministère des Approvisionnements et Services du Canada, Ottawa.

Gaffard, J.L. (1986), "Restructuration de l'espace économique et trajectoires technologiques", in Milieux innovateur en Europe, GREMI, Paris.

Inhaber, H. (1974), "Scientific Cities", Research Policy, no. 3, pp. 182-200.

Jenkins, C.P. and C.P. Kuo (1978), "On Measuring the Social Opportunity Cost of Permanent and Temporary Employment", The Canadian Journal of Economics, XI:2 (May).

Labbé, R. (1980), "Mesure et analyse des économies d'agglomération", Revue d'Économie Régionale et Urbaine, tome IV, no. 4, pp. 399-418.

Lacroix, R. and F. Martin (1987), Les conséquences de la décentralisation régionale des activités de R&D, Conseil de la science et de la technologie du Québec, Ste-Foy, 152 pages.

Lichtenberg, R.M. (1960), One-Tenth of a Nation, Harvard University Press, Cambridge, Mass.

Maillat, D. and J.Y. Vasserot (1986a), "Les milieux innovateurs, le cas de l'Arc jurassien suisse", in P. Aydalot (ed.), Milieux innovateurs en Europe, GREMI, Paris, pp. 217-246.

Maillat, D. and J.Y. Vasserot (1986b), "Conditions économiques et territoriales de la revitalisation des anciennes régions industrielles", presented at the Conference of "Technologies nouvelles de développement régional de l'A.S.R.D.L.F.", Paris (September 1-3), pp. 256-266.

Malecki, E.J. (1980), "Dimension of R&D Location in the United States", Research Policy, no. 9, pp. 2-22.

Malecki, E.J. (1981), "Science, Technology and Regional Economic Development: Review and Prospects", Research Policy, no. 10, pp. 312-334.

Malecki, E.J. (1982), "Federal R&D Spending in the United States of America: Some Impacts on Metropolitan Economies", Regional Studies, vol. 16, no. 1, pp. 19-35.

Malecki, E.J. (1986), "Research and Development and the Geography of High Technology Complexes", in John Rees (ed.), Technology, Regions and Policy, Rowman and Littlefield, Totowa, N.J., pp. 51-74.

Martin, F. (1982), "Progrès technologique et structure industrielle régionale", Actualité économique (July-September).

Miller, R. and R. Côté (1985), "Growing the Next Silicon Valley", Harvard Business Review (July-August), pp. 114-123.

Nourse, H.O. (1968), Regional Economics, McGraw-Hill, New York, p. 21.

Perrin, J.C. (1986), "Le phénomène Sofia-Antipolis dans son environnement régional", in P. Aydalot (ed.), Milieux innovateurs en Europe, GREMI, Paris, pp. 283-302.

Planque, B. (1982), "Les fonctions de recherche et leur environnement local", Revue d'Economie Régionale et Urbaine, no. 3, pp. 283-312.

Planque, B. (1985), "Le développement par les activités de haute technologie et ses répercussions spatiales. L'exemple de la Silicon Valley", Revue d'Economie Régionale et Urbaine, no. 5, pp. 911-942.

Pottier, C. (1985), "The Adaptation of Regional Industrial Structure to Technical Changes", Papers of the Regional Science Association, vol. 58, pp. 59-72.

Rees, J. (1986), Technology, Regions and Policy, Rowman and Littlefield, Totawa, N.J., 377 pages.

Richardson, H.W., "A Review of Techniques for Regional Policy Analysis", Chapter VII of Competing Approaches to Regional Economic Development Essays in Honour of François Perroux, (ed.), B. Higgins and D. Savoie, Allen and Unwin, New York (Forthcoming).

Savy, M. (1986), "Les territoires de l'innovation. Technopôles et aménagement: L'expérience française", Revue d'Economie Régionale et Urbaine, no. 1, pp. 41-60.

Shefer, D. (1973), "Localisation Economies in SMSA: A Production Function Analysis", Journal of Regional Science, vol. 13, pp. 55-64.

Stöhr, W.B. (1986), "Territorial Innovation Complexes", in P. Aydalot (ed.), Milieux innovateurs en Europe, GREMI, Paris, pp. 29-57.

Schwartz, H. (1982), A Guide to Regional Multiplier Estimation, Minister of Supplies and Services Canada, Hull, Canada.

United Nations (1979), Transnational Corporations and the Pharmaceutical Industry, no. E79IIA, New York.

Wachter, S. (1986), "Politiques publiques et découpage de l'espace: l'aménagement du territoire et les pôles", presented at the Conference of "Technologies nouvelles et de développement régional de l'A.S.R.D.L.F.", Paris (September 1-3).

Wallmark, J.T., S. Eckerstein, B. Langered and H.E.S. Holmgvist (1973), "The Increase in Efficiency with Size of Research Teams", IEEE Transaction on Engineering Management, vol. EM-20, no. 3 (August), pp. 80-86.